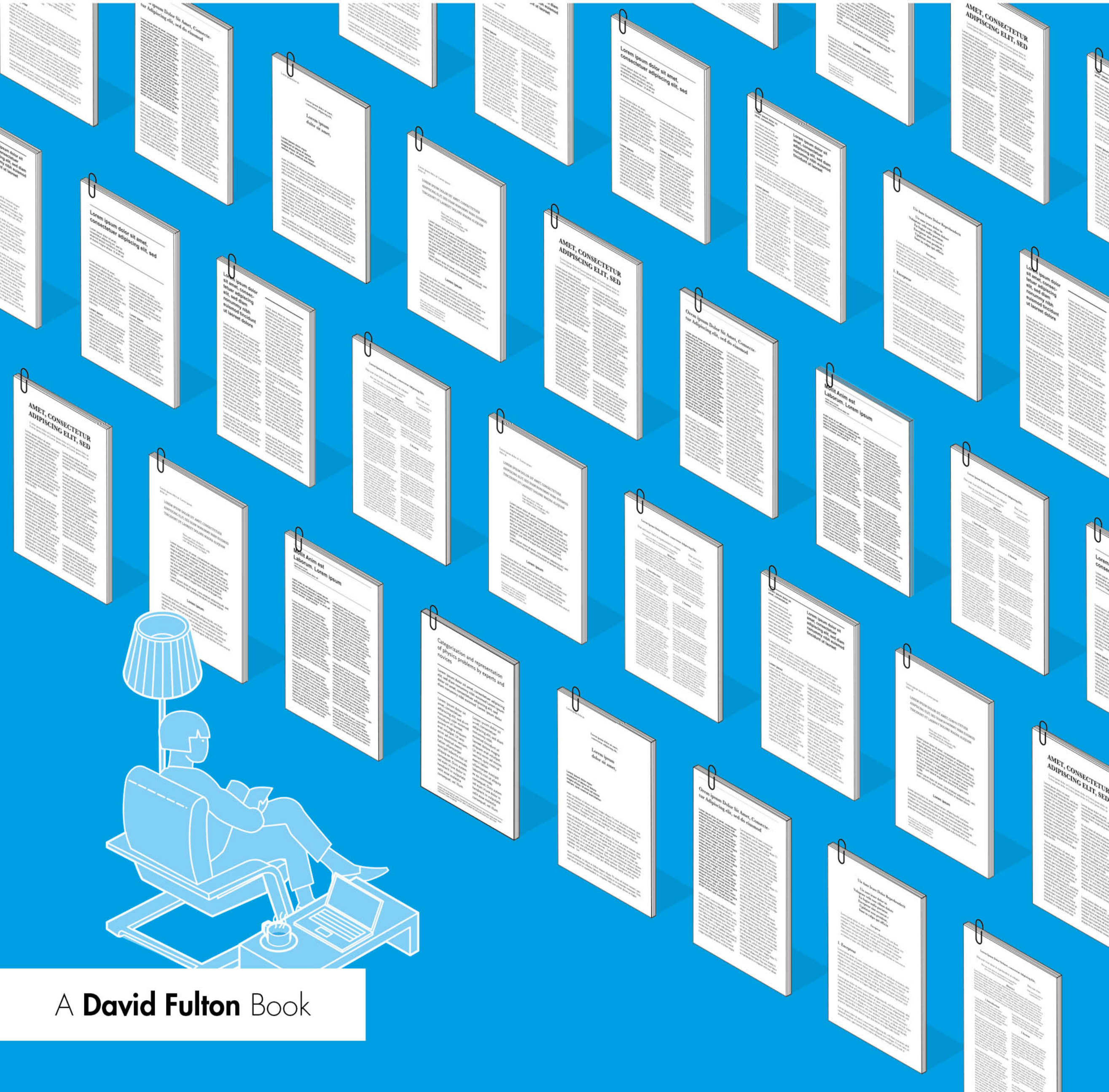
HOW LEARNING HAPPENS

Seminal Works in Educational Psychology and What They Mean in Practice

SECOND EDITION

PAUL A. KIRSCHNER & CARL HENDRICK

ILLUSTRATED BY OLIVER CAVIGLIOLI



A David Fulton Book

Praise for the first edition:

"It is BRILLIANT! *How Learning Happens* should be recommended reading for every PGCE/SCITT/teacher."

– **Dan West**, *@DanWestPhD*

"Just the best book ever about the research that applies to what we do in the classroom."

– **Helen Reynolds**, *@helenrey*

"Quite possibly the best pedagogical book I've ever read. 28 educational giants all in one place with practical strategies and fab illustrations."

– **LyndseyMA5**, *@MorganLyndseyma*

"For a lot of different reasons I personally believe that this is one of the most important books for teachers to read."

– **James Dixon**, *@MrDixonMath*

"I was recently asked what books I'd recommend to a brand-new teacher. I didn't hesitate in saying *How Learning Happens* and *How Teaching Happens*. Not only are they astonishingly beautiful, but they give time-poor teachers digestible research that can positively impact teaching."

– **EMC**, *@EMCTeach*

"What a gem! I can't put this book down! I want to buy it for my whole staff."

– **Enrique Rodriguez**, *@erod04*

"Dr. Kirschner and Dr. Hendrick curated a collection of key works about the underlying processes of learning. Not only did the authors carefully select and summarize the research, they connect the dots making the science accessible, relevant and actionable for the classroom. It's the *what*, the *why* and the *how* packaged together in an easily digestible read – something that is largely otherwise missing in education. As a teacher, I've leveraged the concepts from *How Learning Happens* to maximize the time and quality of my instruction. As a doctoral student, this text has served as an exemplar of how research can be made practical and applicable for educators."

– **Sarah Oberle**, *@S_Oberle*

"So often I've been asked to recommend a starting text for educators interested in the workings of the mind—now I have one. The text Kirschner and Hendrick offer alongside each seminal article does a wonderful job of situating the content in the broader scientific context, and in the classroom."

– **Daniel Willingham**, *Professor of Psychology and Director of Graduate Studies, University of Virginia*

"As the volume of research into psychology and education grows, it becomes ever harder for researchers, let alone teachers, to keep up with the latest findings. Moreover, striking results often turn out to be difficult, or impossible to replicate. What teachers need, therefore, is good guidance about research that has stood the test of time, and practical guidance about how these well-established findings might be used to inform teaching practice, and this is why this is such an extraordinary, wonderful and important book. Paul Kirschner and Carl Hendrick have selected the most important research publications in the psychology of education, and, for each publication, they have provided a summary of the research, the main conclusions, and a series of practical suggestions for how the findings might inform teaching practice. I know of no other book that provides such a rigorous, accessible and practical summary of the last fifty years of research in educational psychology, and anyone who wants to understand how research can improve teaching needs to read this book. Highly recommended."

– **Dylan Wiliam**, *Emeritus Professor of Educational Assessment, University College London*

"It's hard to overstate just how fabulous this book is; a book I've wanted to exist for years and now here it is. A judicious and comprehensive selection of seminal research papers presented by two expert communicators, this is absolutely superb – from the mouth-watering list of contents, and through each of the chapters. I meet teachers in schools every week who, on hearing about various findings from research, feel liberated, enlightened with a whole new perspective on the problems they wrestle with in their classrooms. Teachers are busy – often overwhelmed – and all too frequently have not yet found the time or had the opportunity to engage with research that underpins the profession they've committed their lives to. This book is going to change that for a lot of people. The format is excellent, presenting the original papers alongside insightful commentary and key practical recommendations; a brilliant idea executed with style! Every school should have this book and every teacher should read it."

– **Tom Sherrington**, *education consultant; author of* The Learning Rainforest *and* Rosenshine's Principles in Action

"With the increasing volume of calls for education to become more evidence based, teachers everywhere have shaken their heads and wondered where on earth they're supposed to find the time to locate, read and evaluate the ever-increasing acreage of research papers out there. Worry no more. In *How Learning Happens: Seminal Works in Educational Psychology and What They Mean in Practice*, Kirschner and Hendrick have done the hard work so that you don't have to. The volume you have in your hands has compiled some of the most important and prominent research papers in the field of education and distilled them into a form that is genuinely useful to anyone chipping away at the chalk face. But, not only is this a resource of unparalleled utility, it's also a fascinating and world-enlarging read."

– **David Didau**, *author of Making Kids Cleverer*

"Future historians of education will look back on this period as a Renaissance; a time when dogma and orthodoxy were being challenged, and gate keepers, priesthoods and shamans felt the ground shift beneath their feet. The sleep of reason has bred monsters of pedagogy, and they have been fattened and nurtured by the relative ignorance of the teaching profession. Not a general ignorance, but a specific one: ignorance of the evidence bases behind the claims made in education. This Renaissance has been accompanied by an evolution, as teachers and academics reach out to one another and seek sincere, authentic dialogue. But, unless we stand on the shoulders of giants who have gone before us, each generation is doomed to rediscover what their ancestors painstakingly uncovered. For the health of the profession, we need the best of what we know in one place, so that successive generations of educators can carry on from their ancestors, and carry the conversation into the future rather than tread water endlessly.

This book is the perfect resource with which to do so. I can give no higher accolade than to say that every teacher should be familiar with the research it represents, its chapters should be required reading on every teacher induction course, and no teacher should account themselves a professional until they can demonstrate its acquaintance. I wish I had read it in the infancy of my career."

– **Tom Bennett**, *Founder, researchED*

"In these increasingly evidence-informed days, we are encouraged to be familiar with the research literature and reflect on the finding from within our own frames of reference. This book provides an interesting glimpse into some of the studies that have been influential in the thinking of the authors.

For the research geek, it is a thought-provoking read. It will be adored by many and I hope it introduces some to the complexity of psychology and the study of cognition."

– **Megan Dixon**, *TES*

How Learning Happens

How Learning Happens introduces 32 giants of educational research and their findings on how we learn and what we need to know to learn effectively, efficiently, and enjoyably. Many of these works have inspired researchers and teachers all around the world and have left a mark on how we teach today.

Now updated to include a new section on Memory and Cognition with five new chapters, this revised second edition explores a selection of the key works on learning and teaching, chosen from the fields of educational psychology and cognitive psychology. It offers a roadmap of the most important discoveries in the way learning happens, with each chapter examining a different work and explaining its significance before describing the research, its implications for practice, and how it can be used in the classroom – including the key takeaways for teachers.

Clearly divided into seven sections, the book covers:

- Memory and cognition
- How the brain works
- Prerequisites for learning
- How learning can be supported
- Teacher activities
- Learning in context
- Cautionary tales

Written by two leading experts and illustrated by Oliver Caviglioli, this is essential reading for teachers wanting to fully engage with and understand educational research as well as undergraduate students in the fields of education, educational psychology, and the learning sciences.

Paul A. Kirschner is Emeritus Professor of Educational Psychology at the Open University of the Netherlands as well as Guest Professor at the Thomas More University of Applied Sciences in Belgium. He also has his own educational consulting company, kirschnerED.

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How Learning Happens

Seminal Works in Educational Psychology and What They Mean in Practice

Second Edition

Paul A. Kirschner and Carl Hendrick

Illustrated by Oliver Caviglioli

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Foreword to the second edition

There are two traditional ways in which teachers, including trainee teachers, can obtain research-based information. The first way is to read research in research journals or in edited books. Such work is written primarily for specialised research community members and can be difficult to digest for anyone outside of a particular speciality. As busy professionals who cannot be expected to be conversant with all relevant areas, most of such published work is inaccessible to teachers.

The second way of obtaining research-based information eliminates the need for specialised, research knowledge by using articles in magazines for teachers or by textbooks that summarise research fields. These summaries, if well-written, can work but are susceptible to the biases of the writers and so prone to misinformation. In addition, finding relevant, well-written versions can be difficult.

The first edition of *How Learning Happens* by Paul Kirschner and Carl Hendrick used a brilliant third way of presenting important research information to teaching professionals. Instead of an edited book of research papers or an attempt to summarise a field, *How Learning Happens* chose influential educational psychology research papers and provided an extended discussion of each article. The discussion followed the same format for each article with the following headings: The article title; A quote from the article; "Why you should read this article" which is really a statement on why the article is important; "Abstract of the article"; "The article", which provides the relevant details of the article; "Conclusions/implications of the work for educational practice"; "How to use the work in your teaching"; "Takeaways"; "References"; "Suggested readings and links".

This novel structure provides a perfect vehicle for introducing teachers to seminal psychology articles dealing with the science underlying teaching. The writing is crystal clear and highly intelligible to teachers without a deep background in psychology. This second edition continues the format and clarity of the first edition but adds additional articles, especially articles on cognitive structures and functions. The new articles are exactly the ones that should be added. It is impossible to overestimate the importance of this volume to the teaching profession.

John Sweller
Emeritus Professor of Educational Psychology
University of New South Wales, Australia

Acknowledgements

In the first edition of the book, we thanked a lot of people. Those thanks remain applicable here. For this second, revised edition a special extra word of thanks is needed for all those on social media who reacted so positively to our attempt at making what we know based on good theoretically underpinned empirical research available to a larger audience. The reception was overwhelming and is testament to the collegiate and supportive nature of the wider educational community. Having said that, there are a few people that we want to add to the list of those receiving our special thanks, either because we forgot to include them in the first edition or because we've only gotten to "know" them since its publication. In no specific order, we'd like to thank our many supporters and cheerleaders over the past few years: Tim Surma and the rest of Paul's colleagues at the Expertise Centre Effective Learning where he's guest professor, Pim Pollen and the team at Academica University of Applied Science for all their support, Jim Heal (our co-author of *How Teaching Happens*), Oliver Caviglioli for making "darkness visible", Dylan Wiliam for providing us with characteristically insightful feedback on the first edition, John Sweller, John Hattie, Dan Willingham, Tom Bennett, Craig Doug Lemov, Barton, Greg Ashman, Becky Allen, Tom Sherrington, Iain Henderson, Peps McCrea, Eva Hartell, Sara Hjelm, Héctor Ruiz Martín, Andrew Old, Martin Robinson, Nick Rose, Pedro De Bruyckere, Daniel Muijs, David Didau, James Theobald, Stuart Lock, Alex Quigley, Daisy Christodoulou, Adam Boxer, Kate Jones, Bradley Busch, Ross McGill, Zach Groshell, Phil Naylor, Meg Lee, Helen Reynolds, and finally Nidhi Sachdeva who has done great work translating our chapters into micro-lessons. Apologies to anyone we have forgotten, we'll get to you in the third edition.

And, as things change, we'd like to thank those nearest and dearest to us:

Carl would like to thank his wife Lu for the ocean of patience afforded to him in the writing of this book and he would like to dedicate this book to his daughters Ava, Grace, and Sadie who have taught him more in the first few years of their lives than words can express.

Paul thanks above all Catherine, his muse and the anchor in his life, who makes it possible for him to combine projects like this book with all his other crazy projects. And a special word of love and thanks for his grandchildren Elsa, Benjamin, Liselotte, and Artur who are now small and innocent, but deserve to receive and enjoy good education as they grow up.

Introduction to the second edition

We're incredibly delighted with how the first edition of this book was received. The reception was better than we could have hoped for. Those who have read the first edition and hopefully will be reading this second edition have been so kind and supportive with their comments about the book on social media both to others and personally to us. We had hoped to write something that teachers and teacher educators would find interesting and even useful in their day-to-day teaching but were completely overwhelmed with how it was accepted. For all of this we're extremely thankful to all of you.

Upon reflection, however, although we were very pleased with our initial effort, we weren't completely satisfied. In our eyes there were a few seminal articles we felt weren't as strong in hindsight as we originally thought they would be in terms of classroom utility which was really our main focus for the book. We also realised that we didn't really start at the beginning, which according to Rogers and Hammerstein[1] is a very good place to start. We began with the brain, but again in hindsight, we forgot about those articles which really formed the basis of what we know about how we learn.

The missing elements in the first part of the book all fell within the broader category of memory and specifically how it underpins, foregrounds, and interacts with learning. We felt it necessary to include the work of George Miller and Nelson Cowan on the limits of our short-term/working memory, Endel Tulving's work on the different types of memory (i.e., episodic and semantic) which forms the basis of what we retain in our long-term memory as well as how we retain it. We also felt that subsequent chapters would be better understood if we included Alan Baddeley and Graham Hitch's (and Richard Atkinson and Richard Shiffrin's) work on information processing. As learning not only deals with knowledge acquisition, we added a chapter on John R. Anderson's article on skill acquisition. In addition, we felt that the omission of

1 SEE *DO-RE-MI* FROM THE 1959 RODGERS AND HAMMERSTEIN MUSICAL *THE SOUND OF MUSIC.*

Frederic Bartlett's 1932 book *Remembering* and Donald Rumelhart and Don Norman's work on how schemata are formed were glaring omissions on reflection. Although we speak a lot about cognition, learning to learn, helping students learn to learn, and so forth, we felt that John Flavell's work on metacognition would be a valuable addition. Finally, we added a second closing chapter (is that possible?) in which, after discussing the ten deadly sins of education (the original concluding chapter), we discuss the ways in which seminal research can become distorted into dysfunctional implementations of its original form, what Brown and Campione christened "Lethal Mutations".[2]

For the rest, we've updated, checked, and rechecked the links and QR-codes, added some links to new additional materials, and corrected mistakes that we and others found in the original book.

To the casual observer, teaching can look like a relatively straightforward enterprise, but the deeper mechanisms which drive not just superficial, but long-term learning are often very complex. Indeed, Lee Shulman once noted that "the only time medicine ever approaches the complexity of an average day for a classroom teacher is in an emergency room during a natural disaster".[3] It's our belief that planning instruction without an understanding of cognitive architecture has been a limiting force on teachers and so a driving impetus for this book was to empower teachers with the "best which has been thought and said"[4] regarding how students learn so that they might better create the conditions under which they might do so.

Paul A. Kirschner and Carl Hendrick
January 2024

2 BROWN, A. L., & CAMPIONE, J. C. (1996). PSYCHOLOGICAL THEORY AND THE DESIGN OF INNOVATIVE LEARNING ENVIRONMENTS: ON PROCEDURES, PRINCIPLES, AND SYSTEMS. IN L. SCHAUBLE & R. GLASER (EDS.), *INNOVATIONS IN LEARNING: NEW ENVIRONMENTS FOR EDUCATION* (PP. 289–325). LAWRENCE ERLBAUM ASSOCIATES.

3 SHULMAN, L. S. (1987). THE WISDOM OF PRACTICE: MANAGING COMPLEXITY IN MEDICINE AND TEACHING. IN D. C. BERLINER & B. V. ROSENSHINE (EDS.), *TALKS TO TEACHER: A FESTSCHRIFT FOR N.L. GAGE*. RANDOM HOUSE, 369–397.

4 ARNOLD, MATTHEW (1889). *CULTURE AND ANARCHY; AN ESSAY IN POLITICAL AND SOCIAL CRITICISM* (INTERNET ARCHIVE). SMITH, ELDER.

PART 1

MEMORY AND COGNITION

What does the number of digits in our telephone numbers have to do with how our brain works? Now, the answer is simple. In 1956, George Miller, a Harvard professor, was asked by Bell Telephone Labs in New Jersey to empirically determine how many random digits a person could remember at any one time so that Ma Bell, as the company was known, could determine how many numbers to use in a telephone number. He determined that most people can only remember five to nine things at any given time without resorting to tricks, such as chunking, and that's why American telephone numbers have had, from the beginning, seven digits. But let's look at this a bit more closely. When Paul was a kid living in the Bronx the first two digits of his phone number were the numerical equivalent of the first two letters of his telephone exchange (**FO**rdham = 36) and so were these two also mnemonically chunked bringing us back to six things to remember (**FO**rdham–7–3472) and actually Fordham–7 itself became a chunk as everyone in his neighbourhood had this (367; so we now have only five things to remember). However, we're not there yet. People from Long Island (area code 516) first had to dial the Bronx area code (212) to call him and he had to dial 516 to call a friend or relative on Long Island, so it became longer again. However, since the area code was the same for all Bronxites (and Long Islanders) it too became a chunk. Thus, 2123673472 became Bronx-FO–7–3472 or six items in memory.

This first part of the book sets the groundwork for understanding the rest of the book, discussing articles or book chapters on short-term memory (George Miller), information processing (Alan Baddeley and Graham Hitch), episodic and semantic memory (Endel Tulving), schemata and how memory is organised (Frederic Bartlett), and metacognition (John Flavell).

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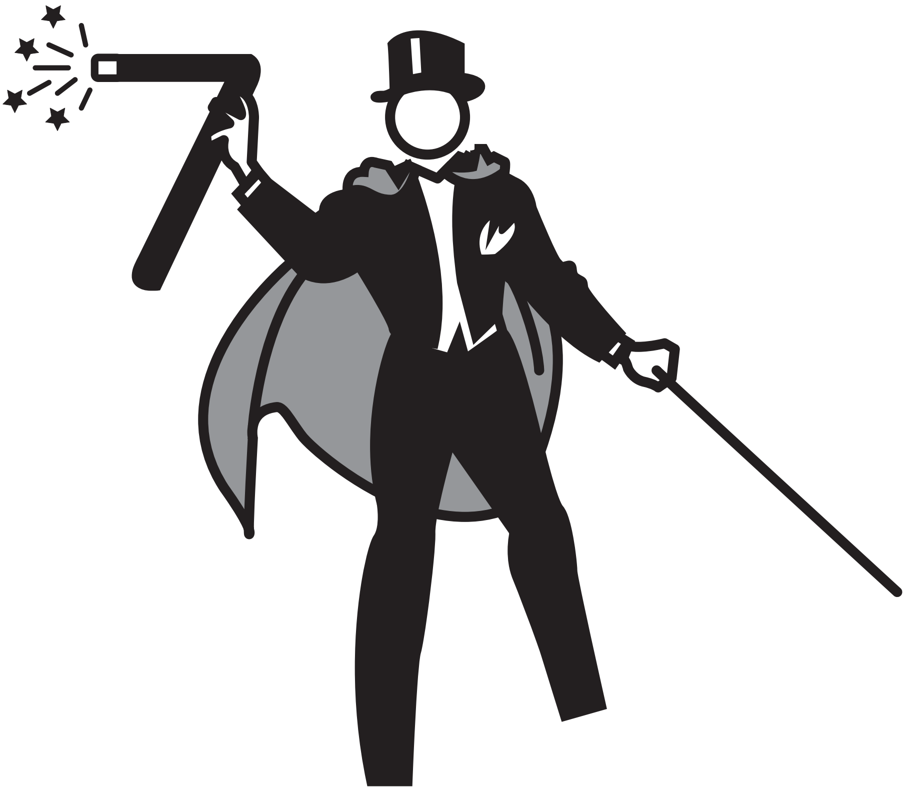
1 WORKING MEMORY

HOW DEEP IS THE WELL?



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1 WORKING MEMORY

PAPER "The magical number seven, plus or minus two"[1]

QUOTE *"The span of absolute judgment and the span of immediate memory impose severe limitations on the amount of information that we are able to receive, process, and remember."*[2]

Why you should read this article

To paraphrase George Orwell in *Animal Farm*, while all the articles in this book are about seminal articles on learning, not all seminal articles are equal in terms of impact. This chapter features possibly the most impactful finding in terms of cognition, learning, and basic cognitive architecture.

Sometimes you sit down and wonder, or maybe even fantasise, how someone came up with something that completely changed how we think, act and/or work. You know, the epiphany that changed everything. One is reminded of the apocryphal tale of Newton supposedly sitting under an apple tree when an apple (why is it always an apple?) fell to the ground and not onto his head, leading him to wonder why it fell perpendicularly and not horizontally and then to theorise that the same force that caused an apple to fall to the ground was also the force that kept the moon in place (Keesing, 1998). Over several years, he worked further on this until he had developed the law of universal gravitation. Or take Archimedes, who when trying to figure out how to determine if a crown was made of pure gold or a mixture of metals supposedly noticed that when at the public baths, the more his body sank into the water, the more water was pushed out (displaced). This displaced water was an exact measure of his volume. Because gold weighs more than silver, he reasoned that a crown made of

1 MILLER, G. A. (1956). THE MAGICAL NUMBER SEVEN, PLUS OR MINUS TWO: SOME LIMITS ON OUR CAPACITY FOR PROCESSING INFORMATION. *THE PSYCHOLOGICAL REVIEW, 63*(2) 81–97.
2 IBID., P. 95.

a gold-silver alloy would have to be bulkier to be the same weight as one composed of pure gold and therefore would displace more water than its pure gold counterpart. Problem solved and a step towards his laws of buoyancy. Archimedes, it is said, shouted "eureka!" ("I've found it!") upon making this discovery. Both moments are what are called *eureka moments*. So is it with one of the most prominent discoveries in cognitive science, namely that our short-term or working memory is limited in size. George Miller (1956), just as Archimedes, probably didn't shout "eureka!", but it was a eureka moment just the same.

Eureka moment

Abstract of the article

My problem is that I have been persecuted by an integer. For seven years this number has followed me around, has intruded in my most private data, and has assaulted me from the pages of our most public journals. This number assumes a variety of disguises, being sometimes a little larger and sometimes a little smaller than usual, but never changing so much as to be unrecognizable. The persistence with which this number plagues me is far more than a random accident. There is, to quote a famous senator, a design behind it, some pattern governing its appearances. Either there really is something unusual about the number or else I am suffering from delusions of persecution.

The article

A LITTLE BACKGROUND

George Miller worked at Bell Telephone Labs.[3] He was tasked with empirically determining how many random digits a person could remember at any time, because the telephone company needed to know how many numbers to use in a telephone number. He determined that most people can only remember five to nine things at any given time without resorting to tricks, such as chunking, and that's why American telephone numbers have had, from the beginning, seven digits.

At a meeting of the Eastern Psychological Association in Philadelphia on April 15, 1955 George Miller delivered a speech that "changed everything". It is important to realise that until then, twentieth century psychology was dominated by behavioural psychology where what happened in our

3 BELL LABS WAS A HOTBED OF COGNITIVE RESEARCH IN THE 1950S AND 1960S WITH RESEARCHERS LIKE GEORGE MILLER, ERNST ROTHKOPF, AND LARRY FRASE (ADJUNCT QUESTIONS, SEE CHAPTER 20, ACTIVITIES THAT GIVE BIRTH TO LEARNING).

Span of immediate memory

heads was a black box. All of a sudden there was this man who spoke of a *span of immediate memory* which was later renamed short-term memory and then working memory, of the *chunking* of information into more meaningful units (letters into syllables and syllables into words), and *recoding*, which is close to what happens when schemata are formed (he spoke of "repackaging material into a few chunks rich in information" and conjectured "that imagery is a form of recoding, too" p. 95).

Variance

Miller based his paper on two things. The first is *variance* and the second is the equivalence of variance to *the amount of information*. In other words, the amount of information that needs to be processed is the same concept as variance in communication systems and "anything that increases the variance also increases the amount of information" (p. 82).

> The similarity of variance and amount of information might be explained this way: When we have a large variance, we are very ignorant about what is going to happen. If we are very ignorant, then when we make the observation it gives us a lot of information. On the other hand, if the variance is very small, we know in advance how our observation must come out, so we get little information from making the observation.
>
> (p. 82)

In communication systems, there's a lot of variability in what goes in (input information) and what comes out (transmitted information). When there's a lot of variance we don't know what's going to happen, but when there's little variance we know what's going to happen. He then began looking at different experiments on what he called *absolute judgement*, trying to determine the point at which the amount of input information causes problems for the amount of transmitted information. Miller put it this way:

Bits of information

> If the observer's absolute judgments are quite accurate, then nearly all of the input information will be transmitted and will be recoverable from his responses. If he makes errors, then the transmitted information may be considerably less than the input. We expect that, as we increase the amount of input information [which he called *bits*][4], the observer will begin to make more and more errors; we can test the limits of accuracy of his absolute judgments. If the human observer is a reasonable kind of communication system, then when we increase the amount of input information the transmitted

4 ONE BIT OF INFORMATION IS HOW MUCH INFORMATION WE NEED TO DECIDE BETWEEN TWO EQUALLY LIKELY ALTERNATIVES, TWO BITS FOR FOUR, THREE BITS FOR EIGHT, ETC.

ASYMPTOTE
A line that a curve approaches as it approaches infinity (see Figure 1.1 where the curve approaches 2.5 bits)

> information will increase at first and will eventually level off at some asymptotic value. This asymptotic value we take to be the *channel capacity* of the observer: it represents the greatest amount of information that he can give us about the stimulus on the basis of an absolute judgment. The channel capacity is the upper limit on the extent to which the observer can match his responses to the stimuli we give him.
>
> (p. 82)

In current terms, he looked at how many items or information elements the working memory can handle before it gets overloaded (i.e., the capacity of our working memory). He then began looking at research on absolute judgements of unidimensional stimuli. One example is asking listeners to identify tones that differed in frequency (Pollack, 1952). When listeners had to discriminate between two or three tones, they never confused them. With four, confusion occurred but was rare. But with five or more, confusion increased in frequency. He plotted the data as shown in Figure 1.1

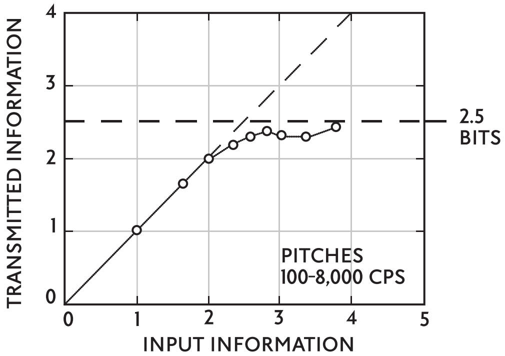

FIGURE 1.1 DATA FROM POLLACK 1952, 1953

As can be seen,

> [T]he amount of transmitted information … increases linearly up to about 2 bits and then bends off toward an asymptote at about 2.5 bits. This value, 2.5 bits, therefore, is what we are calling the channel capacity of the listener for absolute judgments of pitch.
>
> (p. 84)

This means that we're talking about $2^{2.5}$ or about six judgements. He then looked at loudness (Garner, 1953) and found that the point where mistakes were made was 2.3 bits ($2^{2.3}$=5 judgements). Looking at tasting saltiness in tap water (Beebe-Center, Rogers, & O'Connell, 1955), the limit was 1.9 bits or about four distinct concentrations. With respect to visual positions (Hake & Garner, 1951) the capacity was 3.25 bits (9.5

judgements) before mistakes prevailed, and for line length, curvature, and direction approximately 2.7 or 6.5 judgements, etc. In other words, irrespective of the sense, there was a clear limit. Miller writes:

> There is a clear and definite limit to the accuracy with which we can identify absolutely the magnitude of a unidimensional stimulus variable. I would propose to call this limit the *span of absolute judgment*, and I maintain that for unidimensional judgments this span is usually somewhere in the neighborhood of seven.
>
> (p. 90)

Immediate memory (now short-term memory)

He, however, encountered a problem when it came to judgements with respect to letters and words that can be retained in what he called *immediate memory* (which was called *short-term memory* by Atkinson and Shiffrin (1968)) which has been replaced by *working memory* (Baddeley & Hitch, 1974; see Chapter 2, Opening the black box). If one looks at the number of letters in words as distinct bits, then the number seven doesn't hold, but when we jump to the level of words, then order is restored. He writes:

> In order to capture this distinction in somewhat picturesque terms, I have fallen into the custom of distinguishing between *bits* of information and *chunks* of information. Then I can say that the number of bits of information is constant for absolute judgment and the number of chunks of information is constant for immediate memory. The span of immediate memory seems to be almost independent of the number of bits per chunk, at least over the range that has been examined to date.
>
> The contrast of the terms *bit* and *chunk* also serves to highlight the fact that we are not very definite about what constitutes a chunk of information. For example, the memory span of five words that Hayes [1952] obtained when each word was drawn at random from a set of 1,000 English monosyllables might just as appropriately have been called a memory span of 15 phonemes, since each word had about three phonemes in it. Intuitively, it is clear that the subjects were recalling five words, not 15 phonemes, but the logical distinction is not immediately apparent. We are dealing here with a process of organizing or grouping the input into familiar units or chunks, and a great deal of learning has gone into the formation of these familiar units.
>
> (pp. 92–93)

Chunk of information

In other words, what we do is recode it; that is to say, we combine the individual bits of information into increasingly larger chunks of information. David Ausubel (see Chapter 11, What you know determines what you learn) might possibly say that the individual pieces of knowledge are subsumed into larger concepts and assimilated into new schemata (e.g., Chihuahua, Dalmatian, German Shephard, etc. are recoded into the concept dog, and that dogs, cats, gerbils, hamsters, and goldfish are recoded into the concept pet). Someone just beginning to learn Morse code sees a dot and a dash or hears each *dit* and a *dah* as a separate element. Soon the fledgling telegraphist can organise these sounds into letters and handle them as chunks (dash dot dot = C). Then the letters reorganise themselves as words (dash dot dot – dot dash – dash = CAT), which are still larger chunks, after which whole phrases are heard. In other words, this person learns to increase the bits per chunk. His point was that "recoding is an extremely powerful weapon for increasing the amount of information that we can deal with. In one form or another we use recoding constantly in our daily behavior" (p. 94).

And what about the magical number seven that had "persecuted" him for so long? He muses at the end of the article if the seven categories for absolute judgement, objects in the span of attention, and digits in the span of immediate memory are related to the seven: wonders of the world, seas, deadly sins, levels of hell, notes of the musical scale, and days of the week. He decides to withhold judgement. "Perhaps there is something deep and profound behind all these sevens, something just calling out for us to discover it. But I suspect that it is only a pernicious, Pythagorean coincidence" (p. 96).

In the years thereafter much has been written relating to this magical number. Nowadays the limit of items that can be processed at any one time in our working memory is seen as being closer to four. This is based on an article by Nelson Cowan (2001). His article "The magical number 4 in short-term memory: A reconsideration of mental storage capacity" looked at more, newer, and primarily psychological literature where:

- overload was induced before new things to recall were presented (i.e., there's more information already in working memory than can be rehearsed or encoded before time is up),
- steps were taken to specifically block recoding stimuli into larger chunks (i.e., experimental conditions limited using long-term memory and rehearsal processes),
- there was a focus on abrupt changes or discontinuities in performance indices (e.g., proportion correct, reaction time) related to the number of chunks presented, and

- the research looked at indirect effects of the capacity limit (e.g., that respondents in research tended themselves to group lists of items into chunks of about four items for recall).

Be this as it may, the exact number of items in short-term memory isn't the issue, but rather that it's very limited and as such we need to take this into account when we want our students to effectively and efficiently learn.

Conclusions/implications of the work for educational practice

Informational bottleneck

Miller's work showed us, almost 70 years ago, that the "span of immediate memory" (our working memory) forms a bottleneck for the amount of information that we can successfully process. By organising and recoding the input into chunks, we are able to partially alleviate this informational bottleneck. And what does this mean for our educational practice and how learning happens?

When we think about what we ask students to do in a classroom, we tend to think about units of curricular content and how they relate to units of time. So for example, a teacher might say, "Today we're going to cover this topic which includes these facts and concepts which you will be tested on next week." However, learning does not fit into such discrete parts and the unit of a lesson is probably the wrong metric to measure learning, which is why the idea of "showing progress in a lesson" idea is so flawed. However Miller's magic number idea is a powerful one because we can actually see the effects of a learner's immediate (working) memory becoming cognitively overloaded by too many items. In fact, it's usually written all over their faces as any teacher can attest to.

How to use the work in your teaching

As Ausubel illustrated (see Chapter 11, What you know determines what you learn), learning is greatly dependent on what the learner already knows; so for example, a 5-year-old learning to read will learn "tricky words" like "the", which do not conform to the rules they've previously learned about letter/sound correspondences, so when they learn that word it's automated in their memory and they can focus on the underlying meaning of what they are reading. A beginning reader is almost constantly experiencing the magic number seven, which is evident in the amount of concentration required to read a page but a fluent reader flies over the words and is able to focus exclusively on the meaning of the text, until they encounter something not in their long-term memory such as a new word or concept.

So teachers need to be aware of two key points: first, what the student already knows and second, how newly presented information will build on what they know and whether it will overload their working memory beyond that magic number. This is where the rubber hits the road for many learners because students who have relatively well-developed complex schemata or mental models of a given domain of knowledge can take on board a lot more information and work with it to create new understanding because what they need to process it is stored as a chunk in long-term memory and retrieved as such. In other words, what we want students to learn doesn't have an intrinsic difficulty but rather understanding something new is largely dependent on bringing to mind something old, or as cognitive load theory has taught us: the intrinsic load of a task is also dependent on the expertise of the person carrying out the task. To put it another way, what the learner already knows around a new thing to be learned determines how effectively and efficiently they'll learn it.

GOLDEN DELTA
Sweet spot between new information and stored knowledge

The key takeaway here is not to think about what the learner can deal with *in the moment* but rather what they'll be able to deal with *in the future*. So sometimes as teachers, we want to avoid student confusion so much that we pitch new information at a relatively low level so that we avoid going beyond that dreaded number seven which means there is relatively little cognitive struggle, but key to future understanding is getting students into that golden delta where stored knowledge and future knowledge meet, thus helping students build strong mental models which can then be connected with new knowledge and help shape further comprehension of the world, a process which is really the cornerstone of how learning happens.

Takeaways

- The span of absolute judgement and the span of immediate memory impose severe limitations on how much information we can receive, process, and remember.
- If we are able to organise the input simultaneously into several dimensions and successively into a sequence or chunks, we can break or at least stretch this bottleneck.
- Recoding is a very important one in human psychology and is "very lifeblood of the thought processes" (p. 95).
- Miller's work provides us with a yardstick for calibrating what we present to learners and for measuring their performance.
- Simply put, if students are having to remember more than four new things at once, they're likely to become overloaded and engage in off-task behaviours or worse still, lose confidence and motivation.

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VIDEOS

Here's a relatively detailed look at the experiments and findings underlying the classic seven, plus or minus two by Ben Vincent

AVAILABLE VIA WWW.YOUTUBE.COM/WATCH?V=FYCAEKBBOOI

This video explains cognitive load starting with the phone company in the 1950s. George Miller and other psychologists explored the limits of our memory.

AVAILABLE VIA WWW.YOUTUBE.COM/WATCH?V=J-IU195MCWA

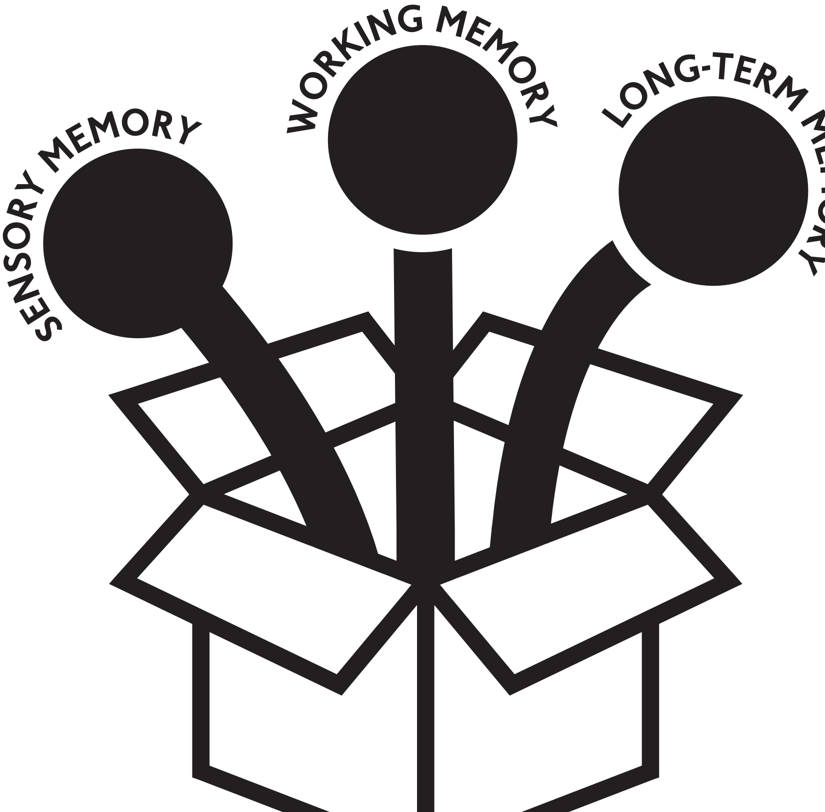
WEBSITES

GEORGE MILLER – MAGIC NUMBER 7 AND CHUNKING... REFERRED TO HIMSELF AS BEING 'PLAGUED BY AN INTEGER'!

AVAILABLE VIA HTTP://DONALDCLARKPLANB.BLOGSPOT.COM/2020/02/MILLER-MAGIC-NUMBER-7-AND.HTML (FROM DONALD CLARK PLAN B: WHAT IS PLAN B? NOT PLAN A!)

2 OPENING THE BLACK BOX

THE BRAIN REDISCOVERED



DOI: 10.4324/9781003395713-3

2 OPENING THE BLACK BOX

PAPER "Working memory"[1]

QUOTE *"We began with a very simple question: what is short-term memory for? We hope that our preliminary attempts to begin answering the question will convince the reader, not necessarily that our views are correct, but that the question was and is well worth asking."*[2]

Why you should read this chapter

The earliest mention of the brain dates from the seventeenth century BCE found on a "medical papyrus"[3] written in hieroglyphs by an Egyptian battlefield surgeon who noted symptoms such as aphasia (a disorder resulting from damage to portions of the brain responsible for language; "he speaks not to thee") and seizures ("he shudders exceedingly") in warriors who had suffered battlefield head trauma. While Aristotle thought the heart to be the centre of our bodily functioning and the brain to be a mere radiator to dissipate its heat, Galen (170 BCE) suggested that the brain was the seat of complex thought, determining personality and bodily functions. Though knowledge was slowly gained on the structure and functions of the brain, it was often by accident and when things went wrong. For

Phineas Gage

example, when Phineas Gage (a railroad construction foreman in the US) had his left frontal lobe blown away when an iron rod he was using to tamp explosives he needed to blast away some rocks in the way went through his head, his doctors saw a marked change in his behaviour

1 BADDELEY, A. D., & HITCH, G. (1974). WORKING MEMORY. IN G. A. BOWER (ED.), *THE PSYCHOLOGY OF LEARNING AND MOTIVATION* (PP. 47–89). ACADEMIC PRESS.
2 IBID., P. 86.
3 THIS IS KNOWN AS THE *EDWIN SMITH SURGICAL PAPYRUS*, AN ANCIENT EGYPTIAN MEDICAL TEXT NAMED AFTER EDWIN SMITH WHO BOUGHT IT IN 1862 AND THE OLDEST KNOWN SURGICAL TREATISE ON TRAUMA.

and personality, leading them to deduce the connection between the prefrontal cortex and certain executive functions. But still little was known about the connection between the brain and learning.

Operant conditioning

Ivan Pavlov demonstrated what's known as classical conditioning (a form of "teaching") followed in the 1950s and 1960s when B. F. Skinner did the same for operant conditioning. Classical conditioning was about how a neutral stimulus could be associated with a reflexive response through repeated pairing (e.g., a bell rings simultaneously with the injection of powdered meat in a dog's mouth causing the dog to salivate; after this, the dog salivates when the bell is rung). Operant conditioning, on the other hand, was about how behaviour could be shaped by the consequences that follow it. Skinner demonstrated that a behaviour followed by a positive outcome (a reward) is likely to be repeated, while behaviour followed by a negative outcome (punishment) is less likely to be repeated. Many consider this the birth of the modern science of learning[4] where children were taught through programmed learning with learning machines. However, what occurred in the heads of dogs, pigeons, and children when they learnt remained a black box. Alan Baddeley and Gordon Hitch expanded on the work of Donald Broadbent (filter model of attention) and Richard Atkinson and Richard Shiffrin (memory model).

Abstract of the chapter

Despite more than a decade of intensive research on the topic of short-term memory (STM), we still know virtually nothing about its role in normal human information processing. That is not, of course, to say that the issue has completely been neglected. The short-term store (STS) – the hypothetical memory system which is assumed to be responsible for performance in tasks involving short-term memory paradigms – has been assigned a crucial role in the performance of a wide range of tasks including problem solving, language comprehension and most notably, long-term learning. Perhaps the most cogent case for the central importance of STS in general information processing is that of Atkinson and Shiffrin (1971) who attribute to STS the role of a controlling executive system responsible for coordinating and monitoring the many and complex subroutines that are responsible for both acquiring new material and retrieving old.

4 THERE ARE MANY ACCOUNTS OF WHEN AND BY WHOM THE FORMAL STUDY OF EDUCATION AND LEARNING BEGAN (I.E., WITH EXPERIMENTS TRYING TO EXPLICITLY STUDY THESE PHENOMENA). IN THIS VEIN WE MIGHT WANT TO ACTUALLY GIVE THIS TITLE TO HERMAN EBBINGHAUS WHO IN 1885 STUDIED AND PUBLISHED ABOUT HOW WE LEARN, REMEMBER, AND FORGET (YOU MIGHT ALSO CALL HIM THE FATHER OF SPACED PRACTICE; SEE *HTH* CHAPTER 14 ON DESIRABLE DIFFICULTIES; SEE NOTE ON PAGE 23 FOR *HTH* DETAILS).

The experiments which follow attempt to answer two basic questions: first, is there any evidence that the tasks of reasoning, comprehension, and learning share a common working memory system?; and second, if such a system exists, how is it related to our current conception of STM? We do not claim to be presenting a novel view of STM in this chapter. Rather, our aim is to present a body of new experimental evidence which provides a firm basis for the working memory hypothesis.

The chapter

Filter Model of Attentional Processing

Donald Broadbent (1958) is seen as the first to describe the human attentional processing system using an information-processing metaphor. He postulated, at about the same time as George Miller (see Chapter 1, Working memory), that humans have a limited capacity to process information and due to this limited capacity, a selective filter is needed for information processing.

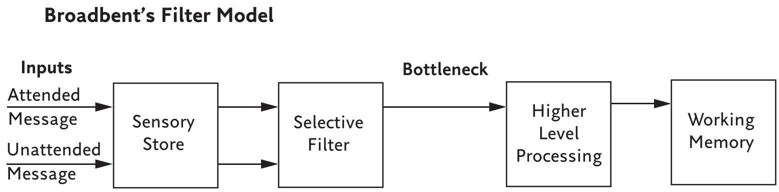


FIGURE 2.1 BROADBENT'S FILTER MODEL (KYLE.FARR, CC BY-SA 3.0, VIA WIKIMEDIA COMMONS; HTTPS://COMMONS.WIKIMEDIA.ORG/WIKI/FILE:BROADBENT_FILTER_MODEL.JPG)

MULTI-STORE MODEL OF MEMORY:

- Sensory Store
- Short-Term Store
- Long-Term Store

Shortly thereafter, Richard Atkinson and Richard Shiffrin (1968) proposed a multi-store model of memory composed of a *sensory register* where information from all of our senses enters memory: a *short-term store* (short-term memory; STM) which receives and holds input from both the sensory register and the long-term store, and a *long-term store*, where information which has been rehearsed in the short-term store is held indefinitely.

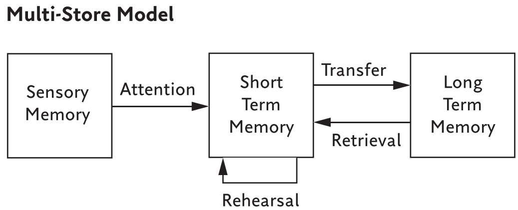


FIGURE 2.2 ATKINSON AND SHIFFRIN'S ORIGINAL MULTI-STORE MODEL OF MEMORY (KURZON AT ENGLISH WIKIPEDIA, PUBLIC DOMAIN, VIA WIKIMEDIA COMMONS HTTPS://COMMONS.WIKIMEDIA.ORG/WIKI/FILE:MULTISTORE_MODEL.PNG)

Working Memory

In 1974 Alan Baddeley and Graham Hitch proposed a new model of short-term memory that challenged the prevailing view of memory as a single system. They suggested that short-term memory is composed of multiple, distinct components that work together to allow us to hold information in mind and manipulate it. This is what became known as *working memory* (WM).

FROM SHORT-TERM MEMORY (STM) TO WORKING MEMORY (WM)

STM and WM are both cognitive processes that involve the temporary storage and manipulation of small amounts of information but aren't the same thing.

STM is characterised by limited capacity, brief duration (typically lasting up to 30 seconds), and is primarily involved in the temporary storage of information that is actively being processed.

WM is more complex and dynamic. It not only temporarily stores information but also actively manipulates and uses the information. The central executive controls attention and directs cognitive processes, the phonological loop processes verbal information, and the visuospatial sketchpad processes visual and spatial information.

Thus, while STM and WM both involve temporary storage, WM is complex and dynamic and not only stores information but also manipulates and uses it.

COMPONENTS:
- Phonological Loop
- Visuospatial Sketchpad
- Central Executive

In their model, in addition to the already mentioned sensory store and long-term store, short-term memory was seen as being composed of three components: a *phonological loop* that holds verbal and auditory information, a *visuospatial sketchpad* that stores visual and spatial information, and a *central executive* that serves as the control system, coordinating the activities of the other two components and directing attention and cognitive resources to tasks as needed.[5]

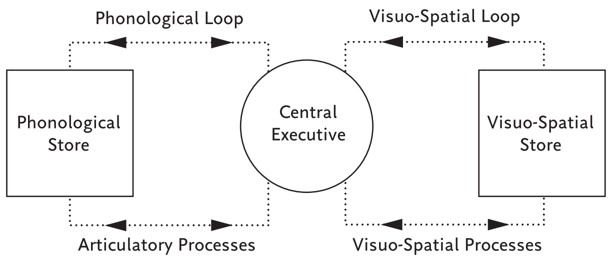


FIGURE 2.3 BADDELEY AND HITCH'S MODEL OF WORKING MEMORY AS PROPOSED IN 1974

They also discussed the role of long-term memory in working memory, noting that long-term memory plays a crucial role in the ability to hold and manipulate information over longer periods of time, suggesting

5 JOHN SWELLER HAS SINCE CONVINCINGLY ARGUED THAT THERE IS NO KNOWLEDGE INDEPENDENT CENTRAL EXECUTIVE (SEE HTTPS://GREGASHMAN.WORDPRESS.COM/2020/02/11/ANARCHIC-MINDS/).

that working memory and long-term memory are separate but interdependent systems.

JOHN SWELLER ON THE EXISTENCE OF A CENTRAL EXECUTIVE

"The human cognitive system is a self-regulating system in the same way as evolution by natural selection is self-regulating. Neither has need for a central executive to control activity. Indeed, there are philosophical objections to a central executive. If we need a central executive to control activity, what controls the central executive? Another executive, ad infinitum? Instead of a central executive, control depends on the intricate relations between the external environment, working memory, and long-term memory. Information enters working memory from the environment via sensory memory. If that information matches what is held in long-term memory, appropriate action governed by the contents of long-term memory can be taken. If it does not match, then working memory must engage in a random generate and test process during problem-solving in order to determine appropriate action. Analogical processes occur in evolution by natural selection. Not only is there no need for a central executive, there is no place for a central executive. The structure of natural information processing systems allows them to function without direction from a central executive." (Personal Communication, April 4, 2023)

Baddeley and Hitch's main research question was whether reasoning, comprehension, and learning share a common working memory system. To do this they conducted ten experiments to investigate the role of working memory in these cognitive processes and identify common patterns that could suggest the same working memory system was involved in all three instances.

To do this they applied comparable techniques in all three cases to identify a common pattern that could suggest the same working memory system was involved in all three instances. The experiments involved manipulating the *cognitive load* of participants by presenting them with different types of tasks that required varying levels of working memory. They then measured participants' performance on these tasks and analysed the results to identify any patterns or trends.

Cognitive Load

A TYPICAL EXAMPLE OF AN EXPERIMENT

Experiment I involved giving participants a reasoning problem requiring them to draw a conclusion based on a set of premises. They had to process 32 sentences based on all possible combinations of sentence voice (active or passive), affirmation (affirmative or negative), truth value (true or false), verb type (precedes or follows), and letter order (AB or BA). They then manipulated the cognitive load of participants by presenting them with a verbal memory preload before presenting the reasoning problem; here one or two items to remember and in Experiment II, six digits. Respondents were then required to process the sentence and having responded "True" or "False", required to recall the letters.

The results showed that the cognitive load had a significant impact on the participants' performance, with those in the high cognitive load condition performing worse than those in the low cognitive load condition. This suggested that working memory played a crucial role in reasoning and problem-solving.

Phonemic Similarity

Articulatory Suppression

An important point here is that they not only looked at the quantitative nature of the load but also at the phonemic similarity of the preload with the eventual task (that they sound similar like the letters "p" and "b" or "know" and "go") and what they called articulatory suppression (articulating/repeating irrelevant information during a verbal task such as "the" or a number such as "one" as a concurrent task while actively attempting to memorise a list of information). Table 2.1 presents their findings across the ten experiments.

TABLE 2.1 SUMMARY OF EXPERIMENTAL RESULTS (FROM BADDELEY & HITCH, 1974, P. 75)

		Verbal Reasoning	**Comprehension**	**Long-term Store**	**Recency**
Memory Load	1–3 Items	No Effect	No Effect	Small Decrement	No Effect
	6 Items		Decrement	Decrement	No Effect
Phonemic Similarity		Decrement	Decrement	Enhancement	No Effect
Articulatory Similarity		Decrement	Not Studies	Decrement	No Effect

Based upon the ten experiments they concluded:

- Allocation of work space: There is a trade-off between the amount of storage required and the rate at which other processes can be carried out.
- The role of working memory in the memory span: The working memory system may contain both flexible work space and also a component that is dedicated to storage.
- Number of working memories: "It seems probable that a comparable system exists for visual memory which is different at least in part from the system we have been discussing" (Baddeley & Hitch, 1974, p. 80).

Both amount of load and type of task influenced performance!

Their findings further supported their argument that the cognitive load had a significant impact on the participants' performance across all three types of tasks. As the cognitive load increased, the participants' performance decreased, indicating that working memory plays a crucial role in all three cognitive processes. They also found that the type of task influenced performance, with tasks that required more reasoning and problem-solving skills being more affected by cognitive load than tasks involving simple language comprehension. These findings suggest that working memory is a critical component of human information processing and plays a crucial role in various cognitive processes.

Overall, Baddeley and Hitch's model of working memory represented a significant departure from both Broadbent's and Atkinson and Shiffren's views of memory in that it saw working memory as a dynamic system which did more than merely filter or store information and sparked a great deal of research into the nature and function of short-term memory. Their model has been refined and expanded over the years, but it remains an important framework for understanding the role of working memory in cognition.

Conclusions/implications of the work for educational practice

How and what we teach

Baddeley and Hitch's article, and actually their legacy, has two very important implications for what we do in school. The first implication has to do with *how* we teach and the second with *what*. With respect to the *how* of teaching, we first need to be aware of the cognitive load of the tasks they assign to students, as higher cognitive loads can lead to worse performance. Working memory has serious limitations and because of this, we must present information in a clear and organised manner, minimising irrelevant information and providing ample opportunities for practice and review. As Baddeley and Hitch showed, there's a common working memory system involved in reasoning, language comprehension, and learning. If we don't take this into account we not only impede student learning, but we also set them up for frustration. What we mean here is that we send a message to our students that it is them who are at fault for their failure to learn and achieve while we are the culprits. We must also realise the possibilities of the multiple memory stores and make use of them effectively and efficiently. Baddeley and Hitch spoke of two as did Allan Paivio (see Chapter 10, One picture and one thousand words) but we actually have at least five memory stores – we have at least five senses – and by using them in a way that they complement and supplement each other, we help to facilitate learning. For example, a teacher might use visual aids to supplement verbal instruction, or incorporate hands-on activities to engage the visuospatial sketchpad. In this way they can help students create better connections in their long-term memory so that they learn better and retain what they have learnt longer.

The latter deals with the need to provide our students with strategies and techniques for managing their working memory load. We're not always able to provide learning situations where the former is the case (e.g., where they must learn from longer texts or where multimedia bombards them with "attractive" but poor learning material). In such cases we need to teach and train – through practice – our students to use strategies such as breaking the learning task into smaller chunks or using visual aids such as mapping, drawing, and imagining (see *HTH*[6], Chapter 13 on generative learning activities) to help them understand and learn. These strategies must be explicitly taught and then practised throughout their school career as they are skills which they need to acquire.

How to use the work in your teaching

There are several ways that teachers can use the information from the Baddeley and Hitch's chapter on working memory to inform their teaching practices:

Cognitive

1. Be aware of cognitive load: We must be aware of the potential for cognitively overloading working memory, particularly when presenting new or complex information.

Clear and organised

2. Present information in a clear and organised manner: We can help reduce the load on working memory and maximise its capacity by presenting information in a clear and organised manner. This includes breaking down complex information into smaller, more manageable pieces, and using visual aids and other multi-sensory approaches to help students process the information.

6 *HTH* REFERS TO: P. KIRSCHNER, C. HENDRICK, & J. HEAL (2022). *HOW TEACHING HAPPENS: SEMINAL WORKS IN TEACHING AND TEACHER EFFECTIVENESS AND WHAT THEY MEAN IN PRACTICE*. ROUTLEDGE.

Repetition and rehearsal

3. Use repetition and rehearsal: Since working memory has limited capacity, it's important to provide opportunities for repetition and rehearsal to help transfer information to long-term memory. Teachers can provide regular review and practice opportunities, including self-quizzing and other retrieval practice techniques (see *HTH* Chapter 14 on desirable difficulties).

Scaffolding and support

4. Provide scaffolding and support: For students with working memory deficits, we need to provide additional scaffolding and support to help them process and retain information. This includes breaking complex tasks down into smaller steps, providing additional explanations and examples, and using visuals and other aids to support understanding.

Chunking and visualisation

5. Teach and encourage the use of chunking and visualisation: Chunking (combining multiple pieces of information into larger units) and visualisation (creating mental images to aid memory) are effective strategies for improving working memory capacity. Teachers can teach these strategies explicitly and encourage students to use them as they process and retain new information.

Takeaways

- Working memory plays a crucial role in various cognitive processes, including reasoning, language comprehension, and learning.
- The cognitive load of a task can significantly impact a person's performance on that task, with higher cognitive loads leading to worse performance.
- Transfer to long-term storage proceeds at a limited rate, and increasing memory load can reduce transfer to long-term storage by decreasing the rate at which control processes necessary for transfer can be executed.
- Working memory is susceptible to interference and distraction, particularly when multiple tasks are being performed simultaneously or when irrelevant information is provided, such as visuals that are "interesting" or "fun" but which only distract – what we call *seductive details*. This can lead to errors and impairments in performance.

Seductive details

- Working memory capacity can be improved through training and practice, particularly in individuals with lower initial working memory capacity. Techniques such as chunking (combining multiple pieces of information into larger units) and visualisation (mentally creating visual images to aid in memory) can also be helpful.

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VIDEOS

ALAN BADDELEY ON THE DEVELOPMENT OF THE WORKING MEMORY MODEL (10:01).

AVAILABLE VIA WWW.YOUTUBE.COM/WATCH?V=MT0NLIHOK30

ALAN BADDELEY ON REHEARSAL IN THE VISUAL-SPATIAL SKETCHPAD (3:16).

AVAILABLE VIA WWW.YOUTUBE.COM/WATCH?V=BEUWVWEW4BI

ALAN BADDELEY ON THE PHONOLOGICAL LOOP (4:56).
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THE TEACHING MACHINE – B. F. SKINNER. TEACHING MACHINE AND PROGRAMMED LEARNING.

From B.F. Skinner experimental study of learning come devices which arrange optimal conditions for self-instruction.

AVAILABLE VIA WWW.YOUTUBE.COM/WATCH?V=JTH3OB1IRFO

WEBSITES

ATKINSON & SHIFFRIN – MEMORY MATTERS... THREE-STAGE MODEL OF MEMORY (FROM DONALD CLARK PLAN B: WHAT IS PLAN B? NOT PLAN A!).

AVAILABLE VIA HTTP://DONALDCLARKPLANB.BLOGSPOT.COM/2020/02/ATKINSON-SHIFFRIN-MEMORY-MATTERS-THREE.HTML

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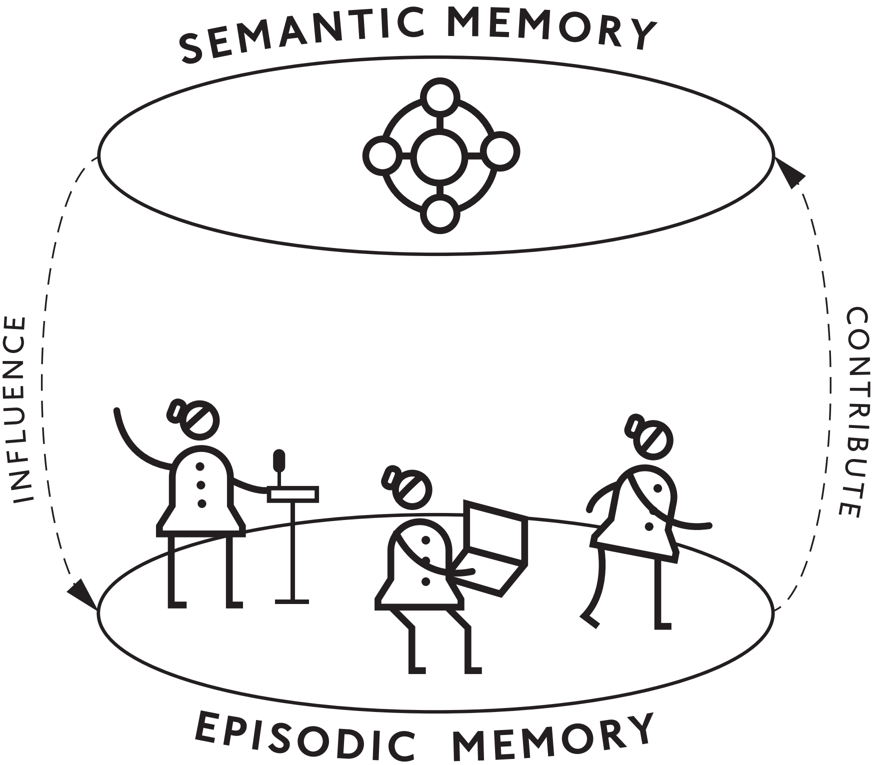
AVAILABLE AT HTTP://DONALDCLARKPLANB.BLOGSPOT.COM/2012/04/BADDELEY-1934-COMPLEXITY-OF-WORKING.HTML

3 AH, YES, I REMEMBER IT WELL

EPISODIC AND SEMANTIC MEMORY



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3 AH, YES, I REMEMBER IT WELL

PAPER "Episodic and semantic memory"[1]

QUOTE *"One of the unmistakable characteristics of an immature science is the looseness of definition and use of its major concepts."*[2]

Why you should read this chapter

In the film *Gigi* (1958) Hermione Gingold and Maurice Chevalier, the aging couple Mamita and Honore, are sitting on a park bench remembering, or rather Chevalier is misremembering, everything about when they first met in song.[3] Chevalier gets all of the details of their meeting wrong, but he ends each stanza with "Ah, yes, I remember it well".

HONORÉ: We dined with friends.
MAMITA: We ate alone.
HONORÉ: A tenor sang.
MAMITA: A baritone.
HONORÉ: Ah, yes, I remember it well. That dazzling April moon.
MAMITA: There was none; and the month was June.
HONORÉ: That's right. That's right.
MAMITA: It warms my heart to know that you remember still the way you do.

This shows perfectly how memory is an elusive concept; that we can be 100% sure that we remember something exactly, but can't and don't. On

1 TULVING, E. (1972). EPISODIC AND SEMANTIC MEMORY. IN E. TULVING & W. DONALDSON (EDS.), *ORGANIZATION OF MEMORY* (PP. 381–403). ACADEMIC PRESS.
2 IBID., P. 381.
3 LERNER, A. J., & LOEWE, F. (1958). I REMEMBER IT WELL [RECORDED BY M. CHEVALIER & H. GINGOLD]. IN *GIGI* [FILM]. METRO-GOLDWYN-MAYER.

the one hand, we think and feel that we remember those things we see, hear, and read as if they were simple truths. "I know what I saw, and I saw…", "I know exactly where I was when [fill in the flashbulb moment]", "Am I not supposed to believe my own ears? I remember exactly that you said that…". On the other hand, through psychological research we know that memories can be easily planted and the memories of witnesses in legal cases can be extremely unreliable (errors of omission and errors of commission). That's because our memory doesn't store exact copies of information like a camera or a tape-recorder (remember them?). Memories are usually the result of making use of partial and fragmentary information that we've retained from a specific situation or event plus instructions/rules for combining that information into a coherent view of that situation or event (i.e. reconstructive memory). In other words, as Daniel Willingham (2009, p. 41) said: "Memory is the residue of thought."

But what is memory? Endel Tulving, in a chapter of a book entitled *Organization of memory*, wrote that:

> the reader who works his [sic] way through all the chapters in their numerical order may experience an abrupt shift in the meaning of the term between Chapters 5 and 6: memory of the later chapters may appear to be not quite the same thing as memory of the earlier chapters.
>
> (Tulving, 1972, p. 382)

To this end he wrote the chapter discussed further here.

Abstract of the chapter

One of the unmistakable characteristics of an immature science is the looseness of definition and use of its major concepts. In experimental psychology, a discipline less than a hundred years old, we can measure our progress by the number and generality of empirical facts and the power and scope of our theories, and we can assess the lack of progress by the degree of ambiguity of our most popular terms.

The concept of memory is a good case in point, although perception, learning, motivation, emotion, and thought could serve as equally relevant illustrations. What exactly do we mean by memory?…Raising the question about the meaning of the term "memory," and consequent analyses, one version of which is presented in this chapter, might even make a modest contribution towards the reduction of the degree of ambiguity characterizing one of the most popular concepts of contemporary psychology.

The chapter

Endel Tulving's 1972 chapter on "Episodic and semantic memory" is a seminal work in the field of cognitive psychology. He was triggered, as stated earlier, by the title of his own book (edited with Andrew Ortony) but also because he noted that in:

> a recent collection of essays on human memory edited by Norman (1970) one can count references to some twenty-five or so categories of memory, if one is willing to assume that any unique combination of an adjectival modifier with the main term refers to something other than any of the referents of other such unique combinations.
>
> (p. 382)

To clarify, he distinguished two types of long-term memory, namely episodic and semantic memory which he saw as two information-processing systems that:

> (a) selectively receive information from perceptual systems or their cognitive systems, (b) retain various aspects of this information, and (c) upon instructions transmit specific retained information to other systems, including those responsible for translating it into behavior and conscious awareness.
>
> (p. 385)

They differ as to (a) what is stored (its nature), (b) what they reference (autobiographical versus cognitive information), (c) the conditions for and consequences of their retrieval, (d) how vulnerable they are to interference, and (e) their dependence upon each other.

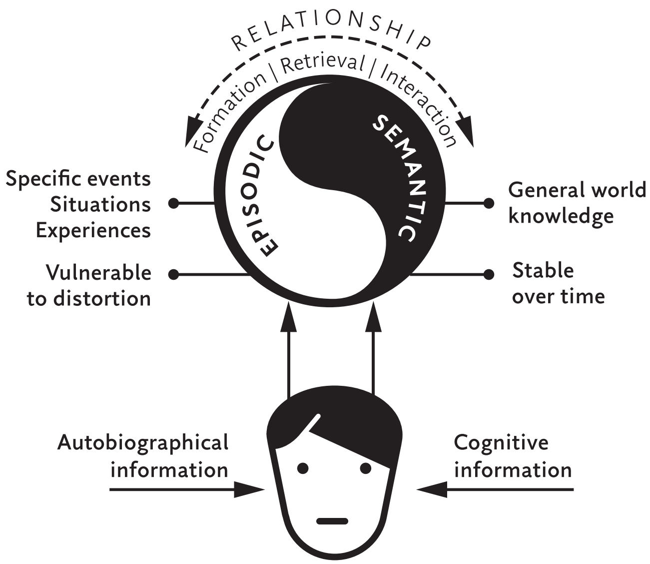

FIGURE 3.1
EPISODIC AND SEMANTIC MEMORY

EPISODIC MEMORY Information stored about the experienced occurrence

Episodic memory is the memory that we have for specific events or episodes with a temporal and spatial context (i.e. something to me happened somewhere at some moment). In other words, they're memories of personal experiences that occurred at a particular time and place. Thus, every "item" in episodic memory represents information stored about the experienced occurrence of an episode or event (p. 387). An event "can be stored in the episodic system solely in terms of its perceptible properties or attributes, and it is always stored in terms of its autobiographical reference to the already existing contents of the episodic memory store" (pp. 385–386). Interesting is that the retrieval of information from the episodic memory store has two conflicting consequences. While it increases the memory's retrieval strength (i.e. the retrieved contents become more accessible to inspection), it also "serves as a special type of input into episodic memory and thus changes the contents of the episodic memory store" (p. 386). In other words, episodic memories are susceptible to change (they can mutate or transform) and information loss (they can become fuzzier) and may even be influenced by information in semantic memory (i.e. when they contradict what we "know").

SEMANTIC MEMORY General knowledge about the world

Semantic memory, on the other hand, is the memory we need to use language; it's what we think with. Tulving called it a "mental thesaurus, [the] organized knowledge a person possesses about words and other verbal symbols, their meaning and referents, about relations among them, and about rules, formulas, and algorithms for the manipulation of these symbols, concepts, and relations" (p. 386). In other words, semantic memory refers to memory for general knowledge about the world that's not tied to any specific episode or context and includes general knowledge about facts, concepts, and ideas that are independent of any personal experience. The semantic system allows us to retrieve information that wasn't directly stored in it (e.g. via inductive and deductive reasoning, we can create new semantic knowledge and memories). Retrieval of memories from the system leaves the contents unchanged and is, thus, "probably much less susceptible to involuntary transformation and loss of information than the episodic system" (p. 386).

As stated, episodic memory is characterised by its specificity and its association with a particular time and place (e.g. while on vacation last year there was an incredible storm with lightning and thunder and the lightning flashes became stronger and the thunder came more quickly as the storm got closer). Semantic memory, on the other hand, is more general and abstract, and not tied to any particular context (since light travels a lot faster (≈3x108 m/s) than sound (343 m/s) the closer the flash is to us, the quicker you'll hear the thunderclap. You can determine how far away the storm is – in metres – by counting the seconds between when you see the lightning and hear the thunder and then multiplying it by about 350).

In line with their different characteristics, they're also supported by different cognitive processes. While episodic memory is thought to rely on mental time travel or the ability to mentally re-experience a past event, semantic memory is thought to be based on the extraction and organisation of general knowledge from experience. This distinction has important implications for understanding how memory works. Tulving proposes that the two types of memory are mediated by different brain systems, and that these systems can operate independently of one another (beginning to see a trend here with Baddeley and Hitch's phonological loop and visuospatial sketchpad in the previous chapter and Paivio's dual coding in Chapter 10, One picture and one thousand words).

And what is the relation between the two? Tulving suggests that semantic memory is built upon episodic memory, and that the extraction of general knowledge from experience is a key aspect of episodic memory processing. This relationship is in his eyes bidirectional, with semantic memory influencing the processing of episodic memories, and episodic memory contributing to the organisation and integration of semantic knowledge.

Behaviourism

One of the repercussions of this idea of at least two memory stores is that it upended the concept of learning that was prevalent in learning research that was often *behaviourist* in nature, namely that memory or learning is simply a question of reinforcing and/or punishing exhibited behaviours whereby links between stimuli are created. In that respect it's possibly a little closer to the *Gestalt* idea of learning, namely that the whole is greater than the sum of its parts. Our memories are more than a collection of isolated facts and experiences, but are *organised and structured* in a meaningful way. Tulving also emphasises the importance of organising and structuring of memories, with episodic memories being organised in a temporal sequence (e.g. proximity between/contiguity of events in time) and semantic memories according to meaning. Learning is the combination of the two.

Gestalt

Memories are meaningfully organised and structured

In bemoaning what he called the "frequent and justified complaints" that psychological research haven't "led to significant insights that could be used for the improvement of education and for the betterment of learning in classrooms", he posits that this is because most of that research was concerned with episodic memory; typical memory tasks required that learners (both humans and laboratory animals) remember what "particular perceptual event occurred in what temporal (sometimes also spatial) relation to other events". Classroom learning, on the other hand, has little to do with remembering personally experienced events and so for him it's not really surprising that the psychological knowledge and insights gained in those laboratories "have little bearing on theory and practice of acquisition of knowledge" (all p. 402). On the one hand, one could say that this is a plea for a different kind of lab experiment related to meaningful learning (think of Ausubel's "psychology of meaningful verbal learning"; Chapter 11, What you know determines what you learn), while on the other hand, it is a step in the direction of what we now call *ecologically valid* research (i.e. whether a study's variables and conclusions are relevant to the real world context).

Conclusions/implications of the work for educational practice

Episodic and semantic memory are parallel and partially overlapping information-processing systems that differ in several ways, including the nature of the stored information in our memories, the meaning that we give to that information when we store it as memories, the conditions and consequences of retrieval of that information when we use or need it, and the memory's susceptibility to interference and even erasure after storage. As such, it provides an influential framework for understanding the different types of long-term memory and their underlying cognitive processes.

Need to create vivid memories

One of the key implications of this work for teachers is to think about the ways in which we want students to remember things. We often hear that to help students better remember something, teachers need to create memories that are more episodic in nature by creating fun or memorable experiences. This can, of course, be important for a broad range of reasons. most of which have little to nothing to do with learning. The problem is that doing this can also have unintended consequences for learning as Maths teacher Craig Barton found out when he taught his class fractions and then wanted them to transfer that knowledge to other contexts. In his 2018 book *How I wish I'd taught maths* he tells of what he calls "The Swiss Roll Incident". He decided that in order to make the learning "memorable" he would buy some Swiss roll cakes into the class and asked them: "Imagine you have 7 Swiss rolls and you can stack them on top of each other. What is the fewest number of cuts you make to ensure 12 people get the exact same amount of Swiss roll and there is nothing left over?" In his words: "Maths in action, and the kids were loving it" (p. 38).

Craig began cutting the cakes and the students had a wonderful time, but four years later, he met one of the students (Veronica) who was now in a different class. He asked her how Maths was going and she said: "it's a bit boring sir, we don't have any fun like that Swiss roll lesson." Craig then asked her out of interest if she remembered what the point of the lesson was, to which Veronica replied: “Swiss rolls!” And there was the problem. They remembered the lesson, but not what it was about.

In attempting to make the learning memorable, he created a lesson that was fun and – apparently memorable – using cakes as a prop to make the lesson memorable. Unfortunately, Veronica had remembered the wrong thing. She had simply remembered the episodic memory of the cakes rather than the deeper underlying concept of fractions.

How to use the work in your teaching

Though two separate memory storage systems, episodic and semantic memory can be harnessed for learning. One way is to teach your students how to create and use mental images so that they can attach the two and thus increase their strength. This is similar to what we learned from *dual coding theory* (see Chapter 10, One picture and one thousand words), what we know about drawing and imagining as two *generative learning strategies* (Chapter 13 in *HTH*), and what forms the basis of what’s known as the multimedia principle, namely that we learn better from words and pictures than from words alone (Fletcher & Tobias, 2005). Another is to make use of narratives or storytelling as a teaching tool to help students make connections between what they experience (episodic) and what the facts, concepts, and procedures underlying them are. This is in a way similar to dual coding where relationships are made between what is in our visuospatial sketchpad and phonological loop.

Takeaways

- Recognise the complexity and nuances of memory and use this knowledge to design effective learning experiences that promote memory consolidation and retrieval.
- Create meaningful associations by encouraging students to create personal associations with new information or link it to their prior experiences to make it more meaningful and memorable.
- Provide opportunities for students to practice and apply new information in a variety of contexts (i.e. create more episodes to which the semantic memories can be linked to; see Chapter 14 in *HTH* on contextual interference as desirable difficulty) to strengthen memory consolidation and retention.
- Use elaborative encoding strategies such as creating vivid mental images (see Chapter 13 from *HTH* on generative learning strategies) to improve memory consolidation and retrieval.

- Use cues or prompts that strengthen and activate the relevant memory traces between the episodic and semantic memories of what should be learnt.
- You can encourage students to remember past events and use this information to plan future actions (Tulving later called this *mental time travel*), which relies on the integration of episodic and semantic memory.

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AVAILABLE VIA HTTPS://UEAEPRINTS.UEA.AC.UK/ID/EPRINT/73863/2/ACCEPTED_MANUSCRIPT.PDF

VIDEOS

Hermione Gingold and Maurice Chevalier in the film *Gigi* (1958) written by Alan Jay Lerner and Frederick Loewe that captures a common problem: misremembering. The song is an exchange between two friends reflecting on their first date.

AVAILABLE VIA WWW.YOUTUBE.COM/WATCH?V=NR276AFHX-I

COGNITIVE APPROACH: EPISODIC AND SEMANTIC MEMORY

AVAILABLE VIA WWW.YOUTUBE.COM/WATCH?V=D3DRZ9SETFO

A TRIBUTE TO ENDEL TULVING

AVAILABLE AT HTTPS://YOUTU.BE/LM8RZOP1E7A

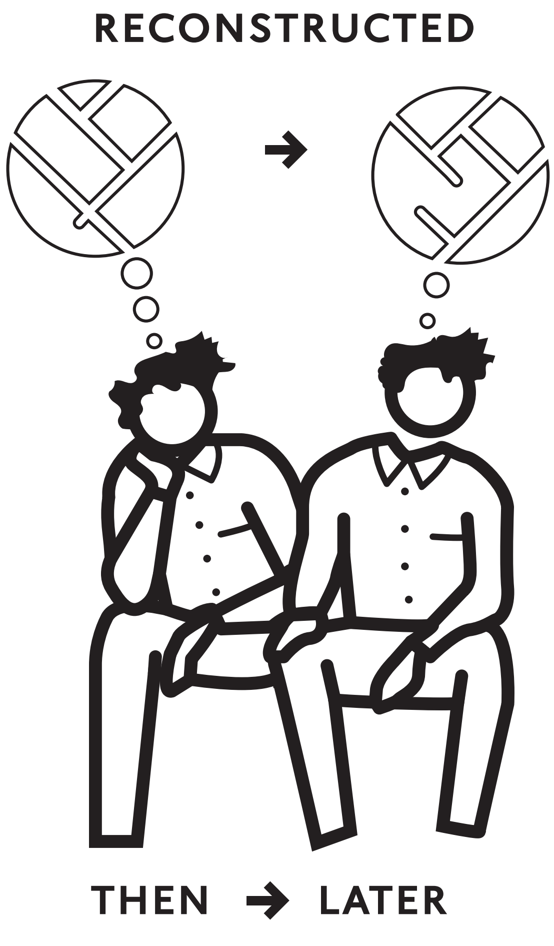
WEBSITES

EPISODIC & SEMANTIC MEMORY: DONALD CLARK IN HIS BLOG WHAT IS PLAN B? NOT PLAN A!

AVAILABLE VIA HTTP://DONALDCLARKPLANB.BLOGSPOT.COM/2020/02/TULVING-EPISODIC-SEMANTIC-MEMORY.HTML

4 "WHAT YOU KNOW, YOU KNOW"

BARTLETT'S SCHEMA THEORY



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4 "WHAT YOU KNOW, YOU KNOW"

CHAPTER "A theory of remembering"[1]

QUOTE *"… a storehouse is a place where things are put in the hope that they may be found again when they are wanted exactly as they were when first stored away. The schemata are, we are told, living, constantly developing, affected by every bit of incoming sensational experience of a given kind. The storehouse notion is as far removed from this as it well could be."*[2]

Why you should read this chapter

At the end of Shakespeare's tragedy "Othello", the arch-villain Iago is asked why he went to such lengths to destroy Othello's life and those around him. His reply, like much of his language in the play, is at once both truthful and deceitful: "What you know, you know." It's an ambiguous statement which proves challenging for the audience but one which also serves as an almost perfect distillation of one key aspect of how learning happens; namely that what we hold in our long-term memory, to a greater or lesser extent, determines how we will come to *know* future information we encounter in the world.

SCHEMA
Organised structure of knowledge

In psychology, the word "schema" is perhaps most associated with Jean Piaget and indeed it was he who first developed its use as a cognitive development theory. But it was English psychologist Frederic Bartlett who actually first introduced the term to developmental psychology in 1932, appropriating the term from Sir Henry Head who first used it in 1918. Bartlett gives him credit for this but Bartlett's formulation of schema is very different from Head's in the sense that he was really the

1 BARTLETT, F. C. (1932). A THEORY OF REMEMBERING. IN *REMEMBERING: A STUDY IN EXPERIMENTAL AND SOCIAL PSYCHOLOGY* (PP. 197–214). CAMBRIDGE UNIVERSITY PRESS.
2 IBID., P. 200.

first to view it not as something static but rather as dynamic mental structures or "masses of organized past experiences" (pp. 197–198). Bartlett's work is significant on several levels. First, he challenged the British empiricist notion that memory consisted of mental images (see Chapter 3, Ah yes, I remember it well, on semantic and episodic memory) which were individual in nature and which were stored in a kind of mental storehouse that we look up like a clerk when needed. Second, his idea was that remembering is not so much recalling information but rather *reconstructing* information by accessing cognitive structured knowledge which operates "not simply as individual members coming one after another, but as a unitary mass" (p. 201). Bartlett's ideas were bold and as we'll see, not entirely correct, but they would go on to transform our subsequent thinking about and understanding of the interaction between memory and learning.

Abstract of the chapter

The most persistent problems of recall all concern the ways in which past experiences and past reactions are utilised when anything is remembered. From a general point of view it looks as if the simplest explanation available is to suppose that when any specific event occurs some trace, or some group of traces, is made and stored up in the organism or in the mind. Later, an immediate stimulus re-excites the trace, or group of traces, and, provided a further assumption is made to the effect that the trace somehow carries with it a temporal sign, the re-excitement appears to be equivalent to recall. There is, of course, no direct evidence for such traces, but the assumption at first sight seems to be a very simple one, and so it has commonly been made.

The chapter

In 1932, Frederic Bartlett conducted a very strange experiment. He asked English participants to read a Native American folk tale titled "The War of the Ghosts" and then asked them to recall the tale at various points in time afterwards. Although his experiments were not what a modern researcher would call "ecologically valid" (he often asked subjects to recall the story as he bumped into them around campus), they nonetheless showed several key insights on how memory functions.

First, his experiments challenged the notion that memory is a repository for information where discrete facts could be retrieved or forgotten as Hermann Ebbinghaus had claimed 50 years previously. What he discovered was that the act of remembering was not so straightforward and he hypothesised that the subjects would not so much remember the story as *reconstruct* it. It's important to note that the

EBBINGHAUS
Pioneer of memory research from nineteenth century; father of the forgetting curve

participants were English and that the material they were being asked to recall was from a different culture. For example, certain words which were unfamiliar to them, such as "canoe", would be changed to "boat"; activities such as hunting seals was changed to "fishing"; and indigenous names such as "Egulac" were completely forgotten altogether. Although his experiments were somewhat unsystematic, they nonetheless showed that the process of remembering is not like saving a file on a computer and then recovering it in exactly the same state as it had been left in. His idea was that memory was a living, breathing entity which is constantly evolving and being reshaped by the subject. He published his findings in a book called *Remembering* and his idea about the reconstructive nature of memory would go on to be hugely influential in the field.

In this chapter of the book, Bartlett begins by referring to Sir Henry Head's work where he was "particularly interested in the functions and character of the sensations which can be aroused by the stimulation of nerve endings in the skin and the underlying tissues" (p. 198). Head, an English neurologist who studied the somatosensory system (the network of neural structures in the brain and body that produce the perception of touch, temperature, body position, and pain) and sensory nerves, was interested in the physiology of movement and sought to relate body posture with mental processes. Head was challenging a previous tradition where there was the idea that the brain has a "storehouse of images of movement"[3]. He notes that Head's work has "great advantages" specifically the idea that "every recognisable (postural) change enters into consciousness already charged with its relation to something that has gone before, just as on a taximeter the distance is presented to us already transformed into shillings and pence" (Head & Holmes, 1912, p. 112). Bartlett then develops this idea in relation to memory by making the following declaration:

> For this combined standard, against which all subsequent changes of posture are measured before they enter consciousness, we propose the word 'schema'. By means of perpetual alterations in position we are always building up a postural model of ourselves which constantly changes.
>
> (pp. 199–200)

Although Bartlett felt that the concept of a schema as a physiological application was useful, he challenged Head's idea that memory was something which was *rising into consciousness* or the idea that we

3 MUNK, H. (1890). *ÜBER DIE FUNKTIONEN DER GROSSHIRNRINDE, GESAMMELTE MITTEILUNGEN MIT ANMERKUNGEN. ZWEITE VERMEHRTE AUFLAGE* [ON THE FUNCTIONS OF THE CEREBRAL CORTEX, COLLECTED COMMUNICATIONS WITH ANNOTATIONS. SECOND EXPANDED EDITION]. HIRSCHWALD.

consciously "use" knowledge as a clerk might use retrieved files from a drawer. This, he claimed, was wrong, and schemata were something which are used without awareness at all, that is to say they are involuntary and automatic.

Remembering is a two-way street

Semantic and episodic memory (see Chapter 3)

In a statement which perhaps anticipates Tulving's constructs of semantic and episodic memory (see Chapter 3, Ah yes, I remember it well), Bartlett notes that:

> In remembering, we appear to be dominated by particular past events which are more or less dated, or placed, in relation to other associated particular events. Thus the active organised setting looks as if it has somehow undergone a change, making it possible for parts of it which are remote in time to have a leading role to play.
>
> (p. 202)

A somewhat amusing point here is that although schema theory is one of the most influential concepts in psychology, it's one which Bartlett didn't even like. He noted that it was "at once too definite and too sketchy" (p. 201). His main objection was that the word suggests some kind of static entity and that it doesn't:

> indicate what is very essential to the whole notion, that the organised mass results of past changes of position and posture are actively *doing* something all the time; are, so to speak, carried along with us, complete, though developing, from moment to moment.
>
> (p. 201)

He suggested that a better term would be of "active, developing patterns" or that the term "organised setting" would be better, but rejected those terms as they had been used in other contexts, so he reluctantly settled on the term "schema" but developed the idea and defines it in more specific terms. He writes:

> 'Schema' refers to an active organisation of past reactions, or of past experiences, which must always be supposed to be operating in any well-adapted organic response. That is, whenever there is any order or regularity of behaviour, a particular response is possible only because it is related to other similar responses which have been serially organised, yet which operate, not simply as individual members coming one after another, but as a unitary mass.
>
> (p. 201)

The key term here is "active organisation" where the idea is that we have structures of knowledge, categorised and interrelated, and which then inform how we understand the world. For example, when a child learns how to eat at a table and use a knife and fork and that food is not a toy to be played with, they're building a schema related to a specific time, place, and activity. In future situations where the child has to sit down and eat, they will have a fully formed sense of what to do.

SCRIPTS
Sequences of expected events

SCRIPTS AS SCHEMATA

A schema is a general framework or category that organises and interprets information. A cognitive script is a schema that is more specific. Roger Schank and Robert Abelson (1975) spoke of scripts which, among other things, contain sequences of expected events. If, for example, you hear someone describe what happened when they went to a restaurant, you don't have to be told what is normally found in a restaurant. You already have a "restaurant schema" (tables and chairs, menu, waiters, kitchen, eating utensils, the cheque, a tip, and other conventional

1 Entering

Customer goes to restaurant
Finds a place to sit
- Seats self
- Seated by hostess
  - Hostess asks, "*How many?*"
  - Customer says, "*One.*"

Customer sits at table

2 Ordering

Customer receives a menu
Reads it
Decides what to order
Waiter takes order
- Waiter sees customer
- Waiter goes to customer's table
- Customer places order

Chef cooks the meal

3 Eating

After some time, waiter brings meal
Customer eats the meal
- Meal may come in several courses
  - Appetizer
  - Salad
  - Main course
  - Dessert and coffee

Certain forks go with certain courses

4 Exiting

Customer asks waiter for check
Waiter brings check
Customer leaves a tip
- Size of tip depends on service

Customer pays
- Gives money to waiter or cashier

Customer leaves the restaurant

features) as part of your background knowledge. A script is essentially a dynamic schema. Instead of a set of typical fixed features in a schema, a script has a series of conventional actions or events that take place. The sequence of expected events in Schank and Abelson's restaurant script begins with a hungry customer entering a restaurant, sitting, ordering, eating, paying, and then ends with the customer exiting.

Bartlett then gives the example of playing tennis or cricket where a player is making a stroke and suggests that this process depends on the "relating of certain new experiences, most of them visual, to other immediately preceding visual experiences". He doesn't make something new nor recall something old but rather the stroke is "literally manufactured out of the living visual and postural 'schemata' of the moment and their interrelations" (p. 202). You can see the influence of Head here as body position is part of the somatosensory system called proprioception. We see this process in elite sports where top level athletes have such sophisticated schemata that they make the most complex tasks look effortless.

Complex remembering

Bartlett then distinguishes this kind of complex remembering with what he terms "relatively low-level remembering" which "tends, in fact, to be rote remembering, and rote memory is nothing but the repetition of a series of reactions in the order in which they originally occurred" (p. 202). Schemata for Bartlett do not operate in such a chronological fashion but rather are accessed and then altered according to new experience:

> We may fancy that we are repeating a series of movements learned a long time before from a text-book or from a teacher. But motion study shows that in fact we build up the stroke afresh on a basis of the immediately preceding balance of postures and the momentary needs of the game. Every time we make it, it has its own characteristics.
>
> (p. 202)

Assimilation and accommodation

This is similar to what Piaget referred to as assimilation and accommodation.

Literal recall vs. reconstruction

One area in which Bartlett's work has been reconsidered is in his assertion that literal recall is a rare phenomenon or that the act of remembering is a process of "construction rather than one of mere reproduction" (p. 205). It's true of course that we recall certain declarative knowledge every day, otherwise we would not be able to function in most situations, but Bartlett's key idea is that, in terms of the recalling of more complex things, "condensation, elaboration and invention are common features of ordinary remembering, and these all very often involve the mingling of materials belonging originally to different 'schemata'" (p. 205).

In the conclusion to the chapter, Bartlett restates his case that the act of remembering is not the "re-excitation of innumerable fixed, lifeless and fragmentary traces" but rather the "imaginative reconstruction, or construction, built out of the relation of our attitude towards a whole active mass of organised past reactions or experience, and to a little outstanding detail which commonly appears in image or in language form" (p. 213). As Wagoner eloquently puts it, "Remembering emerges within the stream of living in order to bring about a novel relationship to the environment and increase one's avenues for action within it" (Wagoner, 2017, p. 544).

Conclusions/implications of the work for teaching

Schema theory is not a directly applicable tool for teaching and learning in the same way that retrieval practice is, but rather a theoretical model which holds huge significance for our broader understanding of how learning happens in the sense that what we have in our long-term memory largely determines how we understand the world.

It's also significant that Bartlett used the active verb "remembering" rather than "memory" to draw attention to the fact that it is a "socially and materially situated activity that involves a myriad of different processes, rather than a self-contained mental faculty sufficient unto itself" (Wagoner, 2017, p. 540). In this sense, remembering is a dynamic process where different elements interact and where those who have well developed schemas in a particular domain are best placed to understand new and uncertain contexts. In other words, it's a cognitive activity which is closely related to, or even lies at the basis of, a study strategy such as retrieval practice. As Orwell (1949) might have put it: "who controls the past controls the future".

Building on Bartlett's ideas, David Rumelhart and Donald Norman (1978) theorised that "learning is not a unitary process" (p. 24) and offered three layers to that process:

Accretion

1. **accretion** which refers to the basic accumulation or building up of facts and information,

Tuning

2. **tuning** which occurs when new information means that an existing schema needs to be modified,

Restructuring

3. **restructuring** where completely new schema need be created based on new facts or information.

See here again the relation to Piaget. So for students with developed schema, there are a number of important consequences. First, they'll be able to identify key points and concepts more easily. For example, a student who has a robust schema of knowledge on irony or sarcasm will be able to identify subtle nuances in a text which might not be apparent to a student without that schema (and many people on social media). In this sense, learning becomes a process of recognising something the student already knows or which is related to something they already know, rather than just merely guessing or trying to fit new ideas into incomplete schemas. We cannot put it any better than Richard Anderson: "The schemata a person already possesses are a principal determiner of what will be learned from a text" (Anderson, Spiro, & Anderson, 1978, p. 434), or as Paul often says: What you know determines what you see and not the other way around.

How to use the work in your teaching

Schema theory has important implications for teaching and instructional design, specifically for the role of prior knowledge in any given domain. To take an example from history, for students to understand the causes of the American Civil War, it's necessary for them to also have an understanding of the Atlantic slave trade and the importance of slave labour to the Confederate states. Here the teacher might adopt several strategies to help students develop the relevant schemata such as explicit instruction on the topic, revisiting material at the start of subsequent lessons, asking students to elaborate on their own understanding, and having students engage in retrieval practice to check for understanding and consolidate knowledge.

In more sophisticated domains of knowledge, there's a danger that students can develop faulty schemata (i.e. form misconceptions) or have an incomplete understanding of something. We know from Chapter 6 (A novice is not a little expert) that novices think in qualitatively different ways than experts and this is largely due to the difference in their schemas. This has important consequences for teaching as for novices, we know that clear instruction, advance organisers, scaffolding, worked examples, and feedback can help develop those complicated schemas so vital for understanding.

Later on in his career, Bartlett would address the criticism of his work that retrieval without construction is rare by claiming "I did not say, I think I did not imply that literal retrieval is impossible, but I did imply that it requires special constricting conditions" (Bartlett, 1968, cited in Crampton, 1978, p. 340). This statement has very important implications for instructional design for it is these “constricting conditions” which form the basis of the teaching materials we need to design to optimise learning.

Takeaways

- The act of remembering is an active and partly reconstructive process.
- Schemata are how the brain organises knowledge.
- Schemata are dynamic and not static.
- If new information doesn’t fit into existing schemas, either old ones will be amended or altered and new ones will be created.
- Past knowledge determines how we process and understand new information.
- Explicit instruction, retrieval practice, and worked examples can help create and strengthen schemata.

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VIDEOS

British psychologist Richard Gregory talks about his personal memories of Frederic Bartlett whom he worked with, including the book "Remembering" and the Ghosts of War experiment

AVAILABLE AT: HTTPS://YOUTU.BE/CUC2ZRSVO8O

VIDEO OF JEAN PIAGET TALKING ABOUT HOW KNOWLEDGE IS STRUCTURED AND WHY HE IS A CONSTRUCTIVIST

AVAILABLE VIA HTTPS://YOUTU.BE/I1JWR4G8YLM

ERNST VON GLASERSFELD: ADAPTATION, ASSIMILATION AND ACCOMMODATION

AVAILABLE VIA HTTPS://YOUTU.BE/LXTZTETSPOG

5 DO YOU KNOW WHAT YOU KNOW? METACOGNITION

DOI: 10.4324/9781003395713-6

5 DO YOU KNOW WHAT YOU KNOW? METACOGNITION

PAPER "Metacognitive and cognitive monitoring: A new area of cognitive developmental inquiry"[1]

QUOTE *"I find it hard to believe that children who do more cognitive monitoring would not learn better both in and out of school than children who do less. I also think that increasing the quantity and quality of children's metacognitive knowledge and monitoring skills through systematic training may be feasible as well as desirable"*[2]

Why you should read this article

One of the many counterintuitive aspects about learning is that the process of how learning happens is often a complete mystery to the learner themselves. They think that they know what and how they're thinking but they usually don't. Another one is that the more expert one becomes in a given domain, the less of an expert they become in knowing how they became an expert. This is also known as the "curse of knowledge" (Camerer, Loewenstein, & Weber, 1989; or as Paul sometimes says: They're butterflies who forgot what it was to be a caterpillar) where, for example, an expert golfer is so far removed from the initial first steps they took as a novice that they're unable to explain to a beginner what they should be doing when they start to learn how to play golf.

In his seminal work, "The concept of mind", Gilbert Ryle (1950) provides a neat distinction between "knowing how" and "knowing that", which although a contested idea, helps shine a light on this confusing phenomenon. "Knowing that" can be conceived of as any form of propositional knowledge such as Paris is the capital of France or 2 + 2 = 4.

1 FLAVELL, J. H. (1979). METACOGNITIVE AND COGNITIVE MONITORING: A NEW AREA OF COGNITIVE DEVELOPMENTAL INQUIRY. *AMERICAN PSYCHOLOGIST*, *34*, 906–911.
2 IBID., P. 910.

"Knowing how" on the other hand can be thought of as more procedural knowledge such as learning to ride a bike where much of what is learned is inexpressible. Karl Polanyi referred to this as "tacit" knowledge, or as he so eloquently put it: "we know more than we can tell" (Polanyi, 1966, p. 4).

This opposition provides a useful framework for thinking about one of the most influential ideas in education in the last 50 years and one which is often cited as one of the most effective approaches for learning: *metacognition*, which was coined by Flavell in the 1970s and is often simplified as "learning to learn". The idea is a simple one, namely that becoming conscious of the process of learning and being able to plan, monitor, and evaluate that process, the learner is harnessing a powerful set of techniques to master any give domain.

Abstract of the article

METACOGNITION
Explicit monitoring and evaluation of one's own learning

Studies suggest that young children are quite limited in their knowledge about cognitive phenomena—or in their metacognition—and do relatively little monitoring of their own memory, comprehension, and other cognitive enterprises. Metacognitive knowledge is one's stored knowledge or beliefs about oneself and others as cognitive agents, about tasks, about actions or strategies, and about how all these interact to affect the outcomes of any sort of intellectual enterprise. Metacognitive experiences are conscious cognitive or affective experiences that occur during the enterprise and concern any aspect of it—often, how well it is going. Research is needed to describe and explain spontaneous developmental acquisitions in this area and find effective ways of teaching metacognitive knowledge and cognitive monitoring skills.

The article

Flavell begins by noting that children are not very good at thinking about the process of thinking itself and in certain experiments, vastly overestimate the extent to which they have learned something.[3] The idea that learners are not very good at monitoring their own learning and judging the results is a fairly consistent one; for example, there is what Koriat and Bjork (2005) refer to as the "illusion of competence". This is often the case when learners reread something they've already read and then *feel* as though they have mastered some area of knowledge simply because it looks familiar to them since they've read it before, but in

3 FOR MORE ON THIS SEE JOL (JUDGMENTS OF LEARNING): MYERS, S. J., RHODES, M. G, & HAUSMAN, H. E. (2020). JUDGMENTS OF LEARNING (JOLS) SELECTIVELY IMPROVE MEMORY DEPENDING ON THE TYPE OF TEST. *MEMORY AND COGNITION*, *48*, 745–758.

reality, they haven't changed their long-term memory in any way so they haven't learned it.

The term "metacognition", now a well-established term in the education sphere, was first introduced by Flavell in 1976. He defined it as "the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear, usually in service of some concrete goal or objective" (p. 232). In this article, written three years later, Flavell expands on this idea and offers a formal model of metacognition which consists of four key dimensions: (1) metacognitive knowledge, (2) metacognitive experiences, (3) tasks or goals, and (4) strategies or activities. In our opinion, the first two dimensions are the most important and, thus, we take a closer look at them in the next section.

Metacognitive knowledge

Metacognitive knowledge involves understanding one's own cognitive processes, as well as understanding that other people may think and learn differently. It's about understanding how people learn and problem solve, which strategies work best for different tasks, and knowing the limits of one's own knowledge and capabilities. According to Flavell, *metacognitive knowledge* is the part of our "stored world knowledge that has to do with people as cognitive creatures and with their diverse cognitive tasks, goals, actions, and experiences" (p. 906). For example, a child may believe that they are better at Maths than at spelling. Within the category of metacognitive knowledge, there are three major variables: person, task, and strategy.

METACOGNITIVE KNOWLEDGE
Person, task, and strategy

PERSONAL LEVEL
The individual's understanding

TASK LEVEL
The task itself

STRATEGY LEVEL
Specific actions taken

At the *personal* (or individual) level, you might believe that there are different types of understanding, such as paying attention, remembering, communicating, problem solving, etc. At the *task* level, there is an appreciation for how organised/disorganised or how trustworthy/untrustworthy the material is and how likely it is you will be successful in achieving a certain goal. For example, a child will instinctively know that understanding the general gist of a story is easier than understanding it word for word. Finally, at the *strategy* level there is an understanding of what specific actions will help them achieve their goals and sub-goals such as paying attention to the main points of a text and then self-testing by repeating them back to themselves after.

A key point according to Flavell is that "metacognitive knowledge is not fundamentally different from other knowledge stored in long-term memory" (p. 907), which is to say that metacognition is not some kind of magic fairy dust but rather something concrete which can be explicitly taught and learned like other forms of knowledge. As he states: "It can lead you to select, evaluate, revise, and abandon cognitive tasks, goals, and strategies in light of their relationships with one another and with your own abilities and interests with respect to that enterprise" (p. 908).

METACOGNITIVE EXPERIENCES
An emotional response

Metacognitive experiences

In contrast, metacognitive experiences are more abstract and fleeting in nature. They involve the conscious awareness of cognitive processes during learning or problem-solving and could include feelings of difficulty, confusion, satisfaction, or even the "Eureka!" moment when you understand something. Anastasia Efklides (2001) adds that these experiences can also be feelings of familiarity, confidence, satisfaction, difficulty, or frustration, or an estimation of how much effort or time is needed to complete a certain task. Flavell gives the example of how you as a learner may experience a "momentary sense of puzzlement that you subsequently ignore, or you may wonder for some time whether you really understand what another person is up to" (p. 908).

So there is a certain interaction between metacognitive knowledge and metacognitive experiences which form what Flavell describes as "partially overlapping sets" (p. 908) where certain experiences become conscious, as it were, to the learner, and where feelings of frustration, confusion, success, or mastery can affect which strategies the learner uses to address specific tasks in the future. At this point, you might still be wrestling with what exactly the difference is between metacognitive knowledge and experience. Thankfully, Flavell provides us with a neat illustration of how they overlap and interact:

METACOGNITIVE KNOWLEDGE VS. METACOGNITIVE EXPERIENCE

"As an example of the former, you sense (metacognitive experience) that you do not yet know a certain chapter in your text well enough to pass tomorrow's exam, so you read it through once more (cognitive strategy, aimed at the straightforward cognitive goal of simply improving your knowledge). As an example of the latter, you wonder (metacognitive experience) if you understand the chapter well enough to pass tomorrow's exam, so you try to find out by asking yourself questions about it and noting how well you are able to answer them (metacognitive strategy, aimed at the metacognitive goal of assessing your knowledge, and thereby, of generating another metacognitive experience)" (p. 909).

Another way to think about this process is that cognitive strategies are used to make progress whereas metacognitive strategies are used to monitor that progress.

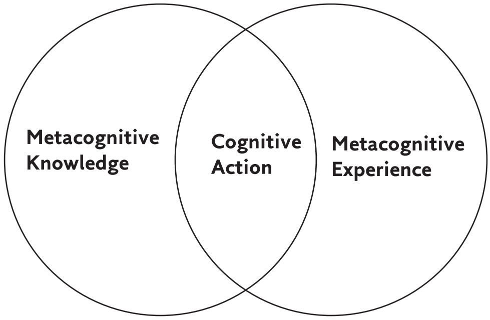

FIGURE 5.1 METACOGNITIVE KNOWLEDGE V ACTION (AUTHOR)

Conclusions/implications of the work for teaching

A key question at the end of this article is whether "thinking about thinking" actually gets in the way of thinking itself. Flavell invites us to consider the "feckless obsessive, paralyzed by incessant critical evaluation of his own judgments and decisions" (p. 910). However, in the intervening years since 1979, there has been much work done in the field of metacognition to translate Flavell's theory into practice and metacognition often ranks as one of the most effective strategies to teach students.

METACOGNITIVE SKILLS
- Monitoring
- Evaluation
- Planning

One specific expansion of Flavell relates to *metacognitive skills* which allow us to manage and control our own cognitive processes. This could involve *planning* how to approach a task, *monitoring* comprehension while learning, and *evaluating* the effectiveness of a chosen cognitive strategy with the goal of eventually being able to *self-regulate* our own learning and behaviour.

As with all knowledge, strategies, and skills, learners can learn/be taught how to acquire, improve, and hone their metacognitive strategies and skills to facilitate their thinking and learning. Some examples of behaviours that need to be learnt and practised in the classroom and outside are:

- self-monitoring – paying attention to one's own thought processes and progress towards a goal,
- self-evaluation – assessing one's own strengths and weaknesses in relation to a task or goal,
- planning – developing a plan or strategy for approaching a task or problem,
- self-instruction – talking oneself through a task or problem, either out loud or internally,

- visualising – creating mental images or diagrams to help understand a problem or concept,
- hypothesising – generating possible solutions or explanations for a problem,
- estimating – predicting the outcome of a problem or task.

Similar to generative learning strategies

If we look closely at these strategies, we can see a strong similarity with many of Logan Fiorella and Richard Mayer's and/or Gavin Brod's *generative learning strategies* (see *HTH*, Chapter 13). By learning how to use metacognitive strategies, learners can better take control of their own learning.

How to use the work in your teaching

As stated in the previous section, there are three major stages of the metacognitive process: planning, monitoring, and evaluating. Teachers can model this process by talking students through their own metacognitive process by asking questions such as those in Table 5.1. In this example, a student who is writing an essay might use the following questions to think metacognitively about the process they are going through. Note that this is independent of the domain. It could be for English, but just as easily for biology, history, economics, or music.

TABLE 5.1 EXAMPLE OF METACOGNITIVE STRATEGIES IN ACTION

Planning	Monitoring	Evaluating
Do I understand the task I am being asked to do?	Have I written an effective introduction which addresses the task?	Have I answered the question effectively?
How many paragraphs will I use and what will go in each?	Am I writing enough for each paragraph?	Have I structured my writing effectively and used a range of sentence types and paragraphs?
What kind of language will I need to use? Formal or informal?	Is the vocabulary I've used in the first paragraph consistent with the one I'm writing now?	Have I managed to use consistently appropriate language throughout?
What sort of argument do I want to arrive at in the conclusion?	Are the points I'm making now building towards the conclusion argument I've planned?	Is there a coherent argument throughout?

And what can/should a teacher do to help achieve this? How can this best be taught? Here are a few tips on how to do this:

- Model different metacognitive approaches: Model the metacognitive approaches that you would use and show your students how to approach a task with special attention illustrating the what, how, and why of the thinking process.

- Facilitate metacognitive learning through lesson structure and environment: Structure your lessons such that students can practice metacognitive strategies. One way is by "splitting'" your lessons into four stages: You model/illustrate, We plan, They do, and We review.
- Give your students learning strategies to use: Explicitly teach your students how to learn and give them opportunities to monitor and review their knowledge and strategies. Provide them with learning strategies discussed earlier like self-instruction, visualising, hypothesising, and estimating.
- Promote reflection: After your students are finished (assignment is completed, exam has been taken) encourage them to reflect on how they studied, what they feel they did well, and what they might want or need to improve next time.
- Encourage self-questioning: Teach your students to ask themselves questions before, during, and after they complete a task. For instance, before beginning they might ask, "What do I already know about this topic?" During the task, they might ask, "Do I understand what I'm reading?" After finishing, they could ask, "What strategies worked well for me and which didn't?"
- Metacognitive talk: Encourage your students to talk through what they're thinking while they carry out a task to help them focus and better understand their thought processes.
- Pair instruction on cognitive strategies with that of metacognitive strategies: Van Merriënboer and Kirschner (2018) call this second order scaffolding. Metacognition isn't a generic skill. It needs to be paired with domain-specific knowledge and cognitive strategies.
- Provide practice opportunities: Provide practice opportunities using metacognitive strategies. Remember we're talking about a skill and skills need practice and feedback.

Takeaways

- Metacognition is the process of actively thinking about one's own learning process.
- Metacognitive knowledge is knowledge or beliefs about the elements of cognition.
- Metacognitive experiences are feelings of familiarity, confidence, satisfaction, or difficulty.
- Strategies used during metacognition are planning, monitoring, and evaluating one's own progress.

- The proximate goal of metacognition is better learning, understanding, and grades. The ultimate goal is being able to self-regulate your own learning in school and for the rest of your life.

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WEBSITES

GUIDANCE REPORT ON METACOGNITION AND SELF-REGULATED LEARNING FROM THE EEF FEATURING POSTERS AND ADDITIONAL TOOLS:

AVAILABLE VIA: HTTPS://EDUCATIONENDOWMENTFOUNDATION.ORG.UK/EDUCATION-EVIDENCE/GUIDANCE-REPORTS/METACOGNITION

VIDEOS

'THE MAGIC OF METACOGNITION' – A LECTURE BY ALEX QUIGLEY AT THE RESEARCHED CONFERENCE HANINGE IN SWEDEN IN 2019

AVAILABLE VIA: HTTPS://YOUTU.BE/UD0VECPY3D8

'THINKING ABOUT 'THINKING' – TWO TEACHERS SHARE STRATEGIES FOR USING METACOGNITION FROM THE LEARNING AGENCY'S SCIENCE OF LEARNING SERIES:

AVAILABLE VIA: HTTPS://YOUTU.BE/OQRDDTJEJ4I

PART II

HOW DOES OUR BRAIN WORK?

RIDDLE

What is a small part of a whole, weighs less than 2% of that whole, uses between 20% and 25% of the available energy, consists of around 190 billion parts, and is mechanical, electrical, chemical, and biological?[1]

What a miracle, our brains! We humans have wonderful bodies. Because of this lump of soft tissue in our heads, weighing – on average – a little more than a kilo, we are able to receive, process, and respond to countless signals from our environment through our eyes, ears, skin, noses, and mouths. Almost effortlessly, we ignore a multitude of unimportant signals and respond specifically to the relevant ones. To top it all off, we can also store an infinite amount of information from those signals for later use.

But how do we make proper use of this miracle when it comes to learning and instruction? John Sweller (2017) stated: "[W]ithout an understanding of human cognitive architecture, instruction is blind".[2] In this respect, it could be the case that many of us in the teaching profession are flying blind.

In this part we discuss how our brains work and what that means for learning and teaching. We explain why students learn some things almost effortlessly without instruction, while other things are learnt with great difficulty through instruction, how our memory works and how we can make it work better, how we (learn to) solve problems, how and why images and words together can help us learn better, how we acquire skills, and why children should not be taught as if they were small adults.

1 ANSWER: THE BRAIN!
2 SWELLER, J. (2017). *WITHOUT AN UNDERSTANDING OF HUMAN COGNITIVE ARCHITECTURE, INSTRUCTION IS BLIND. THE ACE CONFERENCE*. RETRIEVED FROM HTTPS://YOUTU.BE/GOLPFI9LS-W.

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6 A NOVICE IS NOT A LITTLE EXPERT

NOVICES AND EXPERTS

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6 A NOVICE IS NOT A LITTLE EXPERT

PAPER "Categorization and representation of physics problems by experts and novices"[1]

QUOTE *"Not only do experts have more knowledge and can work faster than beginners, they also look at or tackle problems differently (i.e. what you know determines what you see)".*[2]

Why you should read this article

In 1537, a Swiss physician, alchemist, and astrologer named Paracelsus outlined a method for creating homunculi (Latin for *little people*). Short but sweet, a mini-human is created by nourishing a male sperm on human blood in a horse's womb where a small version of a living human child grows. This evolved into what became known as *preformationism*, the theory that animals develop from miniature versions of themselves. Sperm were thought to be complete preformed individuals called animalcules, which developed in the woman's womb into fully formed beings. In 1694, Nicolaas Hartsoecker, in his *Essai de Dioptrique* about what could be seen with the aid of Antoni van Leeuwenhoek's microscope, wrote of and produced an image of a tiny human form curled up inside the sperm (see Figure 6.1), which he called *le petit animal* (animalcule) with the human version being *le petit l'infant* (homunculus). The sperm was a homunculus, identical in all but size to an adult. It is just a matter of growth!

HOMUNCULUS
A miniature human

As odd as this may sound today, many people actually think that this same thing is true about the cognitive/intellectual development of a child (and by extension, a novice) into an adult (and by extension, an expert). A good example of this is discovery learning. The thinking behind this form

1 CHI, M.T.H., FELTOVICH, P.J., & GLASER, R. (1979). CATEGORIZATION AND REPRESENTATION OF PHYSICS PROBLEMS BY EXPERTS AND NOVICES. *COGNITIVE SCIENCE*, 5, 121–152 AVAILABLE FROM: HTTPS://ONLINELIBRARY.WILEY.COM/DOI/EPDF/10.1207/S15516709COG0502_2.
2 AUTHOR'S OWN WORDS.

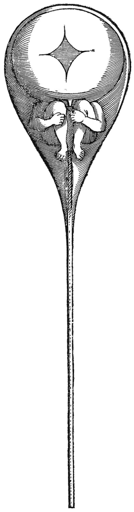

FIGURE 6.1 PREFORMATION, DRAWN BY NICOLAS HARTSOECKER

of education is that since the epistemology of the scientist (i.e. an expert) is to discover and create new knowledge through experimentation, many mistaken educators and researchers have chosen to apply this approach to the school as a pedagogy for teaching students (i.e. novices) (Kirschner, 2009). Michelene Chi, Robert Glaser, and Paul Feltovich broke with this myth showing how experts not only know more than novices, but that they also think differently.

Abstract of the article

This study investigates the differences between how physics problems are represented in novices and experts in relation to the organisation of physics knowledge. Different experiments included: problem categories as a means of representation, category differences used by experts and novices, differences in category knowledge, and aspects of the problems that form problem categorisation and how they're represented. The results from these experiments suggest that experts and novices represent problems differently with particular categorisation of the problems and also that the success in completing the problems depends on domain-specific knowledge. Experts use deep physics principles to categorise and solve problems whereas novices use superficial features.

The article

In their search for differences between experts and beginners in solving problems, Chi and her colleagues focused on the very first step when solving a problem, namely reading and interpreting the problem. When dealing with a new problem, the first question is always: what kind of

Landmarks help classify a problem

problem is this? To answer this question, you often try to remember similar problems that you have encountered before. You search for landmarks. Classifying the problem in a specific category of similar problems is the first step in solving it. The idea is that experts already interpret or categorise problems when reading in a way that's different from beginners, and therefore they're able to solve them more easily, more quickly, and better.

How people categorise a problem depends on previous experiences with similar problems, which shapes how they determine what the problem is and the quality of their solutions. We know this since 1946 when A. D. de Groot published his PhD thesis (which was later translated into English in 1965) on how chess masters interpret chess problems. He found that the chess masters' knowledge and the way of thinking is essentially different from that of beginners. Not only do experts have more knowledge and can work faster than beginners, they also look at or tackle problems differently (i.e. what you know determines what you see). Masters quickly recognise a particular chess position and then determine subsequent moves based on their prior experiences. In the same way, doctors interpret the history (anamnesis) and charts of a new patient by using their knowledge of similar clinical histories and charts that they have dealt with and then make their diagnoses based on this. Thus, our prior knowledge determines the quality of our problem-solving. As experts have both more knowledge as well as qualitatively better knowledge (this is called deep, conceptual knowledge), the categorisation of problems will give them a head start on beginners.

CONCEPTUAL KNOWLEDGE
Deep understanding of concepts and principles

Prior knowledge about problems and their solutions are built through experience with many different types of problems. In this way, experts have acquired rich knowledge about different types of problems and their solutions which they store in their long-term memory; that is they have rich knowledge schemata.

SCHEMA
Cognitive framework which organises knowledge

THE TERM SCHEMA was first used in psychology by Jean Piaget (1896–1980), a Swiss psychologist who studied cognitive psychological development in children. In his words (1952), a cognitive schema is "a cohesive, repeatable action sequence possessing component actions that are tightly interconnected and governed by a core meaning". See it as a way of organising knowledge; a mental structure of already learnt and available knowledge, skills, and even ideas that is used for organising and perceiving new information.

Such a schema may consist of characterisations of different types of problems, possible solutions, different contexts within which these problems may arise, etc. Beginners also have schemata, but these are less extensive and profound (i.e. they are poor). The use of these schemata is therefore less effective for them and sometimes even counterproductive. Beginners often interpret problems by looking at what is called surface characteristics such as “a previous problem also dealt with a moving object and this problem does too” and thus, use the wrong formula (e.g. velocity instead of acceleration). Experts, however, see the underlying concepts of a problem such as “the first problem was about a constant speed, but this is about acceleration, so it’s different”. Because of their extensive and qualitatively better schemata, experts know how to quickly and accurately categorise new problems and link them to a correct solution strategy and solution.

Novices have simple limited schemata Experts can "see" underlying concepts

In their article Chi, Feltovich, and Glaser study the link between a person’s prior knowledge and how (s)he categorises problems. To do this they carried out a series of experiments comparing how first-year physics students (novices) and PhD candidates (experts) divide and classify a series of physics tasks into different types. What they found was that the experts indeed classified the types of tasks differently from the beginners.

Do students with a lot of prior knowledge categorise problems differently than students with little prior knowledge?

The study showed that while experts and beginners both categorised the assignments, they did it in different ways. The beginners categorised the problems based on the characteristics in the description of the assignment (e.g. these problems deal with blocks on an inclined plane). The experts, on the other hand, categorised the problems based on the underlying physical laws (e.g. these problems deal with the law of conservation of energy). Because of their focus on the deeper, underlying physical laws, experts also immediately had a solution strategy that matched the problem while the beginners, due to their focus on surface characteristics, made that link more slowly if at all.

What prior knowledge is actually activated when people encounter a new problem?

In identifying and categorising problems, the researchers mapped the students’ knowledge schemata with respect to the problems. Again, the beginners focused on superficial problem characteristics while the experts focused on physical laws and the circumstances in which they apply.

Which words in the problem description do novices and experts pay attention to when they try to interpret a new problem?

BEGINNERS
Problem-specific categorisation

EXPERTS
Deeper, generalised categorisation

Finally, the researchers asked the students to think aloud and freely associate while reading the problem statements. The goal of this was to find out how the students arrived at their categorisations. It was striking that the beginners based their categorisation specifically on words in the problem statement such as "friction" or "gravity".

Experts, on the other hand, gave descriptions of the states and conditions of the physical situation described by the problem and in some instances, based on transformed or derived features, such as a "before and after situation" or "no external forces".

This study shows that the prior knowledge of experts differs from that of beginners (see Table 6.1). When encountering a new problem, experts think in a very solution-oriented way and their prior knowledge is mainly procedural in nature about how to tackle a problem along with a deep conceptual knowledge about the conditions under which the procedures can be applied. The prior knowledge of beginners, on the other hand, consists mainly of descriptions of the physical characteristics of various problems, but does not include the link with possible solutions.

Conclusions/implications of the work for educational practice

TABULA RASA
The mind as a blank slate

Research that compares the prior knowledge of beginners with that of experts shows that the difference is not only quantitative (i.e. that experts know more) but also qualitative (i.e. their knowledge is also organised differently). This insight brings with it three important implications for education: (1) beginners are not empty barrels that have to be filled, (2) beginners are not "small" experts, and (3) teaching/instruction should take this into account.

TABLE 6.1
DIFFERENCES BETWEEN EXPERTS AND NOVICES

Novices	Experts
■ No access to relevant schemata	■ Possess schemata for encoding elements into a single entity
■ Attempt to remember and process individual elements	■ Skills acquisition without needing to recall the rule
■ Need to apply cognitive capacity to inefficient problem-solving	■ Automation important for complex problem-solving transfer
■ Work backwards (means-end)	■ Work forwards

Based on: Chi, Glaser, & Rees, 1982; De Groot, 1965; Kalyuga, Chandler, & Sweller, 1998; Schneider & Shiffrin, 1977; Wilson & Cole, 1991.

ASSIMILATION
Incorporating new knowledge in existing schemata
ACCOMMODATION
Altering existing schemata to fit new knowledge

For optimal learning, new knowledge must be related to the knowledge that students have already acquired. New knowledge must be integrated into existing schemata.[3] Jean Piaget called this *assimilation* and *accommodation*.

JEAN PIAGET distinguished two important processes in their development: assimilation and accommodation. *Assimilation* is the process by which new knowledge is inserted into existing knowledge schemata while *accommodation* is the process by which existing knowledge schemata are adapted to the new knowledge. When a child sees a Great Dane or a Chihuahua on a leash in the park for the first time, the dogs will be classified in the child's existing dog-schema (assimilation). However, this schema itself will also change, as dogs can from now on be just as big as a Great Dane or as small as a Chihuahua (accommodation).

Beginners have knowledge schemata which are rudimentary, incomplete, shallow, and often contain misconceptions (e.g. naïve hypotheses such as if you kick a ball, then there are still forces working upon it pushing it forward). New knowledge must be given a place in them, either by hanging the new knowledge in them (assimilation) or by adapting them to the new knowledge (accommodation). If a schema contains errors, as is often the case for beginners, then the teacher must focus her/his attention on changing those existing schemata by either eliminating the misconceptions or by helping the student learn and understand the underlying principles. To do this, the teacher needs to make an effort to gain insight into how the student categorises; to understand the schemata so as to take the proper steps to adjust them step by step. It is, thus, extremely important to keep in mind that the novice's prior knowledge and assumptions are not simply a less extensive version of what the expert knows and assumes, but that they really are different.

MISCONCEPTIONS
Error in an existing schema

As the novice is not a miniature expert, it's extremely important to realise that what may work very well for an expert (e.g. discovery learning, problem-based learning, inquiry learning) usually doesn't work well or is even harmful and counterproductive for the novice (and vice versa). This is known as the expertise reversal effect (Sweller, Ayres, Kalyuga, & Chandler, 2003): a reversal of the effectiveness of instructional techniques on learners with differing levels of prior knowledge. While

EXPERTISE REVERSAL EFFECT
What works for experts doesn't work for beginners and vice versa

3 YOU'LL READ MORE ABOUT THIS IN CHAPTER 11, WHAT YOU KNOW DETERMINES WHAT YOU LEARN, WHEN DAVID AUSUBEL AND THE USE OF ADVANCE ORGANISERS IS DISCUSSED.

an expert can be given a problem to be solved after having been taught a certain technique or principle, a novice should be given a more structured approach to using that principle for solving the same problem, for example in the form of a worked example. Kalyuga et al. note here that as the learner advances, a fading procedure – whereby steps in the solution procedure are gradually left open for the learner to carry out her-/himself – is superior to an abrupt switch from worked example to problems. This slow reduction of guidance as learner expertise increases is an example of the *guidance-fading effect;* a direct instructional application that is consistent with the expertise reversal effect.

Epistemology is not pedagogy!

How to use the work in your teaching

DIFFERENTIATION
Tailoring instructional methods for different learners

Differentiation with respect to how one teaches cannot be ignored. This article shows that differentiation is desirable at an early stage in the learning process, including when a learner reads the assignment given to her/him. For example, students who are good at maths may immediately link the assignment to possible solution strategies while weaker students need your guidance to think about the possible solution strategies when categorising the problem. During this supervision it's important to try to make the student's thinking process explicit, so as to try to determine what her/his prior knowledge is, whether or not it's correct, and where it needs to be adapted. Asking students to think aloud and discussing what they have done and why can help you to help them on their way to thinking like an expert.

Takeaways

- Beginners aren't "little" experts; they know less and think differently than experts.
- Children also aren't small adults. They see the world very differently and therefore have to learn differently.
- A teaching approach that works well with an expert will most probably not work well with a beginner and can even be detrimental to their learning.
- Try to differentiate at an early stage.
- The epistemology of the expert is not the proper pedagogy for the learner.
- Beware the "curse of knowledge"[4]: a cognitive bias where instructors who are highly knowledgeable in a domain forget the steps they took to acquire that knowledge and can't understand why novices just don't "get it".

4 KENNEDY, J. (1995). DEBIASING THE CURSE OF KNOWLEDGE IN AUDIT JUDGMENT. *THE ACCOUNTING REVIEW*, *70*, 249–273. AVAILABLE FROM: WWW.JSTOR.ORG/STABLE/248305.

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Suggested readings and links

HOW EXPERTS DIFFER FROM NOVICES.

AVAILABLE FROM HTTPS://NAP.NATIONALACADEMIES.ORG/READ/9853/CHAPTER/5

This chapter in *How people learn: Brain, mind, experience, and school: Expanded Edition* illustrates key scientific findings that have come from the study of people who have developed expertise in areas such as chess, physics, mathematics, electronics, and history. We discuss these examples not because all school children are expected to become experts in these or any other areas, but because the study of expertise shows what the results of successful learning look like.

THE MAKING OF AN EXPERT.

AVAILABLE FROM HTTPS://HBR.ORG/2007/07/THE-MAKING-OF-AN-EXPERT.

This article in the *Harvard Business Review* was written by Anders Ericsson (professor of psychology at Florida State

University), Michael Prietula (professor at the Goizueta Business School), and Edward Cokely (research fellow at the Max Planck Institute for Human Development). They discuss how scientific research has shown that true expertise is the product of years of intense practice and dedicated coaching.

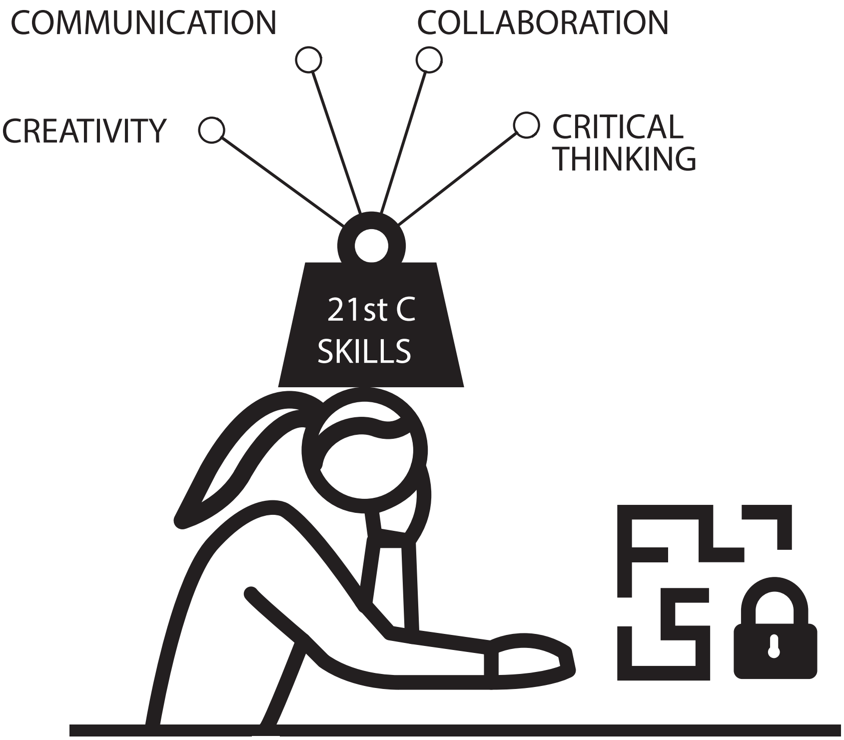
TCU PSYCHOLOGY OF THINKING AND LEARNING "EXPERTS VS. NOVICES".

AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=JZ_C6MNRYFI&T=80S.

A neuropsychological video on the differences between novices and experts. While interesting, the video does break every rule with respect to the redundancy principle from cognitive load theory.

7 TAKE A LOAD OFF ME

PROBLEM SOLVING



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7 TAKE A LOAD OFF ME

PAPER "Cognitive load during problem solving: Effects on learning"[1]

QUOTE *"There seems to be no clear evidence that conventional problem solving is an efficient learning device and considerable evidence that it is not".*[2]

Why you should read this article

Working memory temporarily holds new information

Cognitive load theory has been described by Dylan Wiliam as "the single most important thing for teachers to know" (William, 2017). This theory is based on the limited ability of the working memory to code information. Once learners have built up schemata of knowledge that allow them to work on problems without exceeding their cognitive bandwidth, then they can work independently. Without it, their work might be in vain.

CONSTRUCTIVISM Theory that we construct knowledge from our experiences

Why is this important? Solving problems is possibly the hottest topic in education at the moment. It forms the basis of a number of constructivist approaches to teaching and learning such as problem-based learning, inquiry-based learning, discovery learning, experiential learning, and constructivist learning. Also, it's one of the most highly regarded components of what has come to be known as twenty-first century skills. And finally, it has taken centre stage for many people in both education and industry who propagate the notion that the most important thing at the moment is the acquisition of generic, domain-independent skills and that the best way to learn to solve problems is by solving them (e.g. inquiry/discovery learning).

1 SWELLER, J. (1988). COGNITIVE LOAD DURING PROBLEM SOLVING: EFFECTS ON LEARNING. *COGNITIVE SCIENCE*, *12*, 257–285. DOI: 10.1207/S15516709COG1202_4.
2 IBID., P. 257.

What's the problem? Well let's say you're confronted with a problem that you need to solve. If you're well versed in the subject area, that is to say you have a great deal of the knowledge relevant to solving the problem and you've also solved similar problems, then you follow the necessary steps to define, solve, and then evaluate your solution. You might choose to use a problem-solving strategy that you've used before, but only after determining its similarity to the problem at hand and, thus, whether that strategy is relevant. That is to say you make use of the knowledge and strategies you have stored in your long-term memory. Here, we speak of your having domain-specific knowledge, domain-specific procedural knowledge (i.e. knowing what the steps for solution are) and strategies, and the ability (i.e. the skill) to carry out the steps.

LONG-TERM MEMORY
Permanent store of knowledge

If, on the other hand, you're not knowledgeable in the area, then you're in trouble. The most often used strategy is a version of what is known as *means–ends analysis*. Here you work backwards, comparing your current state (where you are at the moment) with the goal state (where you need to be; the solution) and you look for moves (steps that you possibly can carry out) that will reduce this distance. All of this requires much mental effort. In that process, you will also need to search for and find problem-relevant information, which is very hard to do if you know little about the area. The process ends up being little more than high mental-effort trial and error which is neither effective nor efficient and which often leads to frustration at how long it's taking and the number of dead-ends encountered. In other words, the process is also not very enjoyable.

Means–ends analysis reduces the difference between desired end goal and current state

Mental effort depends on task complexity and level of expertise

MENTAL EFFORT is about how hard a person tries to actively process presented information. It is a combination of perceived demand characteristics (how complex the task is combined with the level of expertise of the person carrying out the task), perceived self-efficacy (the extent that one believes that (s)he is capable of performing in a specific manner to attain specific goals), and level/depth of information processing (the degree to which a person encodes/recodes a source) such that the first two influence the last which determines the amount of invested mental effort.

John Sweller's article forms the basis for why domain-specific knowledge is so necessary for solving problems and why domain-independent skills, such as problem-solving, collaborating, writing, communicating, and so forth, don't exist. If only researchers, teachers, administrators, educational policy makers, and politicians had read and applied the content of this article, then we could have saved a lot of wasted time, money, and energy spent chasing those elusive domain-independent skills.

Abstract of the article

There is significant evidence that the main distinguishing factor between experts and novices in problem-solving is domain-specific knowledge. There is also emerging evidence that conventional problem-solving skills are not effective in acquiring schemata. It is suggested that a reason for this is that both of these processes clash and that conventional means–ends analysis uses up a large amount of cognitive bandwidth which in turn is not available for acquiring schemata. This study uses experimental evidence, a computational model and discusses theoretical and practical implications.

The article

According to John Sweller, extensive research on expert–novice distinctions lie at the basis of his article. Experts and novices differ in their memory of problem state configurations, their problem-solving strategies, and the features they use categorising problems. We know that experts and novices differ with respect to their *memory of problem state configurations* since A. D. de Groot (1946, 1978) studied the difference between chess masters and less experienced players. De Groot found that the grandmasters didn't have a superior working memory nor were they more creative or better at problem-solving, but rather they remembered more meaningful chess-positions. As Daisy Christodolou (2020) writes:

> These expert chess players have memorised the typical patterns of thousands of chess games. When they see a chess end game and rapidly decide what move to make, they can do so because they can compare the game state to all the board positions they have stored in long-term memory. They aren't reasoning; they're recalling. Or rather, their ability to reason is bound up with recall.
>
> (p. 74)

This has been replicated in many fields and is now seen as a given (Chase & Simon, 1973a, 1973b). As regards *problem-solving strategies*, the strategies used by expert and novice problem solvers also differ. As stated, novices use means–ends analysis while experts, in contrast, begin by choosing a strategy that they're familiar with (usually from solving analogous problems) and then work forwards to solve the problem. Experts can work forwards because they recognise each problem and each problem state from previous experience and know which moves are appropriate. They have cognitive schemata in their long-term memory which allow this (Larkin, McDermott, Simon, & Simon, 1980; Simon & Simon, 1978). Finally, regarding the *features used to categorise problems*, experts group problems based on deep structures such as the mode of solution while novices group problems according to surface structures such as how they look (Chi, Glaser, & Rees, 1982; Hinsley, Hayes, & Simon, 1977).

Inquiry-based instruction is demanding on working memory

In addition, inquiry-based instruction requires the learner to search a problem space for problem-relevant information. All problem-based searching makes heavy demands on working memory. Furthermore, that working memory load does not contribute to the accumulation of knowledge in long-term memory because while working memory is being used to search for problem solutions, it is not available and cannot be used to learn. Indeed, it is possible to search for extended periods of time with quite minimal alterations to long-term memory (e.g. see Sweller, Mawer, & Howe, 1982). The goal of instruction is rarely simply to search for or discover information. The goal is to give learners specific guidance about how to cognitively manipulate information in ways that are consistent with a learning goal, and store the result in long-term memory.

EXAMPLE
Categorisation

A SIMPLE EXAMPLE of categorisation based on deep or surface-level structures is how an expert baker may see a problem as opposed to a novice. For the novice, rising is rising, and so if (s)he has learned that increasing the baking temperature of soda bread will make it rise better and faster, (s)he will then see a similar problem with getting normal bread to rise more quickly as a question of raising the temperature. Unfortunately for the novice, while the surface structures may be similar (getting bread to rise), the deep structures aren't. The rising process with baking soda is a chemical one; heat catalyses and thus speeds up the chemical process. Yeast, on the other hand, causes dough to rise based on a biological process; yeast digests carbohydrates and produces carbon dioxide and alcohol. This process works optimally at 37° Celsius and temperatures above a certain level kill the yeast (that's why we bake the dough after letting it rise in a warm place!).

In the rest of the article, Sweller shows how conventional problem-solving is inefficient for acquiring problem-solving schemata and how this lies in the demands made upon our cognitive architecture, and primarily the demands made upon our working memory. Based on a theoretical discussion and a number of empirical studies, he shows that while solving conventional problems via means–ends analysis used by novices can lead to problem-solution, it doesn't lead to schema acquisition; the cognitive effort expended during conventional problem-solving can lead to the problem goal, but not to learning (an educational goal).

Conclusions/implications of the work for educational practice

Sweller concludes that: (1) conventional problem-solving through means–ends analysis imposes high cognitive load; (2) how we solve problems and how we acquire cognitive schemata differ greatly; (3) the cognitive effort expended by conventional problem-solving doesn't aid schema acquisition; (4) as schema acquisition is a basic component of problem-solving expertise, developing expertise may be stunted by emphasising problem-solving; and (5) you don't learn how to solve problems by solving problems!

Learning through problem-solving induces high cognitive load/mental effort

In other words if you want your students to learn to solve problems, they first need both the declarative and procedural knowledge within the subject area of the problem in question. This is also true if you want to teach them to communicate, discuss, write, or whatever twenty-first century skill people are talking about. You can't communicate about something, write about something, discuss or argue about something, etc., without first knowing about that something and then also knowing the rules (i.e. the procedures) for doing it.

How to use the work in your teaching

As a teacher, it is imperative that you avoid means–ends problem-solving. This approach of working backwards from the goal to the problem and then from the givens to the solution creates too much cognitive load and hinders learning. This means that you need to create situations where learners can work forwards. First, they need the (pre)requisite knowledge. Then, they need to have had multiple exposures to situations where they have employed strategies that may be similar to the strategy needed to solve a specific problem.

One of the best ways to do this is to interleave content and problems while teaching as opposed to *blocking* (Van Merriënboer & Kirschner, 2018, call this *variability of practice*). Blocking involves solving one type

INTERLEAVING Mixing up topics to be learned

of problem at a time before the next (for example, “problem A” before “problem B” and so forth). The learning pattern formed looks like this: AAABBBCCC. Interleaving, in contrast, involves solving several related problems mixed up together. The learning pattern here looks like this: ABCBCAACB. This approach helps the learner to choose the correct strategy to solve a problem and helps them see the links, similarities, and differences between problem states. It also leads to increased transfer.

Takeaways

- Acquiring/learning a procedure to solve a problem is not the same as being able to solve a problem. The former is a type of knowledge (procedural knowledge), the latter is a skill.
- If the learner has no relevant concepts or procedures in long-term memory, the only thing to do is blindly search for possible solution steps … novices can engage in problem-solving for extended periods and learn almost nothing.
- Learning happens best when methods are in line with human cognitive structure.
- While solving problems might lead to solving a problem (i.e. reaching the problem’s goal state) in the short term, it doesn’t lead to learning how to solve problems (i.e. education’s goal state) in the long term.
- Means–ends analysis is a bad way to solve a problem. Sometimes the best way to solve a problem is not to “problem solve”.

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A conversation with John Sweller. In mid-2017 Ollie Lovell met with John Sweller to ask him a few questions that he had about cognitive load theory, and his work. John was gracious enough to let him record the conversation and turn it into a series of blog posts. All together, these posts amount to almost 9000 words of text, so they have been split into nine different sub-posts for the convenience of readers.

AVAILABLE FROM WWW.OLLIELOVELL.COM/PEDAGOGY/JOHNSWELLER.

A DISCUSSION OF WORKING MEMORY FROM SIMPLY PSYCHOLOGY.

AVAILABLE FROM WWW.SIMPLYPSYCHOLOGY.ORG/WORKING%20 MEMORY.HTML.

WHAT YOU NEED TO KNOW ABOUT COGNITIVE LOAD: A CONVERSATION WITH JOHN SWELLER.

AVAILABLE FROM HTTP://THEELEARNINGCOACH.COM/PODCASTS/55/.

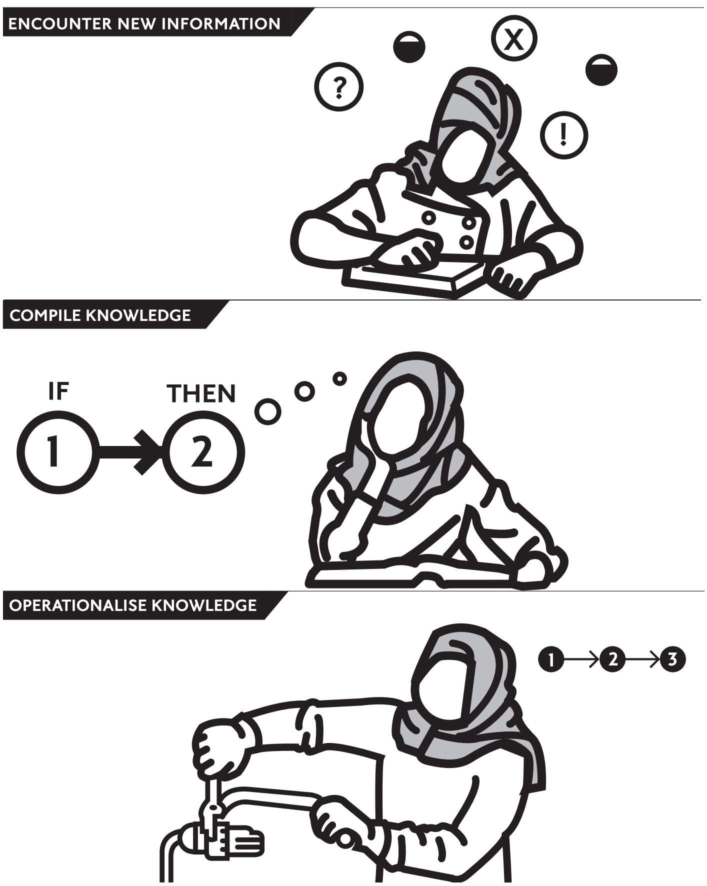
AND HERE'S ANOTHER PRESENTATION BY JOHN SWELLER AT RESEARCHED MELBOURNE IN 2017 ENTITLED *WITHOUT AN UNDERSTANDING OF HUMAN COGNITIVE ARCHITECTURE, INSTRUCTION IS BLIND*.

Our knowledge of human cognition has advanced substantially over the last few decades. That knowledge has considerable implications for instructional design but is almost unknown among instructional designers. Cognitive load theory is an instructional design theory based on our knowledge of human cognition. In this talk John Sweller describes those aspects of human cognition that are relevant to instruction and briefly describes some of the instructional implications that follow.

AVAILABLE FROM HTTPS://YOUTU.BE/GOLPFI9LS-W.

8 DANCING IN THE DARK

SKILL ACQUISITION



DOI: 10.4324/9781003395713-10

8 DANCING IN THE DARK

PAPER "Skill acquisition: Compilation of weak-method problem situations"[1]

QUOTE *"A basic characteristic of the declarative system is that it does not require one to know how the knowledge will be used in order to store it. This means that we can easily get relevant knowledge into our system but that considerable effort may have to be expended when it comes time to convert this knowledge to behavior."*[2]

Why you should read this article

A weak problem-solving strategy (also known as a means–ends analysis) is a problem-solving strategy that involves breaking down a problem into smaller sub-problems and finding the means to bridge the gap between the current state and the desired goal state. In means–ends analysis, you identify the current state, define the goal state, and then work backward to determine the intermediate steps or sub-goals required to reach the ultimate goal. While means–ends analysis can be used to solve a problem, it often isn't very efficient as it relies on trial and error, and sometimes the chosen means or sub-goals may not lead directly to the desired goal.

One of us really liked the television series "House", not least because it shows the difference between weak and strong problem-solving strategies. House and his team often faced complex and puzzling medical cases. Similar to means–ends analysis, House and his team started by establishing the current state, which was the patient's medical condition and the symptoms they were experiencing. The ultimate goal was to diagnose and treat the patient accurately. In each episode, House and his team engaged in a series of steps that aligned with means–ends analysis.

1 ANDERSON, J. R. (1987). SKILL ACQUISITION: COMPILATION OF WEAK-METHOD PROBLEM SITUATIONS. *PSYCHOLOGICAL REVIEW*, *94*(2), 192–210.
2 IBID., P. 206.

They collected information through patient interviews, medical tests, and consultations with other medical professionals. They broke down the problem into smaller sub-problems by investigating specific symptoms, analysing test results, and ruling out potential causes. However, this approach also incorporated a fair amount of trial and error, as they often tried different diagnostic and treatment approaches until they found a solution. It's important to note here that House's own problem-solving approach went far beyond just means–ends analysis. House employed far more deductive reasoning to generate hypotheses about the potential causes of a patient's symptoms. He used his deep medical knowledge and experience to make connections between seemingly unrelated pieces of information to solve the problem. In this chapter, John R. Anderson's Adaptive Control of Thought (ACT*) theory explains how novices begin with trial and error (weak problem-solving) and advance as expertise increases.

Abstract of the article

Cognitive skills are encoded by a set of productions, which are organized according to a hierarchical goal structure. People solve problems in new domains by applying weak problem-solving procedures to declarative knowledge they have about this domain. From these initial problem solutions, production rules are compiled that are specific to that domain and that use of the knowledge. Numerous experimental results may be predicted from this conception of skill organization and skill acquisition. These include predictions about transfer among skills, differential improvement on problem types, effects of working memory limitations, and applications to instruction. The theory implies that all varieties of skill acquisition, including those typically regarded as inductive, conform to this characterization.

The article

ACT: ADAPTIVE CONTROL OF THOUGHT
Simulated cognitive architecture

Beginning in the 1970s, John R. Anderson developed an important theory of how we acquire skills in a given domain which he termed "ACT*" (Adaptive Control of Thought) which is essentially a computational framework which seeks to explain how we encounter and process information. This process has three stages: first, learners encounter new information in the form of declarative knowledge (facts and information about a topic; the *what*), during which time cognitive load is high and they make a lot of mistakes and use verbal reasoning to work out what they're doing. This process is slow and usually filled with errors, sometimes mistakes and sometimes slips. Mistakes are errors in choosing an objective or specifying a method of achieving it, whereas slips are errors in carrying out an intended method for reaching an objective. Second, the learner goes through a process of "knowledge compilation" where they begin to convert that declarative knowledge into procedural knowledge where, for example, they move towards creating a series of rules such as "if-then" statements where they can use knowledge stored in long-term memory to begin to solve problems, for example "If the patient has a fever, then there is probably an infection somewhere". Finally, the learner operationalises declarative knowledge into a series of procedures (the *how*) where working memory is not taken up with sorting new knowledge and a focus on the issue at hand can occur. A simple way to think about it is the difference between writing down the steps needed to ride a bike and then actually riding a bike. In this article written five years later, he focuses on weak-method problem solutions related to this process of moving from declarative knowledge to procedural knowledge.

Declarative knowledge vs. procedural knowledge

In revisiting the ACT* model, there is what Anderson terms the "firing of productions" which is really the execution of certain procedural rules of condition-action (IF-THEN) pairs where if a certain condition occurs, then a related action takes place. In other words, when encountering a problem, we'll look for a similar worked out problem and attempt to use that as strategy as a solution (this is known as pattern-recognition), for example using last year's tax return forms as a model of completing this year's forms. As Anderson puts it: "If a certain type of situation is encoded in working memory, then a certain action should take place" (p. 193). However, a key question arising from ACT* learning theory is how a system, starting out with only domain-general productions, gradually acquires domain-specific productions. After all, domain-general procedures are often useless and when they work, they'll only work some of the time.

PRODUCTIONS
A series of "if-then" procedures

Anderson uses the example of a subject using "LISP", in the 1980s a programming language that was used to model cognition with specific attention to condition-action statements, the manipulation of symbolic expressions and pattern matching capability. Anderson observed that the participants in his research had difficulty solving a given problem because they had a problem specifying the function parameters (the values of the arguments with which the function is going to be called/invoked), something common to many novices in a given domain and which his team also observed in almost 40 other participants. From these observations, Anderson outlines some important features of ACT* theory.

1. Productions as the units of procedural knowledge

Productions are condition-action rules

The central idea of ACT* theory is that productions form the units of knowledge and "define the steps in which a problem is solved" (p. 196). To clarify, "productions" here refer specifically to condition-action rules which guide cognitive processing; an action (something we do) is activated or triggered when its condition (often an event) is or becomes true, for example “If it’s raining outside, then I grab my raincoat or umbrella”.

Goal structure is hierarchical

2. Hierarchical goal structure

There is an overall goal structure which guides and directs the problem-solving and this structure reflects the hierarchical structure of the problem:

> More important than their role in controlling behavior, goals are important to structuring the learning by knowledge compilation. They serve to indicate which parts of the problem solution belong together and can be compiled [*authors: assembled*] into a new production.
> (p. 196)

Weak methods are initially used

3. Initial use of weak methods

Anderson then outlines the key idea in this article, the fact that novices in a given domain often use weak methods to solve problems (see Chapter 6, A novice is not a little expert). One example given is the use of analogy which he describes as being among a group of methods termed “weak” because they “do not take advantage of domain characteristics. Other examples of weak problem-solving methods include means-ends analysis, working backward, hill climbing, and pure forward search” (p. 196).

MEANS/END ANALYSIS
Difference between current state and goal state

Means/end analysis: Identify your current state (your initial state), where you want to be (your goal state), and the means that will get you there.

Working backwards: Similar to means/end where you reduce the difference between initial and goal states by working from both ends.

Hill Climbing:You choose any available option that moves you closer to your goal.*Pure forward search*: Description.

We can add to this *Generate-and-Test* (trial-and-error):You generate a possible solution and then test it.

Knowledge compilation creates productions

4. Knowledge compilation

All knowledge in the ACT* model starts out as declarative knowledge which is then shifted to procedural: “When ACT* solves a problem, it produces a hierarchical problem solution generated by productions. Knowledge compilation is the process that creates efficient domain-specific productions from this trace of the problem-solving episode" (p.197). However, despite the fact that these points describe how knowledge is transformed into skills, it doesn't explain how well the knowledge underlying the skill will be translated into performance. For this, Anderson then adds two more elements:

Strength increases with use

5. Strength of a production

The strength of a production (condition-action rules) predicts how quickly it can be applied and these rules are made stronger with every subsequent usage of them (i.e. how often they're practiced). This increase in strength is very simple, but this strengthening is what actually determines the rate of skill development.

Working memory limits lead to errors

6. Working memory limitations

According to Anderson, there are two reasons why errors are made: either the automated productions are wrong or the information in working memory on which they're based is wrong. However, an important observation in terms of performance limitations is that:

> perfect production sets can display errors due to *working-memory failures*. In fact, slips [authors: application mistakes] can occur in the ACT* theory only when critical information is lost from working memory and consequently the wrong production fires or the right production fires but produces the wrong result.
>
> (p. 197)

Transfer to new domains

Transfer

A key question at this point is to what extent procedural knowledge can be transferred to new problems in a different domain. If the underlying structure of two problems are similar and the productions required are the same, then it's likely that there will be transfer. However, there are situations where a solution to a problem can be simpler than it appears and the subject persists with using (or transferring) previously learnt used solutions that have worked before, a phenomenon known as the *Einstellung effect*.

Einstellung = Setting

The Einstellung effect: "this is the way we've always done it."

This effect refers to the mechanised state of mind where someone will use an automated way of solving a problem, despite the fact that a simpler and often more efficient method is available.

The most famous example of this effect is illustrated in an experiment devised by Abraham Luchins in 1942 called the water jug experiment in which subjects had to use three different jugs of varying volume to arrive at a particular outcome (see Table 8.1).

Problem	Capacity of Jug A	Capacity of Jug B	Capacity of Jug C	Desired Quantity
1	21	127	3	100
2	14	163	25	99
3	18	43	10	5
4	9	42	6	21
5	20	59	4	31
6	23	49	3	20
7	15	39	3	18
8	28	76	3	25
9	18	48	4	22
10	14	36	8	6

TABLE 8.1 THE WATER JUG PROBLEM (LUCHINS, 1942)

In his experiment, the participants were given three water jars, each with the capacity to hold a different, fixed amount of water (in problem 1, Jug A held 21 units of liquid, Jug B 127 units, and Jug C 3 units). The participants had to figure out how to measure a certain amount of water using these jars. They were divided into two groups. The experimental group was given five practice problems, followed by four critical test problems. The control group did not have the five practice problems. All of the practice problems and some of the critical problems had only one solution, which was "Jug B minus Jug A minus 2 times Jug C". In problem 1, they had to measure 100 ounces. The solution was to begin with 127 ounces (Jug B) and then remove some of its contents twice using Jug C (2 x 3 ounces), resulting in 121 ounces remaining in Jug B. Finally, use Jug A to remove 21 ounces, which leaves you with 100 ounces in Jug B. This method (B-2C-A) worked for the first five practice problems but then fails to work for the rest. For example, in problem 6, all they needed to do was remove 3 ounces from Jug A (23 ounces) with Jug C. It's that simple! However, many of the subjects persisted with the more complex method that was successful in problems 1–5.

Working memory limitations and errors

Anderson makes the point that in observing students who were writing computer programmes, there were frequent errors where working memory was overwhelmed. However, there is a curious phenomenon where increased experience in a specific domain led to a greater capacity in terms of working memory which relates to research from Chase and Ericsson (1982) where their work showed that "experience in a domain can increase capacity for that domain. Their analysis implied that storage of domain information in long-term memory became so reliable that long-term memory developed into an effective extension of short-term memory" (Anderson, 1987, p. 203).

Other types of working memory error are where there is a loss of declarative knowledge from working memory or where subjects lose sight of a goal they are trying to achieve or finally when subjects do not have sufficient knowledge of appropriate productions and then execute, or as Anderson puts it "fire", the wrong one.

Relation between ACT* and biologically primary and biologically secondary knowledge and cognitive load theory

Biologically primary vs. secondary knowledge

The critical observer will notice a "strange" likeness between what John R. Anderson wrote and what John Sweller wrote (e.g. limitations of working memory; see Chapter 7, Take a load off me). In 2006 John and his wife Susan wrote an article with the title "Natural information processing systems". In that article, based to a large extent on Geary's work on biologically primary and secondary knowledge (see Chapter 9, An evolutionary view of learning), they spoke of five principles of such systems: information store principle, borrowing and reorganising principle, randomness as genesis principle, narrow limits of change principle, and organising and linking principle.

Relationship between Sweller (principles of evolutionary systems) and Anderson (ACT* theory)

SWELLER VS. ANDERSON

If we compare Sweller's five principles and Anderson's ACT* theory we see a number of interesting connections:

1. The *information store principle* states that the human cognitive system has a limited working memory capacity, and new information must be stored and organised in long-term memory for efficient problem-solving. In ACT*, this aligns with the concept of declarative memory, which represents factual knowledge

and information stored in long-term memory. Problem-solving requires retrieving relevant information from long-term memory to guide decision-making and generate solutions.

2. The *borrowing and reorganising principle* emphasises the importance of transferring and reorganising information across problem-solving domains. In ACT*, this relates to the idea of analogical reasoning and knowledge transfer. Problem solvers can borrow relevant information or strategies from one problem domain and reorganise or adapt them to solve problems in a different domain.
3. The *randomness as genesis principle* suggests that random variations or explorations play a role in generating new solutions or problem-solving strategies. In ACT*, this aligns with the concept of problem space exploration. Problem solvers may generate and consider random variations or possibilities within the problem space to explore different solution paths. This allows for the discovery of novel or unexpected approaches to problem-solving.
4. The *narrow limits of change principle* states that individuals tend to make incremental modifications rather than radical changes in problem-solving strategies. In ACT*, this aligns with the concept of procedural learning. Problem solvers refine and improve their problem-solving skills by gradually modifying and adjusting their strategies based on feedback and experience.
5. The *organising and linking principle* suggests that problem-solving expertise involves the organisation and integration of knowledge and skills. In ACT*, this aligns with the concept of production systems, which represent procedural knowledge and the rules for performing cognitive tasks. Problem solvers organise their knowledge into production rules and link them together to form a cohesive problem-solving framework allowing for efficient and automated problem-solving processes based on established patterns and rules.

Overall, Swellers' principles, when viewed in relation to Anderson's ACT* theory, provide insights into the cognitive mechanisms involved in problem-solving, including knowledge organisation, information transfer, exploration, incremental learning, and the integration of procedural and declarative knowledge.

Conclusions/implications of the work for educational practice

It seems obvious that what we think of as "skills" are simply a successful procedural version of declarative knowledge. In other words, the "skill" of riding a bike is simply an automated sequence of actions based on knowledge gained from instruction and experience riding the bike. However, skill in the form of procedural knowledge is a much more elusive and mysterious form of knowledge in the sense that written instructions of how to ride a bike are completely different to actually knowing how to ride a bike. The other confounding element is that, in many cases, it's very difficult for an expert to explain how they do what they do and what a novice needs to do to get there (i.e. the curse of knowledge). One way to think of procedural knowledge is as "unanalysed" declarative knowledge.

Anderson makes the case that in domains where one can only learn a skill by doing it, the need for formal instruction diminishes. A more useful method of instruction is instead of telling students precisely how to solve problems in a domain, to focus instruction on *why* certain solutions work in that domain. This would seem, at least in part, to help counteract the possible pitfalls associated with the Einstellung effect.

The goal of teaching and learning is to move as efficiently and effectively from means–ends analysis to expert problem-solving. This involves developing a deeper level of expertise and proficiency in problem-solving skills. Here are some principles from ACT* theory that can help in making this transition. First, we should focus on building a strong foundation of knowledge and expertise in learners in the specific domain or field where you want them to become an expert problem solver. Second, expert problem-solving often comes with experience. Engage in practical experiences, hands-on projects, and real-world problem-solving opportunities AFTER acquiring the necessary declarative knowledge. Third, experts develop the ability to recognise patterns and similarities across different problems as well as differences between similar-seeming problems. This involves a teacher helping students learn to analyse a wide range of problems, understanding their underlying structures, and identifying commonalities and recurring themes. Think here about the desirable difficulties (Robert Bjork; see *HTH*, Chapter 14, No pain, No gain) interleaving and contextual interference. Lastly, experts have the ability to think about their own thinking processes (metacognition). They understand their strengths and limitations, and can monitor and reflect on their problem-solving strategies. It's important to help students cultivate metacognitive skills through self-reflection, seeking feedback, and continuously improving their problem-solving methods.

How to use the work in your teaching

When students encounter new problems, they use general problem-solving skills such as analogy, trial-and-error search, or means–ends analysis. Although many of the experiments used by Anderson are on adults or near-adults, he makes the claim that they hold specific relevance for children in the sense that:

> Young children are the universal novices: Everything they are asked to team is a novel skill. Experimentation with LISP programming provides a good approximation to the child's situation in the experimentally more tractable adult. The claim is that children bring weak problem-solving methods to new domains and, like adults, eventually compile domain specific procedures.
>
> (p. 206)

The theory proposed by Anderson can be applied to teaching and learning in the following ways:

- Focus on giving learners declarative knowledge about a domain, rather than teaching them specific problem-solving procedures. This helps them develop better understanding of the domain and helps them apply weak problem-solving procedures to the knowledge they have, in order to develop production rules that are specific to that domain and that use the knowledge. Better, of course, is to also teach them superior and stronger problem-solving approaches.
- Use the theory to predict how learners will transfer skills from one domain to another, and design instruction to facilitate this transfer. For example, if two domains share similar declarative knowledge, learners may be able to transfer production rules from one domain to the other.
- Design instruction that takes into account the effects of working memory limitations on skill acquisition. For example, use small steps, use a pedagogy that doesn't add extraneous load, apply the dual coding theory (Paivio; see Chapter 10, One picture and one thousand words), etc.

Overall, have your instruction focus on helping learners develop a deep understanding of a domain, and encouraging them to develop production rules specific to that domain and that use the knowledge.

Takeaways

- Becoming skilled means converting declarative knowledge into procedural knowledge through a middle process called knowledge compilation.
- Cognitive skills are encoded by a set of productions, which are organised according to a hierarchical goal structure.
- Novices to a specific domain use weak problem-solving skills such as analogy, trial-and-error search, or means–ends analysis.

- In certain domains, where there is a focus on procedural knowledge, the need for formal instruction decreases. For example, you can't really be told how to ride a bike.
- A big part of transforming declarative knowledge into procedural knowledge is about creating a series of rules such as "if-then" statements.

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VIDEOS

John Anderson discusses the origins of his work, the possible implications, and the need to discover why intelligent tutoring systems actually work.
AVAILABLE VIA: HTTPS://YOUTU.BE/CQTUPK8AKAE

A video from the 1980s showing Anderson using ACT* theory to create intelligent tutoring systems for students learning Mathematics.
AVAILABLE VIA: HTTPS://YOUTU.BE/BODH_PW14B0

WEBSITES

JOHN ANDERSON'S HOME PAGE AT MELLON UNIVERSITY.
AVAILABLE VIA: HTTP://ACT-R.PSY.CMU.EDU/PEOPLEPAGES/JA/

USEFUL OVERVIEW OF ACT-R THEORY.

AVAILABLE VIA: WWW.INSTRUCTIONALDESIGN.ORG/THEORIES/ACT/

THE OFFICIAL ACT-R WEBSITE.

AVAILABLE VIA HTTP://ACT-R.PSY.CMU.EDU/

9 AN EVOLUTIONARY VIEW OF LEARNING

EVOLUTIONARY PSYCHOLOGY

BIOLOGICALLY PRIMARY LEARNING

MOVING
SPEAKING
RELATING
FOLK PSYCHOLOGY
FOLK BIOLOGY
FOLK PHYSICS

BIOLOGICALLY SECONDARY LEARNING

CULTURAL KNOWLEDGE:
SCHOOL CURRICULUM
READING
WRITING
MATHEMATICS

DOI: 10.4324/9781003395713-11

9 AN EVOLUTIONARY VIEW OF LEARNING

PAPER "An evolutionarily informed education science"[1]

QUOTE *"Evolutionary educational psychology is the study of the relation between folk knowledge and abilities and accompanying inferential and attributional biases as these influence academic learning in evolutionarily novel cultural contexts, especially schools."*[2]

Why you should read this article

A baby is born. Almost immediately they communicate with the parents. They let them know when they are happy, hungry, and uncomfortable. They smile at their mum and dad within six to eight weeks, who smile back, and they begin to make sounds that are echoed back and forth with the parents. A little later they begin speaking their first words and learn to live and play with others. How is it that babies and toddlers learn and can do these things? How is it that they learn to speak seemingly effortlessly, but a few years later learn to read and write that same language with great pain and difficulty? And why do children in a class have more attention for each other than for school work? In his article, David Geary answers these and other questions by looking at children's learning through an evolutionary lens. Viewing and studying learning from such an evolutionary point of view leads to refreshing insights. It can offer us an explanation for why children are endlessly motivated for some things and for others much less or not at all, and why certain ways of learning are so popular.

1 GEARY, D. C. (2008). AN EVOLUTIONARILY INFORMED EDUCATION SCIENCE. *EDUCATIONAL PSYCHOLOGIST, 43* (4), 179–195. HTTP://DOI.ORG/10.1080/00461520802392133S.
2 IBID., P. 185.

Abstract of the article

Schools are a central interface between evolution and culture. They are the contexts in which children learn the evolutionarily novel abilities and knowledge needed to function as adults in modern societies. Evolutionary educational psychology is the study of how an evolved bias in children's learning and motivational systems influences their ability and motivation to learn evolutionarily novel academic abilities and information in school. I provide an overview of evolved domains of mind, corresponding learning and motivational biases, and the evolved systems that allow humans to learn about and cope with variation and change within lifetimes. The latter enable the creation of cultural and academic innovations and support the learning of evolutionarily novel information in school. These mechanisms and the premises and principles of evolutionary educational psychology are described. Their utility is illustrated by discussion of the relation between evolved motivational dispositions and children's academic motivation and by the relation between evolved social-cognitive systems and mechanisms that support children's learning to read.

The article

We learn many things "automatically" without having to make any noticeable effort. The reason for this is simple, namely that learning certain things is genetically programmed into us as a result of natural selection; certain types of learning are, so to speak, hardwired into us by way of our evolution. This way we learn to recognise faces by looking and comparing, we learn to talk by listening, and we learn to walk through trial and error. They are all forms of learning that we, as a species, have specifically evolved to acquire over many generations. We also call it biological or evolutionary primary learning. Primary skills, such as learning general problem-solving strategies, imitation, recognising faces, communicating through listening and speaking a native language, and social relations including our ability to communicate with each other, have evolved via evolution. Geary speaks of "[H]umans' brain and cognitive systems that have evolved to attend to, process, and guide behavioural response to evolutionarily significant information compose 'biologically primary' or core domains of human cognition, and coalesce around folk psychology, folk biology, and folk physics" (p. 180). Folk psychology (i.e. common sense psychology) deals with awareness of the self, other individuals, and group dynamics; our innate capacity to explain and predict the behaviour and mental state of others so as to deal and form relationships with them (e.g. (s)he's nice or I can depend on her/him). Folk biology deals with how we classify and reason about the organic world around and develop taxonomies about their behaviour and their "essence" (e.g. heuristics we use to make sense of the natural world around us). Folk physics is the untrained human perception of basic physical phenomena that support navigation, forming mental representations of phenomena (e.g. what goes up must come down), and tool construction. Evolutionarily speaking, Geary states that we also have biological biases towards social play and exploration of our surroundings. We acquire such primary knowledge easily, unconsciously, and without explicit instruction merely by membership in a group and as such, do not need to be taught. We also store biological primary knowledge directly in our long-term memory without conscious processing in working memory.

BIOLOGICALLY PRIMARY KNOWLEDGE
Evolutionary skills/ knowledge we acquire naturally like speaking

THOUGH ATTRIBUTED TO CHARLES DARWIN, the phrase *survival of the fittest* was actually coined by Herbert Spencer, an all-around scientist in Victorian England. In everyday language, people understand the term to mean that a stronger animal will defeat a weaker one and, thus, survive. But this is true only in a very specific sense. Survival of the fittest is about evolution to describe the mechanism of *natural selection*, the term that Darwin used. Natural selection is a biological concept and only relates to reproductive strength (i.e. success). In other words it is actually the survival of any form of life that will have the greatest chance of living long enough to both reproduce and, if necessary, care for as many of their offspring long enough so that they too are eventually able to reproduce. In other words the fittest plant or animal is one that is fitter than others, and fit to leave as many copies of itself as possible in successive generations. If we look at primary knowledge like communicating (both orally and physically), recognising others, and forming social bonds with parents and others necessary for survival, then it's clear that without these skills a baby will not survive very long, not reproducing and not perpetuating this non-ability.

NATURAL SELECTION
Traits which lead to survival of a species

As societies became more complicated, more than just this primary knowledge was needed. In addition to staying physically afloat, people need to acquire a different kind of knowledge in order to be able to participate in society. This involves acquiring cultural knowledge, in the broadest sense of the word; this is knowledge that we consciously and not evolutionarily acquire and transfer to following generations such as reading, writing, doing mathematics, working with a computer, or searching the internet. We are no longer solely dependent on information that is immediately available in the here and now, but can make accessible information for many people through information carriers such as teachers and then books. This cultural or secondary knowledge is often separate from the three aforementioned domains and is often taught in schools. We call this type of learning "biologically secondary" and such knowledge and skills are acquired consciously, often requiring considerable effort. Also, unlike the biologically primary generic-cognitive skills, biologically secondary skills tend to be domain-specific (Sweller, 2015; Tricot & Sweller, 2014). In other words, they are the skills we learn in school.

BIOLOGICALLY SECONDARY KNOWLEDGE
Cultural knowledge we don't acquire naturally like reading/writing

SYSTEMATIC PROBLEM-SOLVING
Using both primary and secondary biological knowledge

PROBLEM-SOLVING 101

AT A CERTAIN POINT in our development as *Homo sapiens*, the automatic processes involved in primary learning fell short. To survive in rapidly changing social and ecological conditions, people developed a systematic problem-solving capacity. With this they were able to suppress the innate tendencies to naively explore and to learn in a more systematic way and to solve problems. For example, the tendency to run away from a wolf could be suppressed when the wolf was an affectionate specimen. This possibility for systematic problem-solving is one of the most important characteristics of the human brain. Together with the automatic cognitive processes, this forms the core of the human brain. This enables both primary and secondary learning. Our ability for secondary learning is, however, from an evolutionary point of view, much younger and not as well developed as our predisposition to primary learning. According to Geary, this cognitive architecture has consequences for learning in school and how that should take shape.

How we learn in school

Evolution plays a role not only in what we want to learn, but also in how we prefer to learn. In everyday situations we can lean on heuristics, handy rules of thumb, and mnemonics in our brain. In this way we can give meaning to the world around us quickly and automatically. If you meet someone, your brain usually knows immediately whether it is a friend or a stranger and you can tell by the state of the mouth and eyes if s(he) is happy, angry, or sad. These automatic cognitive processes help us to successfully interact with others. We have mastered these processes by observing, discovering, and playing; a kind of unconscious learning.

It would be nice if we could acquire secondary knowledge with the same ease, but that is not the case. We learn to speak and listen on autopilot, but need explicit instruction to learn to spell and write (see also Chapter 26, Learning techniques that really work, and Chapter 22, Why discovery learning is a bad way to discover things). In contrast to the primary knowledge, the acquisition of knowledge at school does not happen automatically. It takes effort, is conscious, and takes place in the working memory.

Conclusions/implications of the work for educational practice

Evolutionary psychology helps us understand why students learn certain things easily and with a lot of motivation (primary learning) and why other assignments cost them more effort (secondary learning). As Geary says,

PHONETIC DECODING
The identification of word sounds

> [I]f our goal is universal education that encompasses a variety of evolutionarily novel academic domains (e.g. mathematics) and abilities (e.g. phonetic decoding as related to reading), then we cannot assume that an inherent curiosity or motivation to learn will be sufficient for most children and adolescents.
>
> (p. 187)

ROMANTICISM
Cultural movement celebrating the natural state of man

> Children's natural interest in novelty and their motivation to learn their culture will get them started but is not predicted to maintain long-term academic learning, contra Rousseau (1979) and other "romantic" approaches to education.
>
> (see Hirsch, 1996, p. 190)

To properly learn in school, you have to take students by the hand and motivate them to learn in a different way because:

- children will have to suppress their natural tendencies, which itself takes effort,
- children will have to learn in a different way than they do in primary learning, and
- direct instruction by someone with expertise is preferable for secondary learning.

To stimulate motivation for evolutionarily secondary learning in schools, Geary states that teachers can best seek out the grey area between primary and secondary learning. An example that he gives is a parent (or it could be a teacher) who "reads" a picture book to a child. The child is interested, because (s)he likes to focus on the parent (or teacher) and wants to learn the language (primary focus). At the same time, the pictures in the book are abstract versions of the things in the world around them and the communication is not direct in colloquial language, but via a written story (both secondary knowledge). If pupils experience such learning situations often enough and find that they learn something from them, they'll also become motivated to learn other, increasingly abstract, schoolwork. Success leads to motivation and not the other way around.

How to use the work in your teaching

Learning at school takes effort; sometimes a lot of effort. That is not only good to realise, but it also contributes to how students function. Make them aware that you are learning some things by themselves and that you only learn other things if you make an effort. Direct instruction by someone who already controls the substance – you – is a good way to guide students in secondary learning.

As explained earlier, you can motivate students by connecting school secondary learning to natural, primary learning. This can be done by linking teaching material to issues that pupils are already focused on. For example, the direct environment or the social processes. Nowadays we already pay a lot of attention here in schools, such as authentic learning or meaningful learning (see also Chapter 28, The culture of learning). Here too, the connection between the material to be learned and the pupils' world of life is sought.

Takeaways

- People have a natural focus on things that are important for our survival, learning about this is effortless.
- Learning at school requires effort and active use of the working memory.
- Everyone learns to talk and listen without school, learning to read and write is only possible with explicit instruction.
- Students need to be helped to balance or "manage" their own interests alongside the interests of the classroom.
- Students are "naturally" able to develop social skills (biologically primary (folk) knowledge) but must learn appropriate domain-specific application of these skills (biologically secondary knowledge).
- You can motivate pupils by connecting with their natural way of learning.

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KAHNEMAN, D. (2011). *THINKING FAST AND SLOW*. FARRAR, STRAUS AND GIROUX.

Why do we assess the same situation before and after lunch? Why do we think that handsome people are more competent than others? Daniel Kahneman shows in this book that we are much more irrational than we think. He explains that we have two systems of thought: a quick, intuitive way and a slow, well-considered way. Both are extremely practical, but we are often wrong because we use the wrong way of thinking – without our being aware of it.

SWELLER, J. (2016). WORKING MEMORY, LONG-TERM MEMORY, AND INSTRUCTIONAL DESIGN. *JOURNAL OF APPLIED RESEARCH IN MEMORY AND COGNITION*, *5*, 360–367.

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EVOLUTIONARY EDUCATIONAL PSYCHOLOGY AS A BASE FOR INSTRUCTIONAL DESIGN.

AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=ZD33ZREJ0D4.

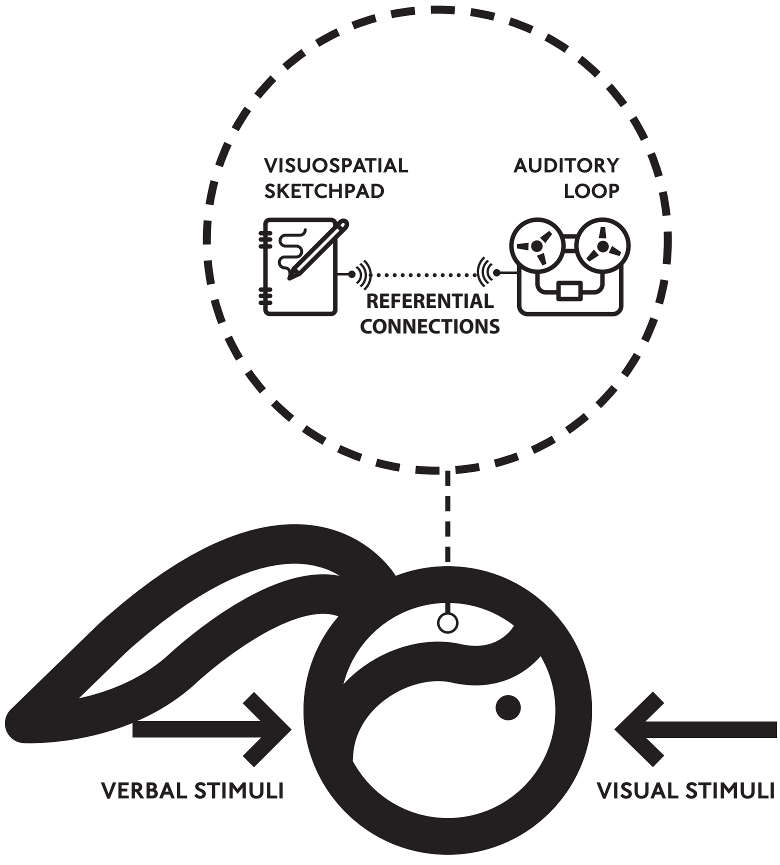
A “video”, actually more a podcast with John Sweller, explaining how evolutionary educational *psychology* relates to teaching and learning.

EVOLUTIONARY EDUCATIONAL PSYCHOLOGY – A POWERPOINT ON THE THEORY.

AVAILABLE FROM HTTPS://ACHEMICALORTHODOXY.FILES.WORDPRESS.COM/2017/06/EVOLUTIONARY-EDUCATIONAL-PSYCHOLOGY.PPTX

10 ONE PICTURE AND ONE THOUSAND WORDS

DUAL CODING



DOI: 10.4324/9781003395713-12

10 ONE PICTURE AND ONE THOUSAND WORDS

PAPER "Dual coding theory and education"[1]

QUOTE *"Human cognition is unique in that it has become specialized for dealing simultaneously with language and with nonverbal objects and events".*[2]

Why you should read this article

You know the saying: *A picture is worth a thousand words*. While there is a basis of truth to it, there are two problems. The first is that this is the case only when the concept represented is concrete and/or unequivocal. An example of the first case is *Lady Justice* (the Roman goddess of justice). To most of us, it is as clear as the nose on our faces but justice is a very abstract concept and without the necessary prior knowledge and cultural history, the statue doesn't explain anything. Or take the term *mammal*. It would take countless pictures to get someone to understand/deduce what this term entails ranging from bumblebee bats, through tree shrews, to cows, people, elephants, and blue whales plus all their distinguishing features. The second problem is that it ignores the fact that the two can be/are cumulative.

Going back to the first case, combining a picture of Lady Justice with an explanation of the purpose of the blindfold (symbol of impartiality without regard to wealth, power, or other status), scales (symbol of measuring the strength of a case's support and opposition), sword (symbol of swift and final authority), and toga (symbol of status) makes the term, and its understanding, both possible and stronger. The same is true for the concept "mammal", which can be determined based upon five

1 CLARK, J. M., & PAIVIO, A. (1991). DUAL CODING THEORY AND EDUCATION. *EDUCATIONAL PSYCHOLOGY REVIEW*, *3*(3), 149–210. HTTPS://DOI.ORG/10.1007/BF01320076.
2 PAIVIO, A. (1986). *MENTAL REPRESENTATIONS*. OXFORD UNIVERSITY PRESS, P. 53.

simple principles, namely: females that bear live young and nurse them, being warm-blooded, having body hair, having a neocortex, and having three ear bones. It is questionable whether someone could deduce these things and successfully classify animals as mammals without a verbal (either textual or oral) explanation.

The second problem, ignoring the fact that pictures and words can be additive in their impact, is the basis of Allan Paivio's *dual coding theory*, the subject of this chapter.

Abstract[3]

ASSOCIATIVE PROCESSES
Creating connections between pieces of information

The theory of dual coding (DCT) presents an explanation for human behaviour and experiences by considering dynamic associative processes that work within a complex network of both modality-specific verbal and nonverbal (imagery) representations. Initially, we outline the fundamental principles of this theory and subsequently illustrate how the fundamental mechanisms of DCT can be applied to various aspects of education. Research shows that factors like concreteness, imagery, and verbal associations significantly influence different educational domains including knowledge representation, comprehension, learning, memory retention, effective teaching, individual differences, motivation to achieve, test anxiety, and the acquisition of motor skills. DCT also holds important implications for the field of educational psychology, particularly within educational research and teacher training. It's not only evident that DCT offers a unified framework to explain a wide range of educational topics, but its mechanistic structure is also adaptable to theories centred around strategies and other higher-level psychological processes. While more research is needed, the tangible models proposed by DCT for understanding the behaviours and experiences of students, teachers, and educational psychologists contribute to a deeper comprehension of educational phenomena and enhance related teaching practices.

The article

In 1969, Allan Paivio published the article "Mental imagery in associative learning and memory" (Paivio, 1969). In that article, he posited that non-verbal imagery and verbal symbolic processes are operationally distinguishable from each other and are differentially available to a learner as associative mediators or memory codes.

NON-VERBAL IMAGERY
Visual representation associated with particular words.

The verbal system processes information in the form of words; Paivio refers to these forms as *logogens*. The non-verbal system processes

3 DUE TO COPYRIGHT ISSUES, WE WERE FORCED TO REPHRASE THIS ABSTRACT AND USED AI TO DO SO.

LOGOGENS
Word

IMAGENS
Image associated with a word

information in the form of the properties that occur in the real world, and this form is called *imagens*. For example, when we think of a tennis ball, we can recall the word (the logogens) for it, but we can also summon up how it feels to hold a tennis ball and how it looks and smells (the imagens). These imagens are directly related to the outside world, while the logogens are an abstraction, a symbol for something in the outside world.

Furthermore, dual coding theory states that connections can arise within each system (i.e. *associations*). For example, you can associate a word like "school" with other words such as reading, writing, arithmetic, teacher, or classroom. And you can associate the image of a school with the smell of the gym or the instructional materials hanging on the classroom wall. Also, connections can also arise between the two systems (i.e. *references*). For example, the word "school" can evoke an image of your own school and the image of a school building can evoke words such as "class" and "learning" (and of course "school"). Paivio illustrated these systems and their relationships (see Figure 10.1).

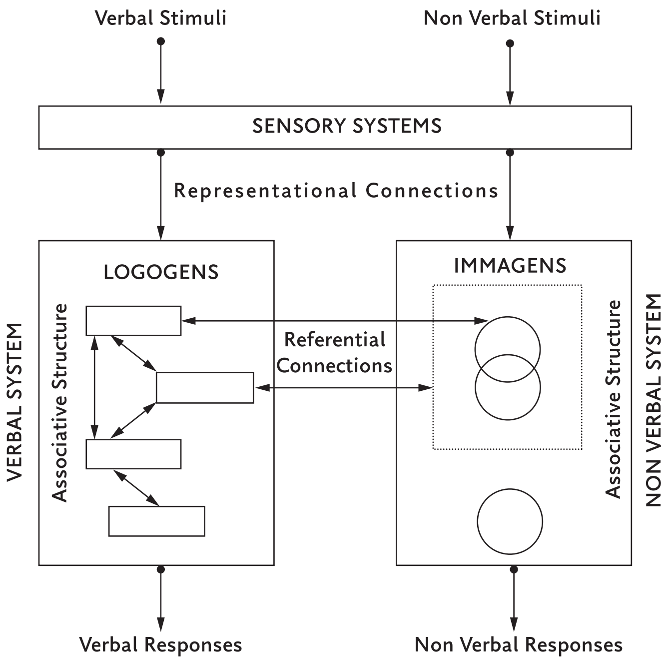


FIGURE 10.1
DUAL CODING MODEL FOR PROCESSING WORDS AND IMAGES

One of the most important predictions from dual coding theory is that the logogens and the imagens have additive effects on memory. In other words, you remember information better if you use both systems at the same time than if you use only one system. This, though today seen as common sense, was a watershed idea at the time. And what's more, research clearly shows that this prediction is correct.

Dual coding theory as basis for cognitive theory of multimedia learning

DCT AS BASIS FOR CLT AND CTMML

DUAL CODING THEORY can be seen as part of the basis for a number of later theories. For example, John Sweller's *cognitive load theory* (1988, see Chapter 7) and Richard Mayer's *cognitive theory of multimedia learning* (Mayer and Moreno, 2003) both build on Paivio's work. Both theories hold that you remember information better if you process it both verbally and non-verbally. In CLT and CTMML at least three principles are directly related to Paivio's work, namely the (1) *modality* or *multimedia principle* which states that words and graphics are more conducive to learning than just text or graphics alone; (2) *redundancy principle* which states that we learn better with animation and narration and that when visual text information is presented simultaneously with verbal information (e.g. when you read your slides to a class) this is redundant and impedes learning; and (3) *spatial contiguity* or *split-attention principle* which holds that we learn better when corresponding words and pictures are presented near rather than far from each other on a page or screen. An example of this can be seen in Figure 10.2.

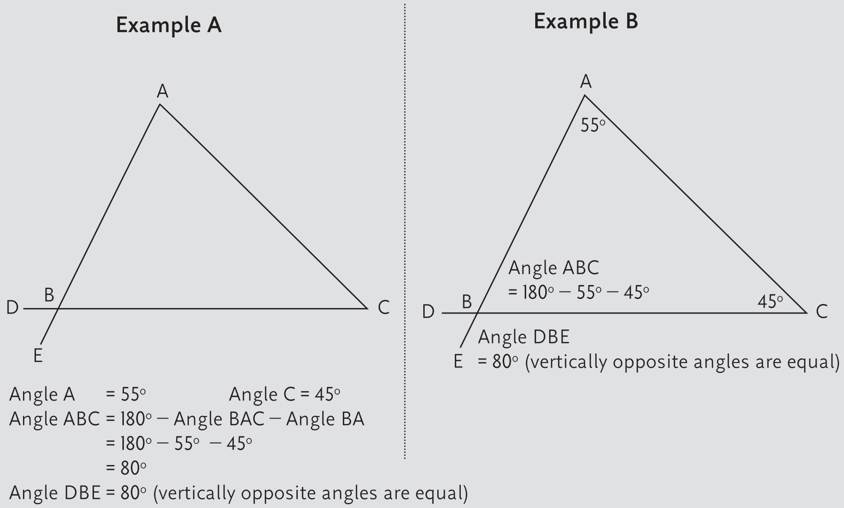


FIGURE 10.2 SPLIT-ATTENTION PRINCIPLE WHERE CORRESPONDING TEXT AND PICTURES ARE EITHER SPLIT (LEFT) OR SPATIALLY CONTIGUOUS (RIGHT)

Dual coding theory also explains why providing concrete things (e.g. examples, information, concepts) to a learner is important. Concrete things are easier to process because they're more "appealing to the imagination"; they evoke images more quickly and more easily than abstract ones. Think about the difference between processing the concepts "tree" (concrete) versus "freedom" (abstract). For "tree", images are more

Concrete examples are easier to process than abstract concepts likely to pop up in your head than for "freedom". To aid in the processing of abstract concepts, you can work with examples. For example, you can explain "freedom" by pointing out the difference between following a lesson in the classroom and playing in the break in the schoolyard.

Also in mathematical education, examples prove their services. Many teaching methods begin by making use of real materials (such as marbles or buttons) and then proceeding to the numbers and numerals (just like words and symbols that refer to the imagens). Slowly you remove the support with the marbles and teach the students to count via symbols. Other examples are pies and slices of pizza to explain percentages or fractions. By making things concrete and using the non-verbal system well, we connect better to how our cognitive architecture works.

Conclusions/implications of the work for educational practice

Looking at teaching and learning through the dual coding lens is useful for educational practice, even if it's only for choosing between the different methods that we have at our disposal: a method that properly combines both systems and uses examples is – from a dual coding theory perspective – preferred. A method that only caters to one system, either verbally or non-verbally, is less useful. And remember, nobody thinks or learns best (i.e. has a visual or a verbal learning style) in an environment that only makes use of one system. These so-called learning styles have been exposed as nonsense in research time after time. There are no "image thinkers" or "language thinkers". Everyone thinks with both systems and everyone benefits from using both. The more often you use the two systems together, the stronger the trace in your memory and the better you will remember and thus will learn.

LEARNING STYLES Bogus theory claiming learners learn best in a preferred style (see Chapter 34, The ten deadly sins of education)

How to use the work in your teaching

The first way to make use of dual coding is to make proper use of images and words when teaching. One of the major mistakes made by teachers (but also by academics presenting at conferences) is that they fill their PowerPoint® slides with words and then proceed to read what's on those slides to their students (audience). The mistake is understandable. You have the idea that by repeating orally what you have written on the slide (i.e. a form of redundancy in the "common" meaning of the word) will strengthen the message. Unfortunately, this has been shown to be a misconception. Also, when explaining a diagram, for example, do it verbally and not through text in or around the diagram. Try using signalling (e.g. animations or highlighting) when you talk a class through a diagram or a formula. Don't explain it in writing on the slide!

When using dual coding theory, it's extremely important to properly mix what you present in words (either orally or textually) with images that can illustrate, explain, and concretise the textual concept. A good example of this is when you try to explain a fairly complex and abstract idea like *affordances*[4], which are the reciprocal relationships between artefacts and agents, and how designers neglect this in their design is to show someone trying to pull open a door with its handle while the door needs to be pushed open, which is completely obvious if there is a push-plate instead of a handle. In Figure 10.3, everyone knows instinctively to push and not pull on the left-hand side and vice versa on the right.

AFFORDANCES
The options an object offers the user

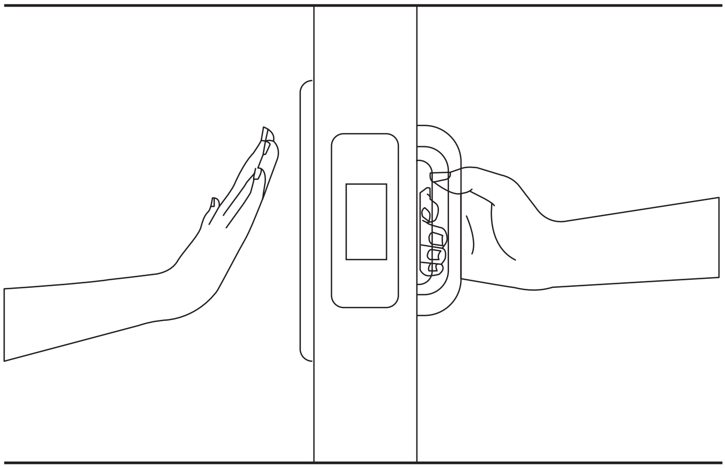


FIGURE 10.3 AN IMAGE THAT MAKES THE CONCEPT OF AFFORDANCES IMMEDIATELY CLEAR (HTTPS://MRJOE.UK/FLAT-DESIGN-AFFORDANCE-AND-USABILITY/)

Or if you're trying to make clear the concept that technology sometimes fails miserably (technology bites back), tell the class about how an escalator was expected to move people more quickly because the stairs move and you climb them too and then let them see an image of people crowding around the bottom of the escalator because everyone stands still once they set foot on the escalator (see Figure 10.4).

4 AFFORDANCES ARE THE PERCEIVED PROPERTIES OF A THING IN REFERENCE TO A USER THAT INFLUENCES HOW IT IS USED. SOME DOOR HANDLES LOOK LIKE THEY SHOULD BE PULLED. THEIR SHAPE LEADS OUR BRAINS TO BELIEVE THAT IS THE BEST WAY TO USE THEM. OTHER HANDLES LOOK LIKE THEY SHOULD BE PUSHED, A FEATURE OFTEN INDICATED BY A BAR SPANNING THE WIDTH OF THE DOOR OR EVEN A FLAT PLATE ON THE SIDE. ORIGINALLY PROPOSED BY JAMES GIBSON IN 1977 (AND REFINED IN 1979), THE TERM AFFORDANCE REFERS TO THE RELATIONSHIP BETWEEN AN OBJECT'S PHYSICAL PROPERTIES (ARTEFACTS) AND THE CHARACTERISTICS OF AN AGENT (USER) THAT ENABLES PARTICULAR INTERACTIONS BETWEEN AGENT AND OBJECT. GIBSON DEFINED THAT "THE AFFORDANCE OF ANYTHING IS A SPECIFIC COMBINATION OF THE PROPERTIES OF ITS SUBSTANCE AND ITS SURFACES WITH REFERENCE TO AN ANIMAL" (GIBSON, 1977, P. 67). A POND, DUE TO THE SURFACE TENSION OF THE WATER, AFFORDS A SURFACE TO WALK ON FOR CERTAIN SPECIES OF FLIES WHILE ALSO AFFORDING A LIVING ENVIRONMENT FOR CERTAIN TYPES OF FISH. KNOBS ARE FOR TURNING AND SLOTS ARE FOR INSERTING THINGS. THESE PROPERTIES/ARTEFACTS INTERACT WITH POTENTIAL USERS AND PROVIDE STRONG CLUES AS TO THEIR OPERATION (THINK OF YOUR CHILD, HIS/HER PEANUT BUTTER SANDWICH, AND THE SLOT IN YOUR VIDEO RECORDER!).

FIGURE 10.4 AN IMAGE THAT MAKES THE CONCEPT OF TECHNOLOGY BITING BACK IMMEDIATELY CLEAR. (PHOTO BY PAVEL LOSEVSKY/ ADOBE STOCK)

EXAMPLES
Encourage learners to create mental images of abstract concepts

You can also use this by appealing to your students' imagination (picture something in their mind's eye). There are many ways to interweave this in educational practice. Examples are asking students to create a mental image of something that has just been discussed, especially if it is an abstract concept. These evoke images with the students more easily and help them to better understand abstract concepts and to remember them. For example, if teaching a play by Shakespeare with a large number of characters and related themes, you could ask them to create a mental image of those characters by focusing on their particular personality traits and how they link up with the thematic concerns of the play. Shakespeare does this quite well himself in fact and the keen reader will be able to conjure up the image of a "green-eyed monster"[5] when considering the character of Iago and the significance of jealousy in the play. Another way is to have them make a diagram of a concept with its sub-concepts in a concept-map. Finally, you can ask students to either illustrate written content or to write descriptions of visual content. In this way you help them on the one hand to create extra memory traces which strengthen the memory. On the other hand, you are asking them to retrieve information that they have already stored (i.e. retrieval practice) which also strengthens the memory.

5 SHAKESPEARE, W. (1603). *OTHELLO* (ACT III, SCENE 3, LINE 169). AVAILABLE FROM HTTP://SHAKESPEARE.MIT.EDU/OTHELLO/FULL.HTML.

Takeaways

- Everyone has two cooperating memory systems, a non-verbal and a verbal system.
- Both systems are active during learning. Image thinkers or language thinkers do not exist.
- The use of both systems is more effective in remembering things than using one system.
- Use examples to explain abstract concepts.
- Extensive experience with objects and environments is a rich basis for later verbal development.
- Offer images and text at the same time so that the learner doesn't have to remember the one part while processing the other.

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AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=6XCZ4XNKPCC.

DUAL CODING THEORY AND MULTIMEDIA LEARNING FROM CIAN MAC MAHON.

AVAILABLE FROM HTTP://BLOGS.ONLINEEDUCATION.TOURO.EDU/THE-DUAL-CODING-THEORY-MULTIMEDIA-LEARNING/.

LEARN MORE ABOUT DUAL CODING THEORY FROM SCIENCE DIRECT, WHICH CONTAINS A WEALTH OF INFORMATION RELATING TO THE THEORY ALONG WITH LINKS TO THE ORIGINAL SOURCES.

AVAILABLE FROM WWW.SCIENCEDIRECT.COM/TOPICS/NEUROSCIENCE/DUAL-CODING-THEORY.

DOUBLE-BARRELLED LEARNING FOR YOUNG AND OLD BY PAUL ALONG WITH MIRJAM NEELEN.

AVAILABLE FROM HTTPS://3STARLEARNINGEXPERIENCES.WORDPRESS.COM/2017/05/30/DOUBLE-BARRELLED-LEARNING-FOR-YOUNG-OLD/.

DUAL CODING – WHAT, WHY, AND HOW BY VICKI BARNETT (RESEARCH LEAD AT NOTRE DAME HIGH SCHOOL).

AVAILABLE FROM HTTPS://RESEARCHSCHOOL.ORG.UK/NORFOLK/NEWS/DUAL-CODING-WHAT-WHY-AND-HOW.

IF YOU WANT TO READ MORE ABOUT AFFORDANCES, ESPECIALLY AFFORDANCES WITH RESPECT TO EDUCATION, READ PAUL'S INAUGURAL ADDRESS AT THE OPEN UNIVERSITY.

AVAILABLE FROM HTTPS://RESEARCH.OU.NL/WS/PORTALFILES/PORTAL/24123339/THREE+WORLDS+OF+CSCL+CAN+WE+SUPPORT+CSCL.PDF.

PART III

PREREQUISITES FOR LEARNING

"You can lead a horse to the water, but the only water that gets into his stomach is what he drinks". This famous quote which comes from Ernst Rothkopf's article on mathemagenic activities[1] should be a wake-up call for all teachers: How do you help make sure that students start drinking and make use of what we offer them in the lessons?

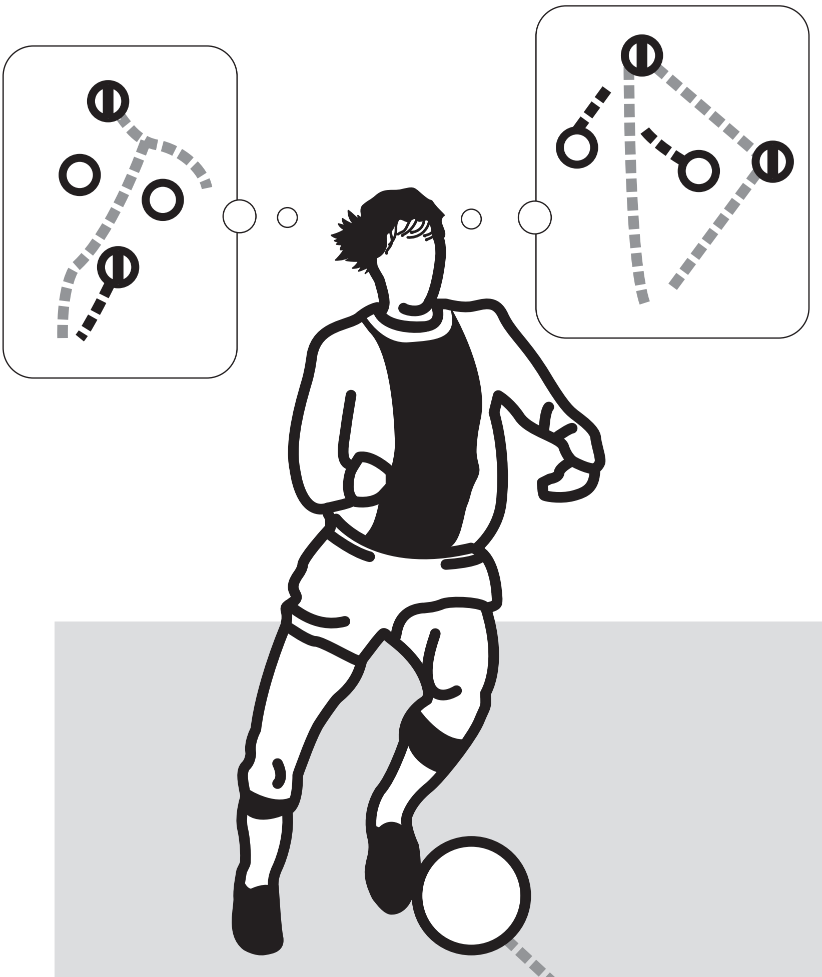
For students to learn effectively, efficiently, and preferably also enjoyably, our instruction must try to meet certain conditions. At the risk of sounding trite, it often helps to have an enclosed space (though sometimes a museum or a walk in nature is also good), paper and pen/pencil (or computers or tablets when applicable), a teacher/instructor, learning materials, and so on. But there are also conditions in which students themselves play a role. These conditions are primarily psychological. For example, students must know and understand what they're doing, have the feeling that they can handle what's coming, be motivated to begin, want to learn or achieve, and feel that they themselves are the masters of their fates and captains of their souls. If students start working on something thinking that they won't succeed, don't understand what they're doing, aren't motivated to begin with, and think that their success is not up to them but that their fate lies in the hands of others, then chances are that they won't learn very well. These and other conditions for learning that lie within the grasp of the student are discussed in this part.

1 ROTHKOPF, E. Z. (1970). THE CONCEPT OF MATHEMAGENIC ACTIVITIES. *REVIEW OF EDUCATIONAL RESEARCH*, *40*, P. 325.

DOI: 10.4324/9781003395713-13

11 WHAT YOU KNOW DETERMINES WHAT YOU LEARN

ADVANCE ORGANISERS



DOI: 10.4324/9781003395713-14

11 WHAT YOU KNOW DETERMINES WHAT YOU LEARN

PAPER "The use of advance organizers in the learning and retention of meaningful verbal material"[1]

QUOTE *"The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly".*[2]

Why you should read this article

Imagine the following. You're walking around a school or a company and you see a setup with lots of glassware, plastic and glass tubes, bubbling liquids, and so forth. If you've never taken a chemistry course, then you probably have no idea what's going on. If you took chemistry in high school, chances are that you remember that this has something to do with distillation. Maybe you even remember that when you distil something (like gin, whisky, or gasoline) you separate two different things that are present together in a liquid. If, however, you studied chemistry at college, then you see that the distillation setup is being put to a specific use, as you see on the water bath instead of a Bunsen burner that the temperature has to be carefully limited to a temperature under 100° Celsius (212 Fahrenheit) and the temperature gauge gives a reading of 78.33° Celsius (173 Fahrenheit), which tells you that ethanol is being distilled. In other words, what you know determines what you see and not the other way around (Kirschner, 2009).

Johan Cruijff (for Brits and Americans Johan Cruyff), who is for one of the authors the greatest football player (soccer for Americans) that ever graced the pitch, was famous for his maxims such as "If I wanted you to understand it I would have explained it better", "If you can't win, make sure you don't lose", or "Playing football is very simple, but playing

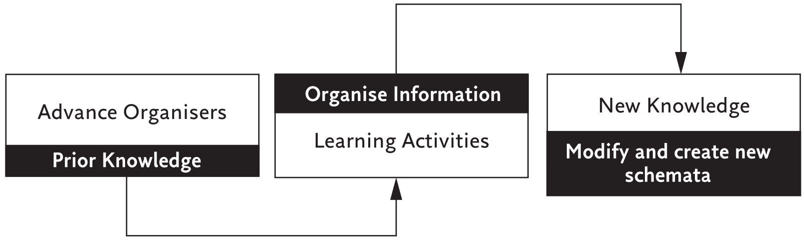
1 AUSUBEL, D. P. (1960). THE USE OF ADVANCE ORGANIZERS IN THE LEARNING AND RETENTION OF MEANINGFUL VERBAL MATERIAL. *JOURNAL OF EDUCATIONAL PSYCHOLOGY*, *51*, 267–272.

2 AUSUBEL, D. P. (1968). *EDUCATIONAL PSYCHOLOGY. A COGNITIVE VIEW.* HOLT, RINEHART AND WINSTON, INC., P. VI.

simple football is the hardest thing there is", but also said "You will only see it when you get it". And that's basically what David P. Ausubel was all about. In his mind, and as reflected in his research and writings, prior knowledge is the most important influence on what is learnt. To ensure that learners have the necessary basis for what they're supposed to learn, even when studying something new, he introduced the concept of the *advance organiser*; a text or presentation at a higher level of *generality*, *inclusiveness*, and *abstraction*, which is presented before the learning event and which forms a conceptual framework for learning the new information (see Figure 11.1).

ADVANCE ORGANISER General, inclusive, and abstract framework presented prior to learning

FIGURE 11.1 SIMPLE REPRESENTATION OF ADVANCE ORGANISERS WITH RESPECT TO LEARNING



Abstract of the article

The purpose of this study is to test the hypothesis that the learning and retention of unfamiliar but meaningful verbal material can be facilitated by the advance introduction of relevant subsuming concepts (organisers). This hypothesis is based on the assumption that cognitive structure is hierarchically organised in terms of highly inclusive concepts under which are subsumed less inclusive subconcepts and informational data. If this organisational principle of progressive differentiation of an internalised sphere of knowledge does in fact prevail, it is reasonable to suppose that new meaningful material becomes incorporated into cognitive structure in so far as it is subsumable under relevant existing concepts. It follows, therefore, that the availability in cognitive structure of appropriate and stable subsumers should enhance the incorporability of such material. If it is also true that "meaningful forgetting" reflects a process of memorial reduction, in which the identity of new learning material is assimilated by the more inclusive meaning of its subsumers, the same availability should also enhance retention by decelerating the rate of obliterative subsumption. In the present study, appropriate and relevant subsuming concepts (organisers) are deliberately introduced prior to the learning of unfamiliar academic material, in order to ascertain whether learning and retention are enhanced thereby in accordance with the theoretical premises advanced above.

The article

The experiment that Ausubel carried out was designed to determine if and how well learners would learn from a 2500-word article about something the learners knew little or nothing about. The article dealt with the metallurgical properties of carbon steel and the participants were students of educational psychology. Before reading the article, the participants were presented with an introductory passage (500 words) which was either an advance organiser (i.e. the experimental intervention condition) or historically relevant background information (i.e. the control condition). The former contained background information at a higher level of abstraction, generality, and inclusiveness; information that could be used as an *ideational framework* for organising the more detailed ideas, facts, and relationships in the to-be-learnt text. The latter contained background information on the evolution of iron and steel processing methods; interesting but not relevant for learning what was in the article. The results show clearly that the group that received an advance organiser scored significantly better on a 36-item examination – taken three days after reading – covering facts, principles, and application of what they had read. Ausubel concluded that the advance organiser (1) facilitated the uptake and retention of meaningful verbal material by drawing upon and mobilising any relevant subsuming (higher-order) concepts already in memory so as to incorporate the new material and (2) provided optimal anchorage for the new material promoting both initial incorporation and later resistance to *obliterative subsumption* (where meaningfully learnt information can't be recalled in the precise form in which it was learnt due to its subsumption/incorporation into a larger concept). He concluded:

IDEATIONAL FRAMEWORK
Conceptual scaffold that incorporates more detailed knowledge

OBLITERATIVE SUBSUMPTION
When a more specific idea becomes indistinguishable from its subsumer until it's forgotten

> Even though this principle seems rather self-evident it is rarely followed in actual teaching procedures or in the organization of most textbooks … in most instances, students are required to learn the details of new and unfamiliar disciplines before they have acquired an adequate body of relevant subsumers at an appropriate level of inclusiveness.
>
> (p. 270)

BEHAVIOURISM
Theory that all behaviours are acquired through conditioning; as a response to a stimulus

What does all this mean? To understand this we must look at Ausubel's ground-breaking book *The psychology of meaningful verbal learning* (1963). The reason why we consider the book ground-breaking is that it broke with the prevalent behaviourist thinking about learning that assumed that learners are essentially passive, and that learning is a response to environmental stimuli. As such, behaviourist learning theory didn't take internal mental states or consciousness into account. In the book, Ausubel speaks of "reception learning", but this term, today, might be a bit misleading. A better term, and one that characterises his theory, is *subsumptive* learning. In plain English, subsumption theory holds that learning is a process in which new, to-be-learnt information is related by learners to what is already present in their existing cognitive structures (i.e. the schemata in their long-term memory). This is similar to another pioneer in cognition, Jean Piaget (1952; see also Wadsworth, 1996), who spoke of learning as a process of assimilation and accommodation. Ausubel's major hypothesis was that learning and retention are facilitated when the learner has acquired a meaningful cognitive framework that allows new information to be organised, assimilated, and subsumed in what is already known.

SUBSUMPTION THEORY
Another name for Ausubel's theory of advance organisers

Types of subsumption:

- Derivative: Linking new things to old
- Correlative: Adding details
- Superordinate: Introducing a higher-level concept
- Combinatorial: Linking higher-level concepts

If we look at Figure 11.2 we can see that there are actually four types of subsumption, namely derivative, correlative, superordinate, and combinatorial subsumption. Each of these processes plays a role in the working of an advance organiser. *Derivative subsumption* is when you add new things to existing cognitive structures, linking them to concepts already known. For example, if you already have the concept of "mammal" you can add the characteristics of "bat", "whale", and "cow" to it without making any change in the concept "mammal". *Correlative subsumption* is when you add new details to what you already know, usually a higher-order concept. This occurs, for example, when you add to the concept of "mammal" that they can fly (bat) or swim (whale). *Superordinate subsumption* introduces a new higher-level concept into which already existing categories can be integrated. This occurs, for example, when the concept of "vertebrate" is added to include "mammals", "reptiles", and "birds". Finally, *combinatorial subsumption* is when ideas are linked (combined) between higher-level concepts such as when one knows form physics; for example, the fact that stationary air-spaces (particularly within hair or feathers) help to keep certain animals warm.

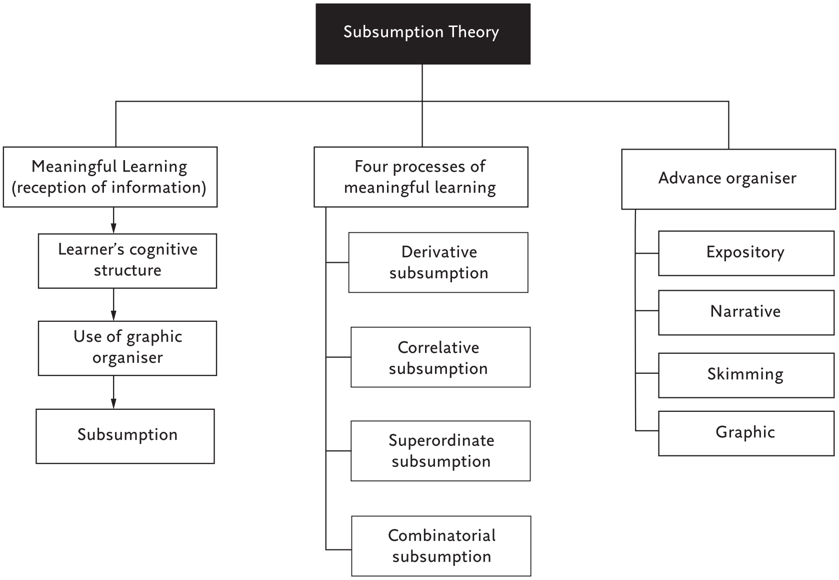


FIGURE 11.2
SUBSUMPTION THEORY

> Even though this principle [subsumption] seems rather self-evident, it is rarely followed in actual teaching procedures or in the organisation of most textbooks... in most instances, students are required to learn the details of new and unfamiliar disciplines before they have acquired an adequate body of relevant subsumers at an appropriate level of inclusiveness.

TYPES OF ORGANISERS
- Expository: Describes
- Narrative: Tells a story
- Skimming: Presents an overview
- Graphic: Visual representation

Also, there are four types of advance organisers that can be used prior to instruction, namely expository, narrative, skimming, and graphic organisers. An *expository organiser* provides a description of new knowledge that learners will need to understand what follows; it is often used when the new learning material is relatively unknown to the learner and it usually relates the new information to what is already known. A *narrative organiser* presents new information in a story format to the learners. It uses stories to activate background knowledge so that learners can make connections to what they know, often creating a personal connection to inspire learning. For example, at the beginning of a lesson you might tell a story that relates to important concepts in the lesson. A *skimming organiser* is an organiser that gives a helicopter overview of the new learning material. It involves focusing on and noting what stands out in the new material such as headings, subheadings, and highlighted information. This acquaints them with the material before they read it more carefully. *Graphic organisers* include different types of visuals such as concept maps, pictographs, Venn diagrams, and so forth. These organisers capitalise on both linguistic and non-linguistic information storage, as discussed in Chapter 10 (One picture and one thousand words) on the dual coding theory.

TROUBLE IN ADVANCE ORGANISER PARADISE?

Barnes and Clawson published an article in the *Review of Educational Research* (RER; 1975) with the title "Do advance organizers facilitate learning?" They concluded that "[T]he efficacy of advance organizers has not been established" (p. 651) for a number of reasons. Their major criticism was that "Ausubel has not operationally defined the advance organizer" and that he "made logical but not operational distinctions between organizers and overviews" (p. 653). This article was followed up by Lawton and Wanska in the RER (1977) in which they criticised Barnes and Clawson. In that article, they support the basic premises of Ausubel, but concluded that more study is needed on how to construct (again the operationalisation question) and use organisers. These two reviews were met with a scathing rebuke by Ausubel himself (1978), again in the RER, of all criticism, and primarily with respect to his lack of operationalisation.

> If these critics had read my books on meaningful verbal learning and on educational psychology (1963, 1968) [as well] as my research articles, they would have found precise operational criteria for an advance organizer and a discussion of how to construct one. (p. 251)

Finally, Richard Mayer wrote in the RER (1979) that there is clear evidence for "an assimilation encoding theory" and that there is "consistent evidence that advance organizers can influence the outcome of learning if used in appropriate situations and measured properly" (p. 371).

Whatever the school of thought is with respect to advance organisers, no one refutes that the availability and presentation of prior knowledge, especially incorporating references to super- and subordinate concepts and their critical relationships, facilitate meaningful learning.

Conclusions/implications of the work for educational practice

New knowledge must be incorporated into existing structures

Research on prior knowledge and its effects on learning give us directions for how best to organise education. In order to create rich and coherent knowledge schemes, students must actively insert new information into existing knowledge structures. Making students' prior knowledge explicit is a first step in learning and can help you to recognise weaker learners, determine the level of your lesson, or group students into different level groups. Barak Rosenshine (2010, 2012) suggests, for example, that the teacher should begin each lesson with a short recapitulation – 3 to 5 minutes – of what was previously learnt and relevant to what is to come. This can be in expository form, but can also take the form of a quiz or a discussion.

Rosenshine's principles of instruction

In order to get a grip on this prior knowledge, or lack of it, you can have students take a small test or quiz before introducing new material. This can be a multiple-choice test, matching, an open question test, or even a test where the students have to indicate which things they recognise and what they entail. Based upon this you can present an advance organiser and/or tailor the instruction to student knowledge. Give students feedback on the results of the prior knowledge test, so that they get insight into what they know and how the new material fits. Taking such a prior knowledge test also helps students see that learning new material requires effort, since they must link the new knowledge to their own personal knowledge structures.

How to use the work in your teaching

RETRIEVAL PRACTICE
A learning strategy which brings already learnt things to mind to boost learning

Retrieval of prior knowledge or framing new knowledge is something that most teachers are familiar with. This is logical in some subject areas because procedures, for example, become progressively more complex. For example, calculating with dozens is difficult if learners have not yet mastered arithmetic with units as well as the concept of a dozen as a unit of 12. You will therefore need to know whether students have already mastered previous steps and/or concepts and help them where this isn't the case.

But also in more thematic subjects such as language, history, or geography, it's important to determine the learners' prior knowledge and/or frame new knowledge. In these subject areas, learners also acquire a lot of their knowledge outside of the school. Complicating this is that this also often differs with the socioeconomic status (SES) of the children. Children from families with a higher SES often have more "world knowledge" and a better vocabulary than children from families with a lower SES (Hart & Risley, 1995). If a child already knows a lot about the subject you want to deal with, you can enrich the content through expository organisers. If, however, there's little prior knowledge, it's a good idea to first pay attention to presenting necessary anchor concepts and their mutual relationships (e.g. through correlative subsumption) and, in that way, offer ideational scaffolding where they can frame the new knowledge.

A well-known example of this can be found in research by Ausubel with Donald Fitzgerald (1961). Students who were supposed to learn about Buddhism were first given a short text on Christianity comparing these two religions. This comparative organiser in Ausubel and Fitzgerald's own words:

EXAMPLE
Comparative organiser

> pointed out explicitly the principal similarities and differences between Buddhist and Christian doctrines. This comparison was presented at a much higher level of abstraction, generality, and inclusiveness than the Buddhism passage itself, and was deliberately designed to increase discriminability between the two sets of concepts.
>
> (p. 268)

The frame of Christianity led to better learning and retention of the text than a historical text prior to reading, and also than an expository organiser that "explained principal Buddhist doctrines at a high level of abstraction, generality, and inclusiveness, without making any reference whatsoever to Christianity" (p. 268).

Takeaways

- Learning involves building on what you already know, so pay attention to the prior knowledge of your pupils.
- The role of the teacher is to bridge the gap between what's already known and what's about to be learnt.
- Activate prior knowledge regularly, for example, by starting the lesson with a short quiz or test.
- If students know very little about a subject, "create" prior knowledge by providing them with a framework (ideational scaffolding) in which they can place new knowledge.
- Present learners first with the most general concepts (more general, abstract, inclusive) and then become more specific (see also Chapter 21, Zooming out to zoom in, on Reigeluth's elaboration theory).
- Instructional materials should include both new and previously acquired information whereby comparisons between old and new concepts are essential.

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AVAILABLE FROM HTTPS://ONLINELIBRARY.WILEY.COM/DOI/PDF/10.1002/TEA.3660200804.

THIS VIDEO (MCREL – CLASSROOM INSTRUCTION THAT WORKS) HIGHLIGHTS THREE DIFFERENT TYPES OF ADVANCE ORGANISERS.

AVAILABLE FROM HTTPS://YOUTU.BE/ARFKDV8AUIK.

DIFFERENT TYPES OF GRAPHIC ORGANISERS AND THEIR PURPOSES.

AVAILABLE FROM HTTPS://YOUTU.BE/_LTLQVKV3YI.

THIS PRESENTATION BY SUSIE GRONSETH FOCUSES ON MEANINGFUL RECEPTION LEARNING AND SCHEMA THEORIES TO UNDERSTAND HOW LEARNERS ACQUIRE, REMEMBER, AND APPLY LEARNT INFORMATION.

A TRANSCRIPT IS AVAILABLE FROM HTTPS://GOO.GL/VQBIMW.

COLLEGE STAR (SUPPORTING TRANSITION ACCESS AND RETENTION) PROVIDES RESOURCES TO HELP ALL DIFFERENT TYPES OF STUDENTS LEARN BETTER.

AVAILABLE FROM WWW.COLLEGESTAR.ORG/MODULES/ADVANCE-ORGANIZERS.

COMMON ADVANCE ORGANISERS AND WHY THEY WORK.

AVAILABLE FROM WWW.UNDERSTOOD.ORG/EN/SCHOOL-LEARNING/PARTNERING-WITH-CHILDS-SCHOOL/INSTRUCTIONAL-STRATEGIES/COMMON-ADVANCE-ORGANIZERS-AND-WHY-THEY-WORK.

12 WHY INDEPENDENT LEARNING IS NOT A GOOD WAY TO BECOME AN INDEPENDENT LEARNER

SELF REGULATION

DOI: 10.4324/9781003395713-15

12 WHY INDEPENDENT LEARNING IS NOT A GOOD WAY TO BECOME AN INDEPENDENT LEARNER

PAPER "A social cognitive view of self-regulated academic learning"[1]

QUOTE *"Student's self-efficacy perceptions depend in part on each of four other types of personal influence, students' knowledge, metacognitive processes, goals, and affect".*[2]

Why you should read this article

When we think of a "self-regulated person", we imagine a highly confident individual planning their day meticulously and executing every task like a machine. This person's motivational energy is often imagined as an *internal* force: they are "driven" in some way by some interior engine that propels them towards success. Motivational posters and inspirational quotes put forward the idea that if you "look inside and just believe in yourself" then anything is possible, but what about the importance of *external* factors on motivation, achievement, and the ability to self-regulate? We all want students to be self-regulated people who are able to regulate their own learning. But what can teachers actually do about it?

SELF-REGULATION Ability to manage one's emotions and behaviour

In this article, Zimmerman's social cognitive approach to self-regulation is significant because he moves the debate away from such theoretical approaches that view self-regulation as an *internal* state that is personally discovered, to one that is strongly influenced by *external* factors such as environmental conditions, teacher instruction and modelling, and peer/parental influence.

What does that mean specifically? Well, Zimmerman offers a model of self-regulation that has a symbiotic relationship between three key factors: personal, behavioural, and environmental. These three elements

1 ZIMMERMAN, B. J. (1989). A SOCIAL COGNITIVE VIEW OF SELF-REGULATED ACADEMIC LEARNING. *JOURNAL OF EDUCATIONAL PSYCHOLOGY*, *81*, 329–339.
2 IBID., P. 332.

form what he calls a "triadic reciprocality" in which they work together to affect students' self-regulatory states. He builds upon the work of Alfred Bandura (1986, p. 454) who noted that how students perform is a product of exterior forces just as much as interior ones: "Behavior is, therefore, a product of both self-generated and external sources of influence".

SELF-REGULATED LEARNING TRIADIC RECIPROCALITY

> SELF-REGULATED LEARNING strategies are actions and processes directed at acquiring information or skill that involve agency, purpose, and instrumentality perceptions by learners. They include such methods as organizing and transforming information, self-consequating, seeking information, and rehearsing or using memory aids.
>
> (p. 329)

Why is this important? Well one of the most common aims in education is to create so-called independent learners; however, allowing students to work independently is paradoxically probably a bad way to achieve this end. The widely held constructivist view that students need minimal guidance and that instructors should be seen and not heard (first vocally aired by Jerome Bruner in 1961) is probably not the most effective way of affecting student self-regulation (at least not in the long run). Rather, providing clear instruction and explicit modelling of solutions and strategies and changing environmental conditions can have a dramatic impact on student achievement (Kirschner, Sweller, & Clark, 2006; Rosenshine, 2012).

A key facet of self-regulation is what Bandura (1982) called "self-efficacy", which is related to two key elements: the knowledge and use of specific learning strategies and self-monitoring of performance.

SELF-EFFICACY

Self-efficacy is an individual's belief in his or her innate ability to achieve goals. In Bandura's words it's a personal judgement of "how well one can execute courses of action required to deal with prospective situations" (Bandura, 1995, p. 2). In other words, it's whether you think that you can do what is asked of you.

It is important to note that self-efficacy is not a general skill but rather is something very much domain specific. For example, a student may have high self-efficacy in history but low self-efficacy in mathematics. It may be the case that their subject knowledge of history means they can break down bigger tasks into smaller, more achievable ones and will have good internal models of what success looks like in that subject, whereas their lack of mathematical knowledge means they don't even know where to start.

A big question facing all educators is how exactly do you create more self-regulated learners? Zimmerman's paper is significant because he emphasises the importance of wider socialising agents on this process such as teachers, parents, and peers. He also offers a useful table of 15 self-regulated learning strategies that were highly correlated with student academic success such as goal-setting, environmental structuring, and seeking social assistance.

Original abstract of the article

Researchers interested in academic self-regulated learning have begun to study processes that students use to initiate and direct their efforts to acquire knowledge and skill. The social cognitive conception of self-regulated learning presented here involves a triadic analysis of component processes and an assumption of reciprocal causality among personal, behavioural, and environmental triadic influences. This theoretical account also posits a central role for the construct of academic self-efficacy beliefs and three self-regulatory processes: self-observation, self-judgement, and self-reactions. Research support for this social cognitive formulation is discussed, as is its usefulness for improving student learning and academic achievement.

The article

Zimmerman defines self-regulated learning as "the degree to which students are metacognitively, motivationally, and behaviorally active participants in their own learning processes" (p. 337). A vital element here is that students have understanding of specific knowledge, skills, and strategies to achieve specific outcomes whereby self-efficacy – the perceptions one has about one's ability to organise and execute skills to achieve those outcomes – plays an important role.

METACOGNITION
Awareness and understanding of one's own thought processes

"Metacognition" means cognition about cognition, or to put it more simply: thinking about thinking. If a student realises that they are not learning in an optimum way and change their practice by adopting more productive strategies, then they are thinking metacognitively.

Now there is a lot of "self" going on here and a lot of this might sound like everything is going on solely within the head of the student, but Zimmerman offers the following model (see Figure 12.1) based on the work of Bandura (1986) as a way of showing that many exterior forces also affect the learner.

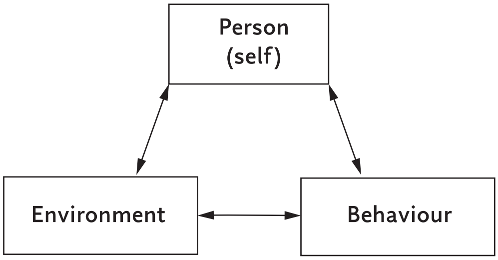

FIGURE 12.1 A TRIADIC ANALYSIS OF SELF-REGULATED FUNCTIONING

Students with high self-efficacy have two specific characteristics. First, they have more effective learning strategies (Kurtz & Borkowski, 1984), and second, they have better self-monitoring of their learning outcomes (Diener & Dweck, 1978; Kuhl, 1985; Pearl, Bryan, & Herzog, 1983) than students displaying low self-efficacy. In other words, student self-efficacy is directly related to what students *know* they can do in a particular area to modify their behaviour. However, when an instructor models how to solve problems explicitly, this can also greatly affect student self-efficacy. Schunk (1981) found that an adult modelling mathematics problem-solving to fourth graders resulted in significantly higher self-efficacy (and better division accuracy) than comparable fourth graders in a control group where there was no modelling.

Skills are domain specific

An important point to make is that self-regulated learning is not an absolute state but is highly variable in time and dependent on context (Thoresen & Mahoney, 1974) and so the idea that you can teach generic independent learning skills that will transfer to a wide range of situations is highly problematic. A key element in whether a student is self-regulated or not will be the level of subject knowledge they will have in that particular domain. For example, a student with an extensive knowledge of "Macbeth" and the broader social and historical context around the play will easily be able to identify a set of revision tasks that will consolidate their knowledge and understanding. Furthermore, they will be able to quickly identify what they *don't* know and try to relate any new knowledge to what they already know. As Zimmerman writes, "students' general knowledge of mathematics will contribute to their ability to divide the week's assignment into manageable daily tasks" (p. 332).

Furthermore, self-regulation has a lot to do with effective planning and a lot of the metacognitive decision-making that students make will depend on their goals. One way of achieving this is to set intermediate

Goal-setting should be specific in time, action, and difficulty

goals with very specific actions in time and difficulty level (Bandura, 1982). Without any specificity, long-term goals rarely work as the learner has nothing to "grip onto" as it were. This is why the often given advice of "do your best" has little effect on motivation or learning (Locke, Shaw, Saari, & Latham, 1981) which again underlines the fact that many attempts to motivate students are of little use.

So what are the environmental factors that can influence student self-regulation? Zimmerman gives special mention to four factors: modelling, verbal persuasion, direct assistance from teachers, and finally the structure of the learning context. Modelling can be particularly effective with low achieving learners as Bandura (1986) points out: "effective coping strategies can boost the self-efficacy of individuals who have undergone many experiences confirming their inefficacy" (p. 400). If learners identify with the coping strategy, that is to say, if they feel it *looks like them trying to solve the problem*, then they are far more likely to benefit. For example, showing students an errorless mastery model is far less effective than showing them a coping model requiring high concentration, persistence, and increased effort (Schunk, Hanson, & Cox, 1987). Additionally, students experiencing verbal persuasion during a task have been shown to have increased self-efficacy (Zimmerman & Rocha, 1984).

MODELLING
Demonstrating and explaining specific strategies

Conclusions/implications of the work for educational practice

So instead of thinking about self-regulation as a purely internal process, we can think about the behavioural and social experiences that affect student self-regulation. Why is this important and what exactly are the strategies students can use? Well first, it means that teachers can actually help students to better self-regulate through modelling, verbal persuasion, and explicitly teaching specific strategies, and second, this paper has a very useful table (see Table 12.1) of 15 self-reported strategies that high school students use. Interestingly, these were very similar to strategies that had been studied in laboratory research (Zimmerman & Martinez-Pons, 1988); 13 out of 14 of these strategies discriminated between student achievement on higher and lower tracks and were also highly correlated with teacher predictions of student self-regulation during class and subsequent test scores.

How to use the work in your teaching

One way to approach student self-regulation is to "reverse-engineer" what successful self-regulation looks like. Explicitly teaching these strategies in Table 12.1 to students and asking them to think about them on three levels – their own beliefs, their actual behaviour, and their

TABLE 12.1 SELF-REGULATED LEARNING STRATEGIES (ADAPTED FROM EFFENEY, CARROLL, & BAHR, 2013

Categories/ Strategies	**Definitions: Statements indicating …**
1 Self-evaluating	student-initiated evaluations of the quality or progress of their work; e.g. "I check over my work to make sure I did it right".
2 Organising and transforming	student-initiated overt or covert rearrangement of instructional materials to improve learning; e.g. "I make an outline before I write my paper".
3 Goal-setting and planning	students' setting of educational goals or subgoals and planning for sequencing, timing, and completing activities related to those goals; e.g. "First, I start studying two weeks before exams, and I pace myself".
4 Seeking information	student-initiated efforts to secure further task information from non-social sources when undertaking an assignment; e.g. "Before beginning to write the paper, I go to the library to get as much information as possible concerning the topic".
5 Keeping records and monitoring	student-initiated efforts to record events or results; e.g. "I took notes of the class discussions"; "I kept a list of the words I got wrong".
6 Environmental structuring	student-initiated efforts to select or arrange the physical setting to make learning easier; e.g. "I isolate myself from anything that distracts me"; "I turned off the radio so I can concentrate on what I am doing".
7 Self-consequating	student arrangement or imagination of rewards or punishment for success or failure; e.g. "If I do well on a test, I treat myself to a movie".
8 Rehearsing and memorising	student-initiated efforts to memorise material by overt or covert practice; e.g. "In preparing for a math test, I keep writing the formula down until I remember it".
9–11 Seeking social assistance	student-initiated efforts to solicit help from peers (9), teachers (10), and adults (11); e.g. "If I have problems with math assignments, I ask a friend to help".
12–14 Reviewing records	student-initiated efforts to reread notes (12), tests (13), or textbooks (14) to prepare for class or further testing; e.g. "When preparing for a test, I review my notes".
15 Other	learning behaviour that is initiated by other persons such as teachers or parents, and all unclear verbal responses; e.g. "I just do what the teacher says".

environment – will help them to feel they have more control over their own progress.

First, ask students to read through Zimmerman's 15 self-regulated learning strategies and ask them to rate themselves on a scale of 1 to 10 on how effectively they use each strategy in their own practice. In doing this, you are encouraging students to think metacognitively about their own learning. Second, ask them to apply these strategies to a specific domain of a particular subject in which they could improve.

Finally, self-regulation is not a state which learners achieve just by working on their own. When students are novices (and almost all students are novices) it can be counterproductive to think students can regulate their own learning. By modelling successful solutions to problems and giving clear guidance and persuasion at the outset, teachers can have a big impact on student self-efficacy. By presenting material in such a way that students feel "OK, I can do this" you are helping them on the way to becoming a self-regulated learner.

Learners are usually novices and should be taught accordingly (see Chapter 6, A novice is not a little expert)

Takeaways

- Self-regulated learning is not just an internal process but rather a combination of personal, behavioural, and environmental factors.
- Independent learning is probably a bad way for a novice to become an independent learner.
- Telling learners to "do your best" is not effective. Long-term goals should be broken down into intermediate goals and most importantly, they should be specific.
- Teacher modelling and verbal persuasion can have a big impact on student self-efficacy.
- Students who know more in a particular domain are better able to think metacognitively about their learning in that domain.
- Make sure that learners have the knowledge and skills necessary for self-regulating their learning.

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Suggested readings and links

BARRY ZIMMERMAN: LEARNING AND THE ADOLESCENT MIND. CONCISE OVERVIEW OF ZIMMERMAN'S WORK.

AVAILABLE FROM HTTP://LEARNINGANDTHEADOLESCENTMIND.ORG/PEOPLE_04.HTML.

BARRY J. ZIMMERMAN, AN EDUCATOR WITH PASSION FOR DEVELOPING SELF-REGULATION OF LEARNING THROUGH SOCIAL LEARNING. PAPER PRESENTED AT AERA.

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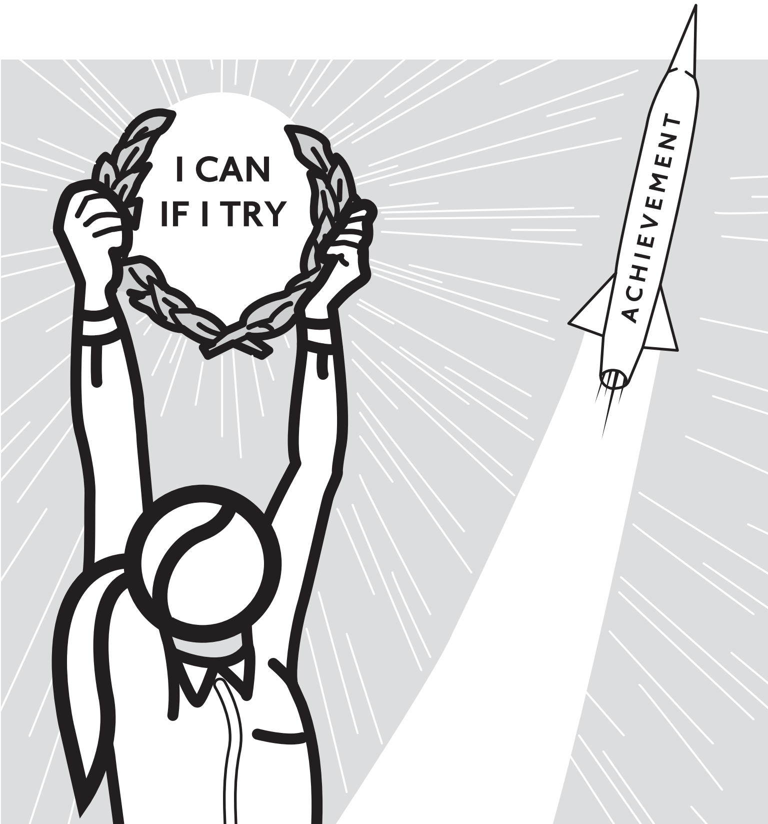
13 BELIEFS ABOUT INTELLIGENCE CAN AFFECT INTELLIGENCE

MINDSET



DOI: 10.4324/9781003395713-16

13 BELIEFS ABOUT INTELLIGENCE CAN AFFECT INTELLIGENCE

PAPER "A social-cognitive approach to motivation and personality"[1]

QUOTE *"Implicit beliefs about ability predict whether individuals will be oriented toward developing their ability or towards documenting the adequacy of their ability"[2].*

Why you should read this article

When you see someone push a door that says "pull" on it, do you view that person as stupid or rather do you see them as someone of otherwise normal intelligence, merely doing an unintelligent thing in that moment? According to this article, your response to that question might reveal a lot more than you think about your self-concept, self-esteem, and your view of the external world.

GROWTH MINDSET The belief that intelligence is malleable

FIXED MINDSET The belief that intelligence is fixed

Carol Dweck's work on motivation over the last 40 years has been hugely influential in education. It's impossible to meet someone in education today who isn't familiar with the term "growth mindset", however her work is also one of the most misunderstood, with many schools reducing her work to cheesy motivational posters and assemblies and the misguided idea that innate ability doesn't matter but effort does. Before the terms "growth mindset" and "fixed mindset" came along, there were the less catchy terms "entity theorist" and "incremental theorist" and a set of ideas which can be crudely summarised in the following sentence: *The extent to which an individual believes change is possible, largely determines their ability to affect change.*

Although her work yielded promising results in the lab, more recent attempts to replicate her findings in the field have led to dubious results (Sisk et al., 2018), and suggest that attempts to change pupils' intrinsic

1 DWECK, C. S., & LEGGETT, E. L. (1988). A SOCIAL-COGNITIVE APPROACH TO MOTIVATION AND PERSONALITY. *PSYCHOLOGICAL REVIEW*, 95, 256–273.
2 IBID., P. 263.

beliefs about the nature of intelligence may not be as malleable as once thought. Despite this, her work in the 1980s is a hugely important contribution to the field of motivation and remains an important consideration for teachers today. If a student believes that they just can't learn the material you're teaching them then why would they bother? There's something liberating about the belief in the basic mutability of the world around us and that we are not prisoners of our DNA. The notion that intelligence is not fixed but rather something that can be refined and improved through effort and embracing challenge is an important starting point for anyone standing in front of a class trying to motivate students to learn.

Abstract of the article

Past work has documented and described major patterns of adaptive and maladaptive behaviour: the mastery-oriented and the helpless patterns. In this article, we present a research-based model that accounts for these patterns in terms of underlying psychological processes. The model specifies how individuals' implicit theories orient them towards particular goals and how these goals set up the different patterns. Indeed, we show how each feature (cognitive, affective, and behavioural) of the adaptive and maladaptive patterns can be seen to follow directly from different goals. We then examine the generality of the model and use it to illuminate phenomena in a wide variety of domains. Finally, we place the model in its broadest context and examine its implications for our understanding of motivational and personality processes.

The article

LEARNED HELPLESSNESS
Not trying after experiencing repeated failures

This article begins by outlining two patterns of behaviour in which individuals display adaptive (mastery-oriented) and maladaptive (helpless) dispositions. The helpless pattern of behaviour is characterised by "an avoidance of challenge and a deterioration of performance in the face of obstacles" (p. 256). In direct contrast to this, the mastery-oriented pattern of behaviour incorporates "the seeking of challenging tasks and the maintenance of effective striving under failure" (p. 259). Carol Dweck and Ellen Leggett then claim that this difference is not accounted for in terms of raw ability (with some of the brightest and most skilled individuals showing the helpless pattern of behaviour) but rather in the way in which both of these types set out to complete a task.

In attempting to explain this phenomenon, they cite research which claims that both of these types of student might be pursuing very different types of *goals* (Dweck & Elliott, 1983). Researchers identified two types of goals: *performance* goals in which pupils are mostly concerned with measurable results such as exam scores and then *learning* goals (these are now referred to as mastery goals) in which pupils are more interested in improving their general competence and mastering the topic. As the authors neatly put it: "in challenging situations, helpless children might be pursuing the performance goal of *proving* their ability, whereas the mastery-oriented children might be pursuing the learning goal of *improving* their ability" (Dweck & Leggett, 1988, p. 259).

Exam scores (performance) are not the same as learning

In other words, if you want students to become proficient in a specific domain of knowledge then describing the desired outcome in terms of a target grade or exam score might actually be a poor way of achieving mastery in that domain. Why is this? Well the authors claim that it all comes down to implicit theories about the nature of intelligence and whether or not you think it is something that can be changed or is a static entity.

To test this, researchers set up tasks where the stated goals at the outset were either mastery-oriented or performance-oriented. When children were given goals that were about the acquisition of skill over evaluation, their assessment of their current ability was irrelevant and they chose a task displaying a mastery-oriented pattern. However when children were given a goal-based evaluation, they chose tasks that they felt were consistent with their *perceived* ability. In short, if students believe that their ability is low and then ask them to do a test that will reveal that perceived ability, they will invariably shut down. Why would you take a test if you think you are going to fail it?

Performance versus mastery

TWO DIFFERENT INFERENCE RULES

Interestingly, students with a *performance goal* have a perception of effort which is inversely related to ability. Their inverse rule states that if you need to put a lot of effort into something, then it must mean you aren't very good at it. However students with a *learning (mastery) goal* tend to use a positive rule where effort and ability were positively related. They agreed with statements such as "when something comes easy to you, you don't know how good you are at it" (Jagacinski & Nicholls, 1983; Surber, 1984).

ENTITY THEORY OF INTELLIGENCE
Fixed mindset

The big question at this point then is, why do certain students favour performance goals which focus on measuring their ability whereas other students choose behaviours focused on the increasing of their ability? For the researchers, this is accounted for by individual beliefs about intelligence. Students with an *entity* theory of intelligence believe that intelligence is fixed and something you cannot control.

INCREMENTAL THEORY OF INTELLIGENCE
Growth mindset

In contrast, students with an *incremental* theory of intelligence believe that intelligence is something which is malleable and can be improved through effort. In other words, they have what is more commonly known today as a *growth mindset*. The way in which an individual conceives of their own intelligence as being a fixed entity was associated with the *performance orientation* whereas a conception of intelligence as being malleable in nature was associated with a *learning orientation*.

The authors then go on to generalise these claims and suggest that the two theories (entity and incremental) have an important part to play in terms of self-concept and self-esteem. For the student with an entity theory of intelligence (a fixed mindset), the self is conceptualised as a "collection of fixed traits that can be measured and evaluated" whereas for the incremental theorist (a growth mindset), the self is seen as a "system of malleable qualities that is evolving over time through the individual's efforts" (p. 266). As a result of these two different self-concepts, the ways in which self-esteem is generated is different. Broadly speaking, *self-concept* is the beliefs you hold about yourself such as whether you are male or female or whether you are good at golf or not, whereas *self-esteem* is the level of satisfaction you have with these attributes. (If you don't care about golf then you won't care if you aren't very good at it.)

SELF-CONCEPT
Core beliefs about oneself
SELF-ESTEEM
How happy you are with yourself

Earlier data collected by the researchers is offered to provide support for this assertion. After assessing their theories of intelligence, children were asked to describe when they felt smart in school, in other words when they felt high self-esteem. As predicted by the researchers, children with an entity (fixed) theory of intelligence reported that they felt smart when their work had no errors or mistakes or when the work was easy. In contrast, the children with an incremental (growth) theory of intelligence reported that they felt smart when they mastered difficult challenges such as when they overcame a task they were previously unable to do or when they were reading a difficult book.

WHAT ABOUT IQ?

Alfred Binet's growth mindset

But isn't the idea of a growth mindset at odds with the notion of IQ? Well perhaps not. Dweck and Leggett claim that Alfred Binet, the grand architect of intelligence testing, was "clearly an incremental theorist" (p. 263) who believed that intelligence and general capacities for learning were improvable through his own training programme:

> It is in this practical sense, the only one accessible to us, that we say that the intelligence of these children has been increased.

> We have increased what constitutes the intelligence of a pupil: the capacity to learn and to assimilate instruction.
>
> (Binet, 1909/1973, p. 104)

> The authors go on to point out the irony that the assessment tool he developed is now widely associated with an entity theory of intelligence and a performance goal paradigm in which intelligence is measured as a largely stable entity. However, these two positions should not be polarised as Dweck and Elliott (1983) point out that one can recognise that there are individual differences in ability but still emphasise the potential for growth within those individuals.

The authors then attempt to generalise the model beyond the self and consider the ways in which entity and incremental theorists view the external world. They suggest that fixed and uncontrollable things tend to be measured and judged whereas things viewed as malleable or controllable tend to be acted upon or developed. The authors posit the idea that individuals with an entity theory of their own intelligence based on test scores or a few mistakes might also judge others as being intrinsically untrustworthy or incompetent based on isolated factors and limited evidence without consideration of contextual factors or the perspective of the individual concerned. An entity theorist with a fixed view of the world might judge a person who makes a mistake as *always* being like that, whereas an individual with an incremental theory might view that person as a fallible individual whose mistake is a necessary stepping-stone to eventual success.

Conclusions/implications of the work for educational practice

It's important to state here that motivational approaches which seek to deny the significance of inborn ability are destined to fail, because they're not true. If you are trying to convince students that innate ability accounts for 0% of success and effort accounts for 100% of success then you are misleading them. Instead of saying to students "talent doesn't matter, only effort matters", what we should be saying to students is "yes, talent and natural ability play a big part in success but effort matters on the margins, and the marginal gains can go on to yield significant gains".

EFFORT
Can have an exponential effect

Furthermore, what is crucial to also understand is that these dispositions really only come into play in the face of struggle or failure.

Both entity and incremental theorists show the same behaviours when the work is easy, but when effort is required, then these differences in behaviour become apparent and it is here that the authors suggest that students' innate beliefs about intelligence can yield marginal gains.

How to use the work in your teaching

A key claim in this paper, and indeed this field, is that the adoption of an incremental theory of intelligence (growth mindset) is positively correlated with goal choice, and here is where teachers can have a big impact. If the objective or outcome of a lesson or unit of study is heavily performance based, that is to say one which leans heavily on target grades for example, then it is possible that many students might adopt an entity view of intelligence and choose performance goals over learning/mastery goals. Students who are set *performance* goals in the form of target grades will invariably ask the question, is my ability adequate? Whereas students who are set *learning* goals might ask the question, how can I improve my performance and ability? So instead of telling the class that success can be determined by an exam score, the teacher might define success in terms of specific knowledge-based targets such as understanding what certain vocabulary means or being able to perform a particular experiment or understanding a tricky philosophical concept.

Motivation through achievement ≠ achievement through motivation

As stated earlier, the efforts to replicate growth mindset interventions in the field have often been patchy and so we might pause to consider if *motivating* students is the best way to motivate them? Is showing them "inspirational" videos or teaching them about the plasticity of the brain the best way to achieve a growth mindset or do students feel motivated when they achieve something? As Graham Nuthall (2007) reminds us: "Learning requires motivation, but motivation does not necessarily lead to learning" (p. 35). What if a growth mindset is viewed as more of a philosophy as opposed to an intervention? All teachers should believe at some level that their students' intelligence is malleable and that they can help them improve it, otherwise why bother? It might be the case that recognising that novices and experts learn in different ways for example (as discussed in Chapter 6, A novice is not a little expert), and that novices in particular need highly scaffolded learning environments (as detailed in Chapter 12, Why independent learning is not a good way to become an independent learner) might be the best way to motivate them. It may be that we have the causal arrow the wrong way round. To put it another way, motivation doesn't always lead to achievement, but achievement often leads to motivation.

GROWTH MINDSET Philosophy or intervention?

Takeaways

- An entity theory of intelligence is one that believes intelligence is largely fixed.
- An incremental theory of intelligence is one that believes that intelligence is changeable.
- A performance goal can lead to students adopting an entity theory (fixed mindset).
- A learning (mastery) goal can lead to students adopting an incremental theory (growth mindset).
- Mastery-oriented children see difficult or unsolved problems as challenges to be mastered through effort and not as failures.
- Innate ability does matter but effort can yield marginal gains.

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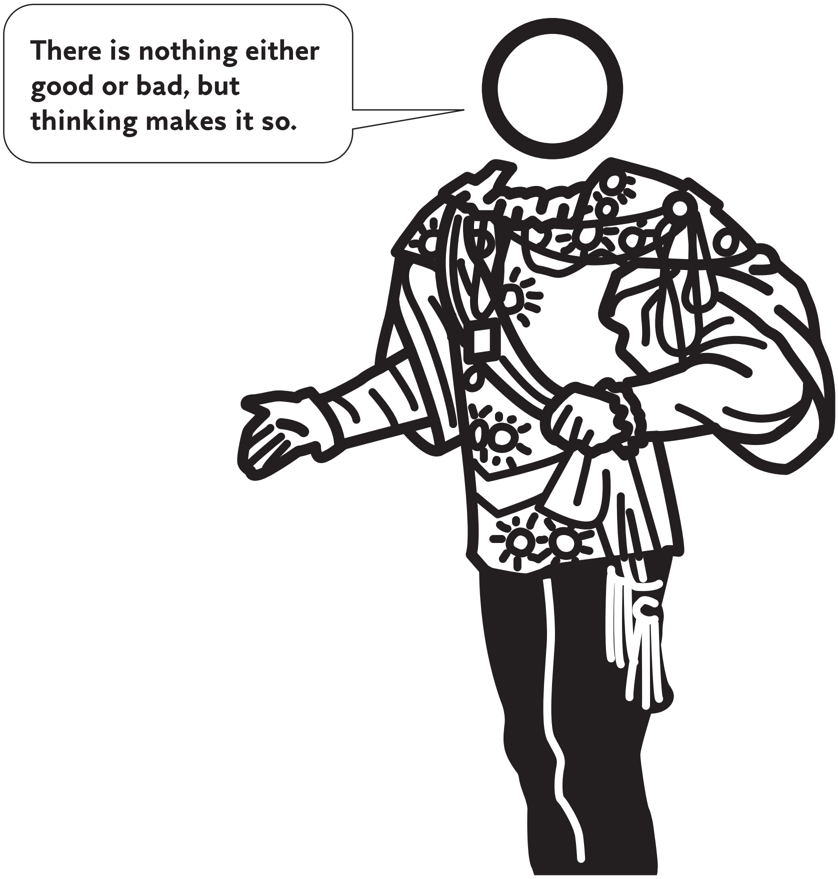
14 … THINKING MAKES IT SO

SELF-EFFICACY



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14 ... THINKING MAKES IT SO

PAPER "Self-efficacy: Toward a unifying theory of behavioral change"[1]

QUOTE *"Perceived threats activate defensive behavior because of their predictive value rather than their aversive quality. That is, when formerly neutral stimuli are associated with painful experiences, it is not that the stimuli have become aversive but that individuals have learned to anticipate aversive consequences".*[2]

Why you should read this article

SELF-EFFICACY
How well you think you can deal with a specific challenge

Why is it that some people feel tremendous fear when encountering a dog in the street? Why do some professional sporting figures perform at a high level in training but underperform on the big stage? And more importantly for our discussion, why is it that some students of near equal ability and experiences perform very differently in certain domains and in certain situations? One explanation might be self-efficacy or "judgements of how well one can execute courses of action required to deal with prospective situations" (Bandura, 1982, p. 122). The person who is terrified of dogs may understand at a logical level that most dogs are not going to attack them but if they *believe* that they are likely to experience severe anxiety in that situation then they are likely to exhibit that behaviour when encountering their neighbour's dog.

The central idea in this article is that it is not so much the situation itself which initiates one's behaviour towards it but rather the way in which one *anticipates* the situation. Many students, for example, can perform at a high level in class discussion and assessments but then experience high levels of anxiety in the exam hall during their finals. In many cases, this has little to do with their ability but rather with

1 BANDURA, A. (1977). SELF-EFFICACY: TOWARD A UNIFYING THEORY OF BEHAVIORAL CHANGE. *PSYCHOLOGICAL REVIEW*, *84*(2), 191–215.
2 IBID., P. 209.

their perception of how they can handle the situation. As noted in the quote from Shakespeare's Hamlet, "there is nothing either good or bad, but thinking makes it so".[3] Self-efficacy refers to the extent to which an individual believes they are capable of successfully completing a task. In that sense, self-efficacy is really a domain-specific trait and is strengthened by positive experiences within that domain as discussed in this chapter.

Abstract of the articles

EXPECTATIONS OF SELF-EFFICACY
Accomplishments, experience, verbal persuasion, physiological states

The present article presents an integrative theoretical framework to explain and to predict psychological changes achieved by different modes of treatment. This theory states that psychological procedures, whatever their form, alter the level and strength of self-efficacy. It is hypothesised that expectations of personal efficacy determine whether coping behaviour will be initiated, how much effort will be expended, and how long it will be sustained in the face of obstacles and aversive experiences. Persistence in activities that are subjectively threatening, but in fact relatively safe, produces, through experiences of mastery, further enhancement of self-efficacy and corresponding reductions in defensive behavior. In the proposed model, expectations of personal efficacy are derived from four principal sources of information: performance accomplishments, vicarious experience, verbal persuasion, and physiological states. Factors influencing the cognitive processing of efficacy information arise from enactive, vicarious, exhortative, and emotive sources. The differential power of diverse therapeutic procedures is analysed in terms of the postulated cognitive mechanism of operation. Findings are reported from microanalyses of enactive, vicarious, and emotive modes of treatment that support the hypothesised relationship between perceived self-efficacy and behavioral changes.

The article

BELIEF AND ABILITY

In the 1960s, educational researchers moving from a behaviourist to a cognitivist view of learning were particularly interested in what goes on in our brain. They compared our brains with

3 SHAKESPEARE, W., & GILL, R. (2002). *HAMLET*. OXFORD UNIVERSITY PRESS, P. 259.

> computers that worked with input and output based on rational models and steps. The challenge was understanding how people process and store knowledge in the brain. In the 1970s and 1980s we began to also pay attention to the learning process itself and the learner's role in it. Learners don't always work rationally like computers; they make choices, choose a task (or don't), start on it, give up or persevere, and so on. All of these choices determine what someone ultimately learns. One of the most influential things in this regard is the belief in one's own abilities. Learners often choose a task or an approach that they think will give them the best results. Bandura added that students also expect a link between their own ability – or their belief in their own ability – and the result. They choose a task that they think they can complete or a strategy that they think will work.

Learners expect a link between their ability and the result

In this article, Bandura offers a theoretical framework based on the claim that psychological procedures "serve as a means of creating and strengthening expectations of personal efficacy" p. 193). He examines changes in behaviour, specifically looking at cognitive processes such as decision-making or through procedures such as the completion of actions. He argues that both of these approaches work in tandem to produce change but that completing tasks oneself as opposed to watching others complete them was more effective in increasing self-efficacy.

An *outcome expectancy* is one where an individual will estimate that a certain behaviour will lead to certain outcomes whereas an *efficacy expectation* is the belief that an individual can carry out the behaviour that is needed to achieve the outcome. In other words, people avoid threatening situations that they believe are beyond their coping capabilities yet they will more readily get involved in situations that they believe they can handle. For example, you might know and *believe* that you need to eat well and exercise to lose weight but you may lack the motivation to carry out the required action of eating healthy food and regularly going for a run.

Difference in outcome expectancy and efficacy expectation

Bandura outlines four main sources of information (see Figure 14.1) in which an individual's self-efficacy is fostered: performance accomplishments, vicarious experience, verbal persuasion, and physiological states.

PERFORMANCE ACCOMPLISHMENTS
Self-efficacy through task mastery

Performance accomplishments refer to experiences where individuals take on a task and master it, thus giving a sense of accomplishment and greater confidence when encountering a similar task in the future. Interestingly, Bandura makes the claim that self-efficacy through mastery can generalise to other situations such as overcoming a phobia of animals, leading to better coping skills in social situations and reducing fear of other animals. However he stresses that the effects occur most prominently with activities which are more similar to the original mastery activity.

VICARIOUS EXPERIENCE
Self-efficacy through seeing others succeed

Vicarious experience refers to the fact that it is not only personal mastery that can lead to increased self-efficacy. When we see other people experience threatening situations and overcome them, this can improve our own sense that we will improve and complete a task if we persevere and sustain our efforts. In other words: "if they can do it, so can I".

VERBAL PERSUASION
Raises expectations more than outcomes do

Verbal persuasion is an easier intervention to achieve in the sense that it's relatively easy to talk to someone and suggest that they can achieve something if they make the effort. However, as you would expect, this approach is not as effective at increasing self-efficacy as ones where the individual experiences mastery themselves. In many cases verbal persuasion "is aimed mainly at raising outcome expectations rather than at enhancing self-efficacy" (p. 198). A key point here is that it's not just enough to persuade people that they can do something, you have to provide "provisional aids for effective action" (p. 198). In other words, it is not enough to tell someone they *can* do it, you also have to show them *how* to do it.

PHYSIOLOGICAL STATES
Anxiety can impair performance

Physiological states, or "emotional arousal" as Bandura puts it, refers to the fact that high levels of anxiety usually impair an individual's ability to complete a task regardless of their ability to complete the task. For example, a football player who never misses a penalty in training can be overcome by fear in a real match situation and miss the penalty due to anxiety rather than ability. In this situation you often hear the phrase "The pressure got to him" or "He choked". In education we often see this with students who experience severe anxiety about studying or tests despite the fact that they're able to do them. Put simply, the fear of the experience is worse than the actual experience. As Bandura notes: "By conjuring up fear-provoking thoughts about their ineptitude, individuals can rouse themselves to elevated levels of anxiety that far exceed the fear experienced during the actual threatening situation" (p. 199). The anticipation of the task is far worse than actually doing the task.

However, there is a distinction to be made between these four levels of information as environmental events and how they are processed by the individual on a subjective level. In certain situations, individuals will attribute success to external factors such as luck or the degree of difficulty of a task as opposed to their own effort or ability (see Chapter 15, How you think about achievement is more important than the achievement itself). This is particularly problematic when certain aids are used in an attempt to boost self-efficacy, such as tasks which are too

External attribution of success

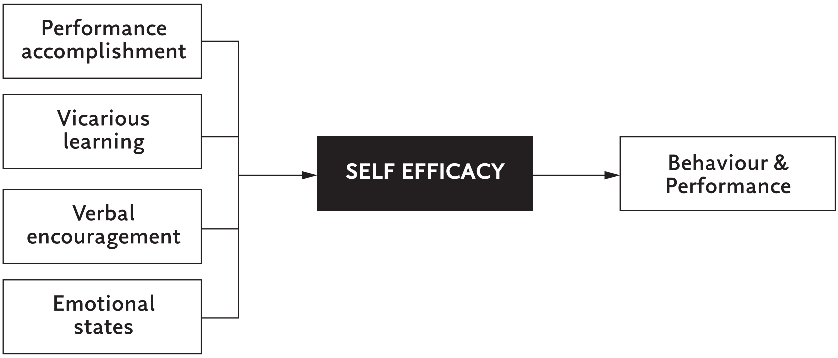

FIGURE 14.1 COMPONENTS OF SELF-EFFICACY (SOURCE: BANDURA, 1977)

simple. As Bandura puts it. "To succeed at easy tasks provides no new information for altering one's sense of self-efficacy, whereas mastery of challenging tasks conveys salient evidence of enhanced competence" (p. 201).

It's claimed that it's possible to create generalised, long lasting changes in self-efficacy. This involves initial induction activities such as clear instruction and modelling, removing the external aids (i.e. support, guidance, scaffolding) to confirm personal efficacy, and then finally allowing for independent practice and mastery will strengthen and generalise expectations of efficacy (see Chapter 23 on Direct instruction).

In addition, self-efficacy is highly contextual. Certain situations or tasks require more skill than others and carry a higher risk of negative consequences. Expectations will vary accordingly: "Thus, for example, the level and strength of perceived self-efficacy in public speaking will differ depending on the subject matter, the format of the presentation, and the types of audiences that will be addressed" (p. 203). This phenomenon would explain why teachers are usually highly confident speaking to their teenage or undergraduate students about a topic on which they know a great deal, yet may feel anxiety speaking about the same topic to their peers, where there is a greater threat to their professional standing and where the audience is far more knowledgeable than their students. All situations are not equal.

To test this theoretical model, ophidiophobics (i.e. people with a fear of snakes) were tested on their ability to confront their fear of snakes through two different therapeutic interventions. One group watched a facilitator engage in increasingly more threatening interactions with a boa constrictor and the other group actually performed those tasks themselves, becoming more and more exposed to handling the snake. A control group had neither treatment. The results were that the individuals who confronted their fear of snakes through direct handling had more self-efficacy in subsequent tests when confronted with a snake and were able to generalise this self-efficacy to different breeds of snakes.

EXAMPLE
Exposure as a means of increasing self-efficacy

THE INSIDIOUS MINDSET?

Issues with growth mindset interventions

In her study on motivation, Carol Dweck (Dweck & Leggett, 1988) saw that students differ in how they think about competence and intelligence. She made a distinction between two different ways or mindsets: a static (fixed) and a growth-oriented (growth) mindset. Students with a fixed way of thinking saw competence as something that must manifest itself immediately and otherwise not. They dropped out or stopped doing something if they couldn't do it right away. On the other hand, students who had a growth-oriented way of thinking believed that ability could grow through hard work and practice. They persisted, even when it was difficult or when they encountered problems.

Today, researchers question the reliability of Dweck's original studies. Later studies showed different results, including that growth-oriented thinking doesn't lead to better learning (Sisk et al., 2018). Dweck's research is also based on a very unreliable method of self-report by students. That students think differently about competence and intelligence is true, but the influence of these ways of thinking on learning performance has never been well demonstrated. Despite all of the recent scientific proof and refutations, this theory has become widely accepted and innovation processes have even been designed based on it.

Conclusions/implications of the work for educational practice

Self-efficacy is domain specific and predicts success

Bandura (2006) later argued that self-efficacy measures should be subject-specific as opposed to generalised and there is a lot of evidence that these subject-specific measures are a strong predictor of attainment (Meece, Wigfield, & Eccles, 1990). For example, measures of writing self-efficacy proved to significantly predict writing achievement as scored by student essays (McCarthy, Meier, & Rinderer, 1985). This has two serious implications for educators: first, self-efficacy is largely domain specific and educators should be wary of approaches aimed at boosting self-efficacy that are based on inspirational quotes or motivational posters. There does not appear to be a *global* self-efficacy where individuals can improve self-efficacy in a general sense. Second, self-efficacy is a strong predictor of success in a particular domain and so instruction should be tailored to allowing students to experience success in that domain to affect self-efficacy.

A central claim in this article is that self-efficacy affects the choice of action that an individual makes, particularly in terms of persistence and effort. Individuals who have low self-efficacy in a particular domain are unlikely to expend much effort to complete a particular task, whereas those with high self-efficacy are more likely to readily take on a task and see failure as a means to eventual success. However, how do educators harness this theoretical model to help their students?

First, returning to Bandura's four components, we can think about the conditions which teachers can create to bolster self-efficacy and it's clear that when students experience success vicariously and then personally, they're likely to experience increased self-efficacy. Clear instruction and modelling of material to be learned is something teachers can do.

SHOW HOW IT'S DONE

> Modeled behavior with clear outcomes conveys more efficacy information than if the effects of the modeled actions remain ambiguous. In investigations of vicarious processes, observing one perform activities that meet with success does, indeed, produce greater behavioral improvements than witnessing the same performances modeled without any evident consequences.
> (Bandura, 1977, p. 197)

In addition to a teacher modelling success, another element to consider with vicarious experience is to allow students to see their peers being successful in a specific task. For example, when students complete an essay on a literature assignment, instead of marking their work and handing it back, a teacher might show the class three examples of students doing that task at a high level and then ask the student to talk the class through how they constructed the essay, what ideas and concepts they used, and the ways in which they phrased their ideas.

The key thing here is that there are clear outcomes modelled for the given behaviour, so telling students in general terms that "hard work achieves results" might be true in a general sense but it's unlikely to lead to changes in behaviour, whereas showing students the specific steps required to solve an algebraic equation, for example, and then giving them the time and space to independently practice and achieve success doing it is more likely to lead to improved self-efficacy.

Vague advice is ineffective, be specific

Finally, let students work (i.e. make assignments) at their own level, with goals that are within their reach. Bandura himself mentions a number of factors within learning environments that guarantee or increase the self-efficacy of students, such as:

- Focusing on "learning" instead of "knowing": students will then see that they can grow and that knowledge and skills are not innate traits.
- Discouraging mutual competition and emphasising personal progress and achievement.
- Focusing feedback on progress and not on mistakes (see also Chapter 24, Assessment *for*, not *of* learning, and Chapter 25, Feed up, feedback, feed forward).

How to use the work in your teaching

EXAM ANXIETY
Anticipation is often worse than actual experience

Self-efficacy is a complex cognitive capacity and one which is often formed and consolidated over many years, but one thing that teachers should be aware of is exam or performance anxiety. As Bandura states: "It is often the case that fears and deficits are interdependent. Avoidance of stressful activities impedes development of coping skills, and the resulting lack of competency provides a realistic basis for fear" (p. 199). As stated previously, emotional reactions to performance can cause anxiety, which can initiate avoidance behaviours and seriously impair one's ability to carry out the task. In other words, the anticipation of the task is far worse than *actually doing the task*. To address this, Bandura suggests modelling as a way of alleviating potentially negative emotional states and teaching coping skills by demonstrating effective ways of dealing with threatening situations. So when dealing with students who encounter anxiety around academic writing or exam situations, teachers can break down the component elements of writing an essay and model how to write an introduction and develop an argument for example, and then "expose" students to exam situations by creating the kinds of situations they will encounter in the real situation such as a timed exam in class. Like the penalty taker who is near perfect in training but overcome in a real match, you are never going to be able to properly recreate the kinds of pressure a real life exam will create, but it will go some way to prepare students to cope with their anxiety through mastering simulated versions of the real thing.

WHY MOTIVATIONAL POSTERS DON'T WORK

> The impact of verbal persuasion on self-efficacy may vary substantially depending on the perceived credibility of the persuaders, their prestige, trustworthiness, expertise, and assuredness. The more believable the source of the information, the more likely are efficacy expectations to change.
>
> (Bandura, 1977, p. 202)

In addition, when giving advice to students or in one-on-one discussions, it is important to not use vague, nebulous language or instructions. It might seem like the right thing to do to say "you can achieve anything if you just believe" but advice like this might have an adverse effect. Instead, it's more effective to provide very clear instructions on what is required to achieve a particular task, then model how to do it and finally allow the student some independent practice to boost self-efficacy.

EXAMPLE
Low self-efficacy

In the classroom, low levels of self-efficacy usually means that a student has a distorted view of a task they are faced with and believes that it is much harder than it actually is. In some situations, low self-efficacy is justified. For example if you had to run 100 metres in less than 10 seconds you would be right to think you can't do it (unless you're Usain Bolt) but in educational settings, tasks are usually within the competence level of the students being asked to do them. Low self-efficacy can also lead to avoidance behaviours and poor planning, and so another approach can be to alleviate this by careful sequencing of instruction and tasks and removal of guidance when appropriate, to ultimately lead them to the mastery of a particular task and the feeling of accomplishment, which is really the most powerful determinant of self-efficacy.

Takeaways

- Self-efficacy refers to the relative belief one has about their ability to complete a task.
- Self-efficacy is boosted by having successful experiences and mastering a task or topic.
- It can also be boosted through seeing others succeed and through persuasion, though this is less strong.
- Emotional states when anticipating a task, such as anxiety, can make a task seem much harder than it actually is.
- Anxiety can be addressed through teacher modelling and exposure to simulated pressurised situations.
- Give students the chance for success experiences by giving them tasks they can handle.
- Focus on "learning" instead of "knowing"; in this way students discover that they can grow.
- Discourage mutual competition and emphasise personal progress.

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BANDURA, A. (1997). SELF-EFFICACY: THE EXERCISE OF CONTROL. W. H. FREEMAN.

A FASCINATING INTERVIEW WITH BANDURA ABOUT HIS LIFE AND WORK IS

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SELF-EFFICACY. AN ACCESSIBLE VIDEO ON SELF-EFFICACY AND MOTIVATION.

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A USEFUL TIP-SHEET FROM THE APA ON HOW TO TEACH FOR SELF-EFFICACY IS

AVAILABLE FROM WWW.APA.ORG/PI/AIDS/RESOURCES/EDUCATION/SELF-EFFICACY.

THE NAIL IN GROWTH MINDSET'S COFFIN? A BLOG FROM DAVID DIDAU.

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A VIDEO OF SNAKE EXPOSURE THERAPY IS

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15 HOW YOU THINK ABOUT ACHIEVEMENT IS MORE IMPORTANT THAN THE ACHIEVEMENT ITSELF

ATTRIBUTION THEORY

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15 HOW YOU THINK ABOUT ACHIEVEMENT IS MORE IMPORTANT THAN THE ACHIEVEMENT ITSELF

PAPER "An attributional theory of achievement motivation and emotion"[1]

QUOTE *"A virtually infinite number of causal ascriptions are available in memory. However, within the achievement domain, a relatively small number from the vast array tend to be salient. The most dominant of these causes are ability and effort. That is, success is ascribed to high ability and hard work, and failure is attributed to low ability and the absence of trying".*[2]

Why you should read this article

When a football team loses a game, the coach is usually interviewed afterwards and you tend to get two types of response. The first coach will blame the referee, the opponents' unambitious tactics (they parked the bus in front of the goal), or just plain bad luck. In some cases, they will even blame the pitch. The second type of coach will not blame external factors and instead look inwards and blame the team themselves, claiming, "we just didn't work hard enough today" or "the strikers didn't get the passes they should have gotten". Both of these responses are an attempt to not only make sense of a particular performance, but also to ensure any future performance will still be under their control. The coach who blames the referee allows their team to retain a degree of agency in the future, as they will not always have the same referee. (However, the coach is also missing a vital opportunity for the team to learn from their mistakes in the match.) Similarly, the coach who assigns blame on internal factors like effort is not

1 WEINER, B. (1985). AN ATTRIBUTIONAL THEORY OF ACHIEVEMENT MOTIVATION AND EMOTION. *PSYCHOLOGICAL REVIEW*, 92(4), 548–573.
2 IBID., P. 549.

saying their team is *perpetually* not good enough. After all, many teams with "inferior" players can beat "superior" teams with the right tactics and application. (S)he is saying that they can increase their effort in the future and perform better. One thing you'll almost never hear a coach say is "they have better players than we do and so are a much better team" despite the fact that often this is the most obvious factor to anyone watching the game.

ATTRIBUTION THEORY
What we think causes our successes or failures

EXAMPLE
Perceived vs. actual cause

Attribution theory is essentially the causes that individuals attribute to their own successes or failures. Weiner's work looks more closely at how those perceptions affect their emotional state and crucially, how that process affects their subsequent motivation for future tasks. A hugely important factor is that the *perceived* cause is more significant than the *actual* cause. For example, a student's emotional response to a bad test score is more important than the score itself because it can establish a pattern of future behaviour that can prove to be self-defeating. As Hamlet said to Rosencrantz, "there is nothing either good or bad, but thinking makes it so"[3]. If a student feels that their poor score in a mathematics test is down to a fundamental lack of ability that they have no control over, then their negative emotional response is likely to result in a lack of effort in the future despite the fact that this might not be true. However, if a student blames poor performance on a lack of effort, they may feel an initial degree of shame but there is still the possibility that they can change this behaviour in the future to achieve success.

This article by Bernard Weiner (1985) seeks to systematise how students in achievement-related contexts attribute causes to academic outcomes, and how those attributions affect future motivation and performance. As Heider noted in 1958, we are all "naïve psychologists" seeking to make sense of an uncertain world and understanding how students respond to academic performance and how this affects their future motivation is an important string to any teacher's bow (Heider, 1958).

Abstract of the article

A theory of motivation and emotion is proposed in which causal ascriptions play a key role. It is first documented that in achievement-related contexts there are a few dominant causal perceptions. The perceived causes of success and failure share three common properties: locus, stability, and controllability, with intentionality and globality as other possible causal structures. The perceived stability of causes influences changes in expectancy of success; all three dimensions of causality affect a variety of common emotional experiences, including anger, gratitude, guilt, hopelessness,

3 SHAKESPEARE, WILLIAM. (1992). *THE TRAGEDY OF HAMLET, PRINCE OF DENMARK*. NEW FOLGER'S ED. WASHINGTON SQUARE PRESS/POCKET BOOKS, P. 36.

pity, pride, and shame. Expectancy and affect, in turn, are presumed to guide motivated behaviour. The theory therefore relates the structure of thinking to the dynamics of feeling and action. Analysis of a created motivational episode involving achievement strivings is offered, and numerous empirical observations are examined from this theoretical position. The strength of the empirical evidence, the capability of this theory to address prevalent human emotions, and the potential generality of the conception are stressed.

The article

Building on the pioneering work of Fritz Heider in the 1950s, Bernard Weiner establishes the fact that causes within achievement contexts are broadly ascribed to a set of internal and external factors. For example, a student might ascribe poor performance on a test to an internal cause such as lack of effort or ability or they might ascribe it to an external one such as test difficulty or teacher bias. Weiner developed this idea in the 1970s when he noted that within both of these domains, some causes are stable whereas some are prone to fluctuation. Furthermore, students tend to attribute academic outcomes to one of the following four causes: ability, effort, task difficulty, or luck. Of these four, ability and effort were cited as the most common.

CAUSES OF ACADEMIC OUTCOMES:

- Ability
- Effort
- Difficulty
- Luck

In addition to the locus dimension, Weiner added another to this dynamic: stability, which describes how stable these specific causes are over time – something which becomes crucial when considering how much control one has and as a result, how motivated one is in the future. In this dimension, elements such as ability or aptitude are seen as relatively stable causes whereas mood and effort are seen as more variable.

TABLE 15.1 LOCUS OF CONTROL DIMENSION 1 (ADAPTED FROM WEINER, 1985)

	Internal	**External**
Stable	Ability	Task Difficulty
Unstable	Effort	Luck

However, it was realised that this did not quite capture the problem as to the "naïve attributor", effort might be perceived as a stable characteristic, and tasks can be changed to become easy or difficult. Although effort is an unstable cause in the sense that we can expend more or less effort in a given situation, there is also the belief that a person can be just simply lazy, which is seen as a far more stable construct. As Rosenbaum (1972) notes, mood, fatigue, and effort are all internal and unstable causes but effort is different in the sense that it can be manipulated in a way that mood or fatigue cannot. Therefore, a third dimension of "controllability" (Weiner, 1979) was added to account for this. So for example, a cause of success or failure might be internal *yet uncontrollable*, such as mathematics aptitude. It's not uncommon to hear students, or indeed many adults, say "I'm just not good with numbers".

TABLE 15.2 LOCUS DIMENSION 2 (ADAPTED FROM WEINER, 1985)

	Internal		**External**	
	Controllable	**Uncontrollable**	**Controllable**	**Uncontrollable**
Stable	Effort	Ability	Teacher bias	Difficulty of test
Unstable	Domain	Mood	Lack of help Luck knowledge	

Link between experience and expectation

Crucially, when students experience success or failure and ascribe causes to those outcomes, those attributions affect their *expectations* of future failure or success. There is also the question of incentive – a student may feel confidence and expect success but their motivation to work for a test may depend on whether that test counts towards their final grade or whether it is just a one-off test. Weiner then details the emotional response to attributing different causes to performance. Following the outcome of an event, individuals will experience an initial positive or negative reaction or what is described as a "primitive" emotion. The next thing to happen is to ascribe a cause to that outcome and this is where emotions such as anger, shame, and guilt can have a devastating impact on future performance.

So students who experience failure and attribute that to internal, stable causes such as personality or ability are likely to experience a lack of self-esteem and will often shut down and give up, saying "I'm just no good at this". Conversely, students who attribute failure to external, unstable causes are likely to blame it on other people or outside factors and so miss an opportunity for growth and reflection that might lead to future improvement.

Conclusions/implications of the work for educational practice

When students experience academic success, the behaviour that led to that success is positively reinforced and they are likely to engage in that behaviour again. Conversely, when a student experiences failure, their evaluation of that failure is critical in determining future behaviours. By attributing their failure to an internal and stable cause such as ability, their emotional response can be shame, guilt, and frustration and can lead to a negative cycle of underachievement. However, in many cases, Causes of success or failure are not often clear

the factors determining success or failure are not so set in stone. The combination of unstable causes such as effort, persistence, and specific subject knowledge go a very long way in most academic environments and are malleable, that is to say, students can do something about it.

The other important factor is to remember to always be honest with students in terms of their effort and level of attainment. It is one thing to inspire students but another to give them a false picture of where they are that can have potentially damaging effects. For example as Weiner (1980) notes:

PRIZES FOR ALL Not good for long-term motivation

> Causal attributions determine affective reactions to success and failure. For example, one is not likely to experience pride in success, or feelings of competence, when receiving an "A" from a teacher who gives only that grade, or when defeating a tennis player who always loses.
>
> (p. 362)

The teacher who only says positive things to their students is a little bit like the boy who cried wolf. Praise is a potent tool to use in motivating students, but if it becomes the default, then students develop a resistance to it and disregard it. However, the teacher who can cultivate a culture where success is linked to effort and not latent ability is likely to contribute to student success.

How to use the work in your teaching

Attribution theory is probably most useful when working with students who have experienced repeated academic failure and have low motivation. Those types of students can often become trapped in a negative cycle where learned helplessness takes over and their behaviour becomes a self-fulfilling prophecy. With students like this, it is crucial to address fundamental beliefs about their performance in order to improve future performance, and so a coaching approach where they're asked a series of questions with a period of reflection can yield positive results. The kinds of questions teachers might ask are:

Five key questions for demotivated students

1. What happened in that test?
2. How did you feel about it? (primitive emotion)
3. Is this something to do with you or something else? (internal/external)
4. Is this reason fixed or does it change over time? (stable/unstable)
5. Can you change this and if so, how? (controllability)

It may be the case that there are genuine external/uncontrollable factors which have affected student performance such as the difficulty of a particular test or just plain bad luck, but the crucial point is that their *perception* of the cause is more significant than the *actual* cause. The more a student feels that they have no control over a situation, the less they are likely to respond positively to that situation. The vast majority of students are doing tasks that are within their capability given a relatively constructive set of personal conditions, proper instruction, and the requisite amount of effort.

OWNERSHIP
Students need to feel they have control

A vital aspect of attribution theory is the extent to which individuals feel they have *ownership* over a situation. If a student has a misconception about their academic performance, citing internal causes such as a lack of ability or external ones like teacher bias as a reason for underachievement, it can be transformative to shift their thinking towards variables that they can do something about such as increased effort, skills, and knowledge, all of which they can change with the right approach.

Takeaways

- When attributing academic success or failure to particular causes, there are three common properties: locus, stability, and controllability.
- The *perceived* cause of academic performance is as significant as the *actual* cause.
- The relative stability of a cause affects how students will "expect" success in the future.
- Student's emotional response to performance can profoundly affect future motivation.
- It is important to shift student thinking away from uncontrollable factors to controllable ones.
- Constant positive praise can dilute the effect of that praise over time.

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Suggested readings and links

USEFUL PRIMER OF ATTRIBUTION THEORY WITH POSSIBLE APPLICATIONS.

AVAILABLE FROM HTTPS://WWW.INSTRUCTIONALDESIGN.ORG/THEORIES/ATTRIBUTION-THEORY/.

MCLEOD, S.A. (2012). *ATTRIBUTION THEORY*.

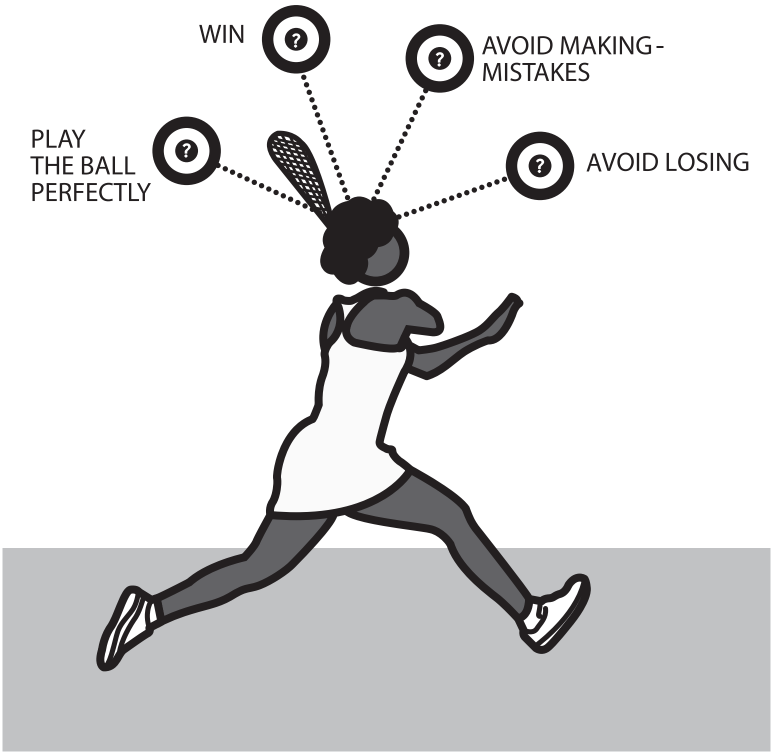
AVAILABLE FROM HTTPS://WWW.SIMPLYPSYCHOLOGY.ORG/ATTRIBUTION-THEORY.HTML.

ATTRIBUTION THEORY – BASIC COVARIATION (VIDEO FROM KHAN ACADEMY).

AVAILABLE FROM WWW.KHANACADEMY.ORG/TEST-PREP/MCAT/INDIVIDUALS-AND-SOCIETY/PERCEPTION-PREJUDICE-AND-BIAS/V/ATTRIBUTION-THEORY-BASIC-COVARIATION.

16 WHERE ARE WE GOING AND HOW DO WE GET THERE?

GOAL ORIENTATION



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16 WHERE ARE WE GOING AND HOW DO WE GET THERE?

PAPER "Multiple goals, multiple pathways: The role of goal-orientation in learning and achievement"[1]

QUOTE *"Future research on achievement goals needs to move beyond a simplistic mastery goals (good) versus performance goals (bad) characterization to consider multiple goals, multiple outcomes, and multiple pathways to learning and achievement in multiple contexts."*[2]

Why you should read this article

People who seem to be doing the same thing are often doing it based on different reasons. Take practising on a squash court. While some people might go to the squash court or sign up for lessons because they want to master the strategies, tactics, and techniques of playing the game well (i.e. they want to master the game), others might seemingly do the same thing because they want to win (i.e. they want to be better than others in the game). While some people might spend a lot of time practising alone and with others because they don't want to make silly mistakes when they play (i.e. they're trying to avoid mistakes), others also spend a lot of time practising to ensure that they don't play worse than others (i.e. they're afraid of losing). All four of these squash players have different motivations to take lessons and practice. In research into the people's motivation (and students are people), we try to take this into account. We also try to look at other things that influence what they do and why they do it, such as whether people think that they are capable of achieving their goals and to what extent they can influence the outcome. We came across some of these things in Chapter 13, Beliefs about intelligence can affect intelligence

1 PINTRICH, P. R. (2000A). MULTIPLE GOALS, MULTIPLE PATHWAYS: THE ROLE OF GOAL ORIENTATION IN LEARNING AND ACHIEVEMENT. *JOURNAL OF EDUCATIONAL PSYCHOLOGY, 92*, 544–555.

2 PINTRICH, P. R. (2000B). A MOTIVATIONAL SCIENCE PERSPECTIVE ON THE ROLE OF STUDENT MOTIVATION IN LEARNING AND TEACHING CONTEXTS. *JOURNAL OF EDUCATIONAL PSYCHOLOGY, 95*, 667–686, QUOTED FROM P. 676.

and Chapter 15, How you think about achievement is more important than the achievement itself. In addition to these two important determinants of what we actually learn, we can also look at the goals that students have when they study. Paul Pintrich shows in his article on goal orientation that students have different reasons for starting on a task that can be divided into two categories: namely learning or performing.

Abstract of the articles

ADAPTIVE OUTCOMES
Results which change based on process

Mastery goals have been linked to adaptive outcomes in normative goal theory and research; performance goals, to less adaptive outcomes. In contrast, approach performance goals may be adaptive for some outcomes under a revised goal theory perspective. The current study addresses the role of multiple goals, both mastery and approach performance goals, and links them to multiple outcomes of motivation, affect, strategy use, and performance. Data were collected over 3 waves from 8th and 9th graders (N = 150) in their math classrooms using both self-report questionnaires and actual math grades. There was a general decline in adaptive outcomes over time, but these trends were moderated by the different patterns of multiple goals. In line with normative goal theory, mastery goals were adaptive; but also in line with the revised goal theory perspective, approach performance goals, when coupled with mastery goals, were just as adaptive.

The article

THREE COMPONENTS OF MOTIVATION:
- Value
- Expectancies
- Affect

At the end of the 1980s – thanks to Paul Pintrich – goal theory emerged to explain student motivation in an educational setting. In his view, this motivation had three components, namely: "(a) value (including task value and achievement goal orientation), (b) expectancies (including control beliefs, self-efficacy beliefs, and expectancy for success), and (c) affect (focusing primarily on test anxiety and self-esteem)" (Harackiewicz & Linnenbrink, 2005, p. 76). Combining multiple theoretical perspectives, he noted the importance of integrating the study of task value with achievement goal research, as a learner's achievement goal orientation might help determine her/his achievement behaviour, while value would affect the strength of the learner's behaviour.

Mastery versus performance goals

Building on Dweck (1986) and Dweck and Leggett's (1988) work on motivation and learning (see Chapter 13, Beliefs about intelligence can affect intelligence) Pintrich's work concerned the motivation that students need to start working on a task at all: the so-called goal orientation. He distinguished between mastery goals (goals aimed at learning and understanding the material) and performance goals (goals focused on performance). Mastery-oriented students start working on a task because they want to learn and understand how to carry out the task and are intrinsically motivated to do so. On the other hand, performance-oriented students are focused on the grade that they can earn by completing a task; they start working on a task to score and, preferably, get a better grade than their classmates. Their motivation is extrinsic. In Pintrich's (2000a) words:

> mastery goals orient students to a focus on learning and mastery of the content or task … In contrast, performance goals orient students to a concern for their ability and performance relative to others and seem to focus the students on goals of doing better than others or of avoiding looking incompetent or less able in comparison to others. (p. 544)

Goal orientation is domain specific

It's important to note here that a person's goal orientation isn't general, but depends on the subject area or even the specific task because goal orientation is affected by a student's feelings of efficacy, task value, interest, positive affect, etc. A high school student learning words in a foreign language might focus on getting good grades on the weekly exams so as to score better than classmates, but be intrinsically motivated in mathematics and simply want to master the material, regardless of how others perform.

In addition to the distinction between mastery and performance orientation, Pintrich brings in a second important difference in goal orientation, namely approach and avoidance. While important for both mastery and performance orientations, this difference is especially important for the latter. If your performance goals are approach oriented, then you want to do better than others and demonstrate your ability and competence (i.e. you want to outperform others). In contrast, if your performance goals are avoidance oriented, then you want to avoid looking stupid or incompetent (i.e. you want to avoid looking bad). This difference also exists with regard to mastery orientation. If your mastery goals are approach oriented, then you'll work on a task because you want to really learn how to do something well. In contrast, if your mastery goals are avoidance oriented, then you'll work on a task because you're afraid that if you don't, you won't master the material or learn everything that can be learnt (see Tables 16.1 and 16.2).

APPROACH ORIENTED
Demonstrate ability

AVOIDANCE ORIENTED
Avoid looking bad

Research carried out by Pintrich and his colleagues has revealed that these four different goal orientations are related to different outcomes in the class such as grades, motivation, choice of strategy, and so forth.

PERFORMANCE ORIENTATION
Concerned with exam results

What does this all mean? Let's first take a look at those learners with a performance approach goal orientation. Research (e.g. Senko, Hulleman, & Harackiewicz, 2011) has revealed that these learners are motivated

TABLE 16.1
FOUR DIFFERENT GOAL ORIENTATIONS WHEN TACKLING A TASK

	Mastery goals	**Performance goals**
Approach orientation	Focus on mastering the task Own subjective or personal standards for success, progress, understanding	Focus on performing/looking better than others Normative standards such as grades, class ranking
Avoidance orientation	Focus on avoiding misunderstanding Own subjective or personal standards for what isn't good	Focus on avoiding appearing to be stupid and/or worse than others Normative standards such as grades, class ranking

TABLE 16.2
FOUR DIFFERENT GOAL ORIENTATIONS WHEN TACKLING A TASK WITH RESPECT TO A SUBJECT

	Mastery goals	**Performance goals**
Approach orientation	I want to be able to read and write well in Spanish so I practice this a lot, both at school and at home.	I practice the Spanish words in the workbook every day because I want to get the best grade in Spanish.
Avoidance orientation	I do all of the Spanish exercises in the workbook because I'm afraid that if I don't, then I won't learn to read and write Spanish well.	I practice the Spanish words in the workbook every day because otherwise I'll get the lowest grade in my class.

to be the best (not the best that they can be but the best within their class), to appear to be the smartest and most competent in the class. As a result, they work hard, put in a lot of effort in exceeding their peers, and generally score well on exams. Learning is not their goal per se; they work to learn but for what we might call "the wrong reason". These learners work hard, but aren't very engaged in their learning and often resort to superficial learning strategies aimed at showing proficiency like memorising.

A bigger problem are those learners with a performance avoidance goal orientation. These learners try, at all costs, to avoid making mistakes so as not to appear to be incompetent. They are generally very anxious, study in a disorganised way, avoid help offered (accepting help is seen as an admission of incompetence), often get low marks, and have little interest in their work. In their studies, they'll avoid taking risks so as to lessen their chances of failing, leading them to take well-trodden paths and choose tasks that are simple and don't challenge them. If they fail, then they often become frustrated and give up.

MASTERY ORIENTATION
Learning and understanding as ends in themselves

Mastery learners, on the other hand, are less of a problem, regardless of whether they have an approach or an avoidance orientation. In their research, Senko, Hulleman, and Harackiewicz (2011) showed that students who are focused on mastering a task, that is, have a mastery orientation, are very positive about their learning process. They often enjoy their lessons, continue when tasks become difficult, find help easily, can manage themselves well, use in-depth learning strategies, experience positive emotions in the classroom, and see the assignments they have to make as valuable. According to Lisa Bloom (2009), "mastery goals may be optimal for academic engagement" (p. 179). Learners with a mastery goal orientation tend to have higher feelings of self-efficacy, become – via their success – more self-motivated, try harder and work longer, and seek challenges. When they "fail", they don't give up, but rather try harder.

Mastery and performance are not mutually exclusive

CAN STUDENTS PURSUE MULTIPLE GOALS AT THE SAME TIME?

Pintrich (2000a) asked students to fill in a questionnaire about their goal orientation. It showed that students can pursue multiple goals at the same time. They can work for a subject because they want to master the subject, but also because they want to get a good grade. These two orientations are, thus, not mutually exclusive. In fact, pursuing both goals at the same time should yield a theoretical advantage; these learners are not only intrinsically motivated, but also want to get good grades. The question is to what extent it's possible for students to pursue both goals, because the different goals also require a different focus during learning. This can be solved if learners, for example, focus on learning during the semester, but shift their focus to getting a good grade when studying for a test (Senko, Hulleman, & Harackiewicz, 2011).

Conclusions/implications of the work for educational practice

Goal theory gives teachers insight into how students can think and how they can perform tasks. It helps to understand why students do or do not do certain things. The results show that certain orientations in learning are indeed better than others. An orientation to mastery itself will help students develop an intrinsic motivation for a certain subject or task. By learning for mastery they will learn for the long-term and not just for a test. A focus on performance can help students perform better and help them get the best out of themselves, but is often short-term learning. The student learns for the exam, gets a good grade, and then often forgets what has been learnt. Nicholas Soderstrom and Robert Bjork (2015) discuss this in their article, "Learning versus performance: An integrative review". They write:

> The primary goal of instruction should be to facilitate long-term learning – that is, to create relatively permanent changes in comprehension, understanding, and skills of the types that will support long-term retention and transfer. During the instruction or training process, however, what we can observe and measure is performance, which is often an unreliable index of whether the relatively long-term changes that constitute learning have taken place.
> (p. 176)

RETENTION AND TRANSFER Not just remembering information but being able to use it

Both orientations can occur at the same time and both can help students with their learning process. The combination is the most beneficial as the student gets a good grade while learning for the long-term. Only the avoiding orientations have the opposite and deleterious effect.

How to use the work in your teaching

Learning is a risky business because, by definition, learning means doing something you don't know how to do. It is, thus, important to make it less risky by reducing the cost of failure. There are a number of ways that you can do this. You can, for example, make sure that your reaction to a mistake is one of interest and support rather than of criticism. It's also a good idea to give your students the chance to view their "failures" (i.e. mistakes) constructively. Give them additional opportunities to learn what they can't do without harsh consequences, giving them the opportunity and even the drive to identify their mistakes and correct them.

Failure can be a powerful learning tool when viewed constructively

Of course, as a teacher, you also have to grade your students, so make sure that your students maintain a positive outlook and don't act based on fear or other negative emotions. Grades can stimulate learners if they feel that a good grade is within their reach if they do their best, but grades are counterproductive if they make students anxious or insecure, especially if they have an avoidance orientation. In that case focus on increasing their intrinsic motivation by using formative assessment (see Chapter 24, Assessment *for*, not *of* learning), giving good feedback (Chapter 25, Feed up, feedback, feed forward), and giving them tasks at their own level (Chapter 17, Why scaffolding is not as easy as it looks). To improve intrinsic motivation, emphasise that learning is not about grades; that you're more interested in whether they understand how to solve a task and how to apply the right strategy than whether the answer is correct (see Figure 16.1). In other words, move the focus more to the learning process and less on the result. If you do this, then mistakes may no longer be seen as something to be anxious about and to avoid, but rather as interesting because you can learn from them.

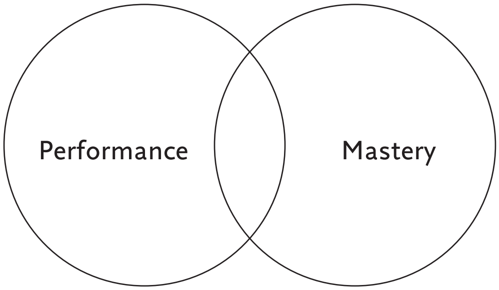

FIGURE 16.1 THE SWEET SPOT WHERE PERFORMANCE MEETS MASTERY

Takeaways

- There are two different goals that play a role in how the learner studies: they can want to master a subject or they can want to perform well.
- Both goals can have positive consequences: the mastery goal learners are often intrinsically motivated, the performance goal-oriented learners often achieve higher marks.
- Learning because you are trying to avoid failure (or even not mastering the subject) has negative effects on the learning processes of students.
- Students can pursue both orientations (i.e. mastery and performance) at the same time.
- Teach students that making mistakes is neither scary nor bad because you can learn from those mistakes.
- This means that you need to make the classroom a safe place so that students will take the risks involved in learning.
- When you give your students a learning task, design them just beyond their current ability level but within their reach.
- Try to encourage performance goal approach learners to learn in a deeper way (i.e. not just memorise, but understand) and to discourage "avoiders" from choosing the easiest way for the easiest tasks.

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***GOAL ORIENTATION THEORIES*. IN THIS VIDEO PROFESSOR BRETT JONES SHOWS WHAT GOAL THEORY IS AND ITS IMPLICATIONS FOR EDUCATION.**

AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=IONAS7_9Q34.

THE MARSHMALLOW TEST – THIS "TEST" (MISCHEL, EBBESEN, & RASKOFF ZEISS, 1972) WAS MEANT TO DETERMINE HOW YOUNG CHILDREN DEAL WITH FRUSTRATION AND DELAYING GRATIFICATION.

AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=QX_OY9614HQ.

PART IV

WHICH LEARNING ACTIVITIES SUPPORT LEARNING

Back in the dark ages of teaching, we thought of students as either blank slates or sponges. They know nothing when they begin and we offer them information that they can suck up like a sponge sucks up water. Languid and completely dependent on others, they merely respond to external stimuli without thinking.

Admittedly, sometimes this behaviourist approach works pretty well. Think of practising addition and multiplication tables by repeating them together with the rest of the class in first or second grade or repeatedly making maths sums through a computer program (i.e. drill-and-practice). This way you learn to automatise math skills without having to think about it too deeply, which makes more complex math tasks a lot easier.

But since the 1960s we know that in most cases students are neither blank slates nor sponges and that learning really requires thinking and focused learning activities. In this section we cover some of the ways that teachers can support learning activities that students must undertake to effectively, efficiently, and enjoyably learn. Topics covered include the role of scaffolding for learning, tutoring and other instructional techniques, effective problem-solving, and mathemagenic activities (those activities that give birth to learning).

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17 WHY SCAFFOLDING IS NOT AS EASY AS IT LOOKS

SCAFFOLDING

DOI: 10.4324/9781003395713-21

17 WHY SCAFFOLDING IS NOT AS EASY AS IT LOOKS

PAPER "The role of tutoring in problem solving"[1]

QUOTE *"Well executed scaffolding begins by luring the child into actions that produce recognizable-for-him solutions. Once that is achieved, the tutor can interpret discrepancies to the child. Finally the tutor stands in a confirmatory role until the tutee is checked out to fly on his own".*[2]

Why you should read this article

How do young meerkats learn to hunt and eat scorpions without being killed? More importantly, how do adult meerkats "teach" them? Well first the adults provide them with a dead scorpion with the stinger removed to allow them to begin the process. Next they bring them a dead scorpion with the stinger attached to take things up a notch, and finally they bring them a live scorpion with all guns blazing to complete their training. This would seem that meerkats are expert teachers who can differentiate learning to suit the learner but actually it is thought that they are responding to pup calls and carrying out this task on instinct instead of complex thought.[3] What makes teaching a distinctly human affair is characterised by what Gergely and Csibra (2011, p. 1149) describe as "the cognitive mechanisms that enable the transmission of cultural knowledge *by communication* between individuals".

Intentional teaching versus instinctive teaching

At the time this paper was written, there was a belief that humans were really the only species who truly teach in an "intentional" way (Bruner, 1972; Hinde, 1971). The young meerkat may well be learning how to hunt scorpions but to what extent are they being purposefully *instructed*

1 WOOD, D., BRUNER, J., & ROSS, G. (1976). THE ROLE OF TUTORING IN PROBLEM SOLVING. *JOURNAL OF CHILD PSYCHOLOGY AND CHILD PSYCHIATRY, 17*, 89–100.
2 IBID., P. 96.
3 WWW.YOUTUBE.COM/WATCH?TIME_CONTINUE=60&V=48RHTGTNXRI.

through communication? The authors of this paper, David Wood, Jerome Bruner, and Gail Ross, sought to explore how purposeful and communicative instruction happens between humans, specifically an adult and a group of 3-, 4-, and 5-year-olds as they try and solve a problem using wooden blocks.

Prior to the publishing of this article, problem-solving or skill acquisition activities were traditionally seen as lone activities, and social interaction was usually framed as modelling and imitation. However situations where there is a tutor or teacher involved (i.e. someone who is an expert and knows how to resolve a particular problem) involve a much more nuanced dynamic. The term given to this process by the authors was "scaffolding", and in doing so they created one of the most influential and commonly used terms in teacher training today. However as we shall see, the term covers a highly complex process requiring great skill and deftness from the teacher and, like the meerkat learning to hunt scorpions, it can very easily go wrong if not done properly.

SCAFFOLDING Guided support given to learners which is systematically removed as they learn

Abstract of the article

The study examines the process of tutoring where an adult or expert assists someone who is not an adult or an expert. This is explored through a task where an adult tutor teaches children aged between 3 and 5 to build a model of something which is, at first, outside their range of ability. This tutorial process is somewhat different to a traditional one where the expert knows the answer and the tutor does not. We examine a 'natural' tutorial to further understanding regarding natural and automated teaching approaches. This study is not the testing of an hypothesis but rather a systematic description of how the children react to these different forms of assistance. The focus here is on problem-finding activities as opposed to problem-solving activities (Mackworth, 1965).

The article

This article focuses on a study in which the authors examined how 30 children aged 3, 4, and 5 responded to an adult teacher giving them assistance in a task where they had to fit together 21 blocks into a pyramid. The tasks were designed to be entertaining in order to engage the children but also challenging and within their capabilities. A central aim of the teacher was to allow the children to figure things out for themselves as much as possible, and to provide only verbal support initially and intervene only if necessary. The relative success or failure of the child would determine the actions of the teacher.

Provide support and intervene when necessary

As the children attempted to solve the problem, the teacher responded to three types of behaviour. First, if the child ignored the task and simply played with the blocks she would present constructed pairs of blocks to get them started. If the child had begun to construct but had overlooked a feature, the teacher would gently use a verbal cue to get them back on task. Lastly, if the child began to construct in the way modelled to them, the teacher would allow them to correct any errors that they encountered.

THE EXPERIMENTAL TASK

The task was to build a pyramid of blocks that would fit together (see Figure 17.1). After 5 minutes of playfully experimenting with the blocks, the actual task began. Usually the teacher then showed the child how to connect two blocks, but, if they had already connected two blocks together, she picked them up as an example and asked the student to make more. If the student simply ignored the question, the teacher showed the connected blocks to them again. If the child had started with the blocks but forgotten something, the teacher drew attention to it verbally. Where possible, she let the student go ahead.

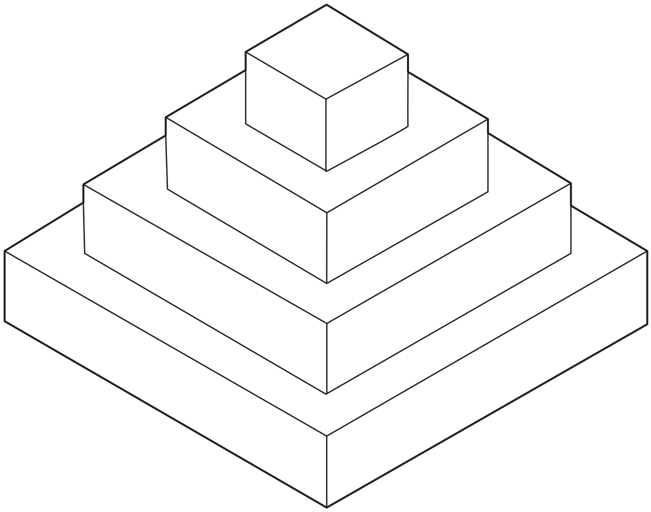

FIGURE 17.1
A REPRESENTATION OF THE BLOCK TASK BY WOOD, BRUNER, AND ROSS (1976)

As you might expect, the behaviour varied between the 3-, 4-, and 5-year-olds and each group had different needs. Interestingly, there was a difference in how effective the help offered was. For example, when teachers attempted to explain the solution to the 3-year-olds, it was only effective one out of every five times; however this method worked more than 50% of the time with 5-year-olds. Clearly, different age groups required different levels of assistance. For the 3-year-olds, the proportion of completely unassisted constructions was 64–65%, for the 4-year-olds it was 79.3%, and for the 5-year-olds it was 87.5%.

The researchers concluded that the role of the teacher with the 3-year-olds was mainly to keep them on task. It will come as no surprise to any parent that these children completely ignored the teacher's suggestions, despite the fact that they could recognise the beginning of an effective solution such as fitting two blocks together. With the 4-year-olds, there was more listening to the teacher, who was able to provide encouragement and correction as the task proceeded. The 5-year-olds were able to ask the teacher for support and check their solutions. Crucially, the authors claim that scaffolding "withers away" for the 5-year-old children and they speculate that for a 6-year-old, that support would be unnecessary.

From these observations, the authors define scaffolding as helping the child into actions that have a *recognisable-for-him* [*sic*] solution. In other words, the teacher is able to assist the child in recognising the journey they are about to take. As the authors state,

> *comprehension of the solution must precede production*. That is to say, the learner must be able to recognise a solution to a particular class of problems before he is himself able to produce the steps leading to it without assistance.
>
> (p. 90)

UNDERSTANDING THE DESIRED OUTCOME IS KEY
Comprehension precedes production

The important point here is that the child must understand the relationship between means and ends before they begin the task, or as the authors neatly put it, "comprehension precedes production" (p. 94).

Another important element of this process is the way in which the teacher needs to keep two opposing things in mind at once. Not an easy task, but then teaching is a complex business. Problem-solving has a deep structure that is not always apparent until nearing the end of production and in providing effective scaffolding, the teacher needs to not only bear in mind the deep structure and correct solution but also the tutee's current conception of that deep structure and possible solution. Only then will a teacher be able to offer the right form of assistance. As the authors state, this means that, in effect, the teacher needs two theories to bear in mind during instruction.

TWO THEORIES
Instructor must keep in mind the deep structure and the current state

THE TWO THEORIES

> Without both of these, he [*sic*] can neither generate feedback nor devise situations in which his feedback will be more appropriate for *this* tutee in *this* task at *this* point in task mastery. The actual pattern of effective instruction, then, will be both *task* and *tutee* dependent, the requirements of the tutorial being *generated* by the interaction of the tutor's two theories. (p. 94)

Conclusions/implications of the work for educational practice

The six functions of scaffolding

The key element of this article is the close definition of scaffolding, which the authors then systematically describe more precisely as having six different "functions":

1. *Recruitment*: The teacher must somehow elicit the problem solver's interest in the task and the kinds of skills needed to complete it.
2. *Reduction in degrees of freedom*: This essentially refers to the teacher simplifying the task to a much smaller number of possibilities so that the tutee is not overwhelmed. For the confused novice, the choice between a right step and an obviously wrong one is much easier than a wide array of different steps which they can't tell apart.
3. *Direction maintenance*: Keeping the tutee interested and focused on the task in hand is a vital part of scaffolding, especially when (s)he would experience success on a simpler part of the overall task such as pairing two blocks and want to keep doing that repeatedly as opposed to taking the next step.
4. *Marking critical features*: The teacher should mark out or emphasise key milestones in the development of the task. The key thing here is to make visible discrepancies between where the child is at the moment and where they need to go next.
5. *Frustration control*: Having empathy concerning the possible frustration of the child is a vital aspect of scaffolding and requires deft skill as there is a danger that if the teacher makes it too easy, then the child can develop too much dependency on the teacher.
6. *Demonstrating*: It is not enough to simply model solutions to a task, the effective teacher will perform an "idealisation" of the task to be performed. This can be an execution of the problem to be solved by the child, who may have already partially executed the problem. By elaborately performing the task, the teacher allows the child to more easily imitate the steps required to solve the problem.

COMBINING SKILLS

Higher versus lower order skills

When solving a problem, there is a hierarchical skills structure. Before you can take on a higher level of skills, you must first master the underlying skill. If we translate this into the block problem that Wood and his colleagues used, you could say that pupils first have to learn how to recognise blocks and learn how to connect them. Once they have mastered these two skills, they can combine them into the skill where they immediately take two matching blocks and connect them. It is therefore important that the lower order skills are achieved first.

How to use the work in your teaching

Scaffolding is a highly complex process requiring a wide range of skills from the instructor or teacher. To properly scaffold, the teacher needs to possess and show a range of emotional skills such as empathy and patience. (S)he also needs to know when and how to provide close support and also when and how to take it away. Finally, they need to be able to hold two mental models at once; their own mental model of the overall problem to be solved and crucially, the child's mental model to be solved. Leading the child to being able to see the discrepancies between where they are at in their own journey and the problem to be solved is the key skill required and not an easy thing to do. Rather like the delicate task of building a pyramid of blocks used in this study, if any part of the scaffolding is shaky, then the whole thing can come crashing down. Possibly the first thing to think about when introducing novel things to your students, of course after determining what the learning goal is, is to not make the lesson too long. Model and/or demonstrate what the student needs to do. We know that modelling, especially when you also verbalise what you're doing, including your thought processes (primarily for older students), is a very effective way of teaching something new. This is closely related to what is known as the *zone of proximal development* (Vygotsky, 1978). You then need to give your student sufficient time to practise constantly checking for understanding or skill, but – and here's the complication – don't let them flounder too long. At this point you need to give just-in-time and "level appropriate" assistance. Finally, remove the scaffolding when the learner is capable of doing it alone!

ZONE OF PROXIMAL DEVELOPMENT
Difference between what the learner can do without guidance and what they can do with it

Takeaways

- Pupils from different levels need different ways of guidance while solving a problem.

- Scaffolding is actually a form of differentiation.
- Students must first master a low-level skill before they can handle a skill of the next level.
- With scaffolding you offer the right support (i.e. support that is just above the level of the student; this helps you to reach a higher level for the student).
- The scaffolding must be reduced as the pupil can do it alone.
- It's crucial to not only understand the problem to be solved but also to be able to see the learners' conceptions of the problem to be solved and help them see the difference.

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A VIDEO ABOUT SCAFFOLDING CHILDREN'S LEARNING IS

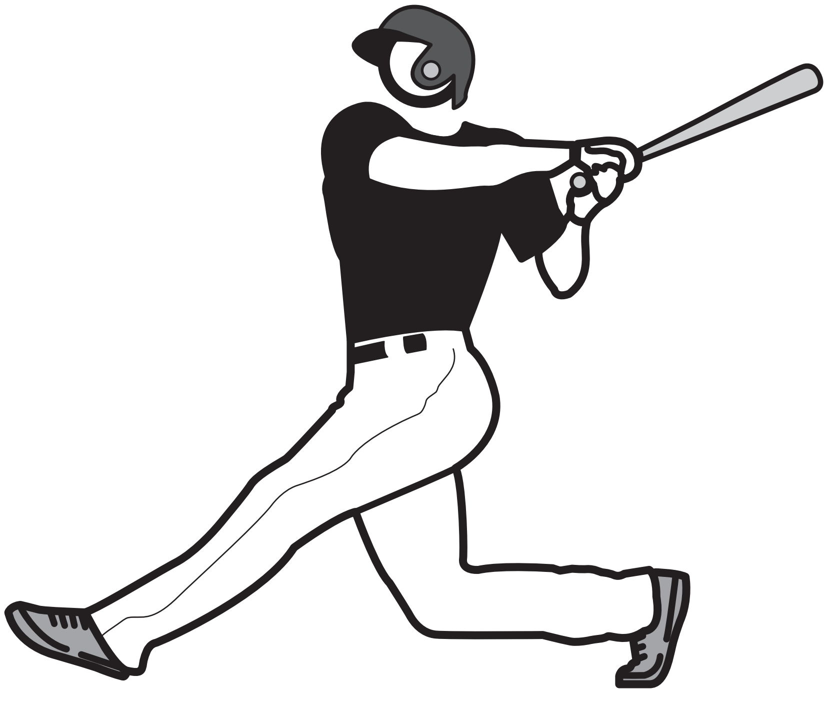
AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=5HWDBSX_KDO

JEROME BRUNER – HOW DOES TEACHING INFLUENCE LEARNING? JEROME S. BRUNER HAD JUST TURNED 99 LESS THAN A WEEK BEFORE THIS VIDEO WAS FILMED.

AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=ALJVAUXQHDS

18 THE HOLY GRAIL

ONE-TO-ONE TUTORING



DOI: 10.4324/9781003395713-22

18 THE HOLY GRAIL

WHOLE CLASS TEACHING AND ONE-TO-ONE TUTORING

PAPER "The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring"[1]

QUOTE *"The tutoring process demonstrates that most of the students do have the potential to reach this high level of learning. I believe an important task of research and instruction is to seek ways of accomplishing this under more practical and realistic conditions than the one-to-one tutoring, which is too costly for most societies to bear on a large scale. This is the '2 sigma' problem".*[2]

Why you should read this article

What is the optimum strategy for batting in baseball? If a home run gives the greatest reward, why wouldn't a player try to hit a home run every time? Well the conditions which allow for a player to hit a home run are relatively rare and run a high risk of punishment if not executed exactly right. Attempting to swing for the fences every time can mean a player is struck out more often than not, and so the regular strategy is to vary one's game, incorporating a range of techniques that when performed alone might not deliver major results, but when used in combination, can add up to something far greater than the individual sum of its parts.

One-to-one (1:1) tutoring is the teaching equivalent of a home run. As this article shows, it delivers far superior results than conventional teaching (the average tutored student's performance is above 98% of pupils in a conventional class), however it's a costly enterprise and so it's rare that the average student gets to be tutored individually. For the most part, students are taught in classes averaging 25–30, and so the puzzle that Benjamin Bloom poses is: given that we cannot teach every pupil individually, which teaching methods will work *in combination* to provide

1 BLOOM, B. (1984). THE 2 SIGMA PROBLEM: THE SEARCH FOR METHODS OF GROUP INSTRUCTION AS EFFECTIVE AS ONE-TO-ONE TUTORING. *EDUCATIONAL RESEARCHER, 13*(6), 4–16.
2 IBID., P. 4.

2 SIGMA
Two standard deviations

the same results of individual tutoring? Bloom refers to this conundrum as the "2 sigma problem" and as we shall see, it's a problem with no clear solution.

Abstract of the article (abridged from introduction)

Two University of Chicago doctoral students in education, Anania (1982, 1983) and Burke (1984), completed dissertations in which they compared student learning under the following three conditions of instruction: 1. Conventional, 2. mastery learning, 3. tutoring [.] the most striking of the findings is that under the best learning conditions we can devise (tutoring), the average student is 2 sigma above the average control student taught under conventional group methods of instruction. The tutoring process demonstrates that most of the students do have the potential to reach this high level of learning. I believe an important task of research and instruction is to seek ways of accomplishing this under more practical and realistic conditions than the one-to-one tutoring, which is too costly for most societies to bear on a large scale. This is the "2 sigma" problem. Can researchers and teachers devise teaching–learning conditions that will enable the majority of students under group instruction to attain levels of achievement that can at present be reached only under good tutoring conditions?

The article

This article focuses on a study done by two doctoral students in which they compared student learning under three conditions:

1. *Conventional*. Students learn from a teacher in a regular class dynamic of around 30 students where tests are given periodically.
2. *Mastery learning*. Students in the same class size are given the same instruction and the same formative tests but are also given corrective procedures and parallel tests to indicate how well the students have mastered the subject matter.
3. *Tutoring*. Students learn from a teacher alone or in maximum groups of two or three. They are given the same formative tests but with the mastery format outlined previously.

MASTERY LEARNING
Pupils achieve prerequisite level before moving onto new content

Students were randomly assigned to one of the three conditions and the same amount of instruction was given to all three groups apart from the corrective work in the latter two groups. The study occurred over 11 periods of instruction over a three-week period.

As one might expect, there were notable differences in final achievement between the groups. The average student in the tutored group performed a lot better – about two standard deviations (2 sigma) above the control (conventional) group. The average student in the mastery learning group was about one standard deviation above the average of the control class.

WHAT ARE STANDARD DEVIATION AND EFFECT SIZE?

Standard deviation (*sd* or σ – the Greek letter sigma) is a number used to represent how measurements are spread out in relation to an average of a group or population. This can be heights, weights, achievement in school, etc. For IQ, for example, the population average is 100 and the standard deviation is 15. This means that an IQ of 85 or 115 differs 1 σ from the population and an IQ of 70 or 130 differs 2 σ. Also, 68.2% of the population falls within 1 σ of the average (thus between an IQ of 85 and 115) and 95.6% of the population within 2 σ (between 70 and 130; see Figure 18.1).

Effect size (*d*) is a measurement used to express the size of a particular effect, for example to quantify the size of the difference between two different teaching approaches. In general we speak of a small (d = 0.2), medium (d = 0.4), or large (d = 0.6) effect size. John Hattie defined d = 0.4 as the hinge point because in his studies he found that this effect size is approximately what one will see if we do nothing special but just measure achievement gains after one year of school (i.e. pure maturation[3]). That means if an intervention doesn't exceed this 0.4, you could have just as well done nothing and let the child age, and if it's less than 0.4, then it actually hindered learning.

STANDARD DEVIATION
How measurements are spread out

EFFECT SIZE
Size of the difference between two teaching approaches

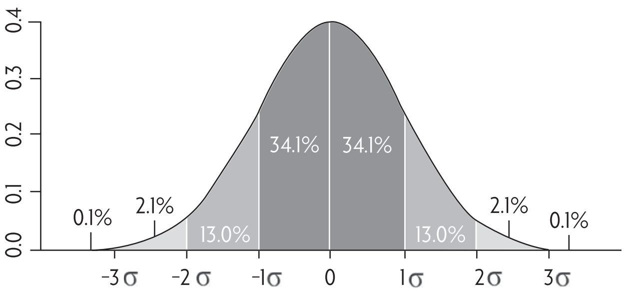
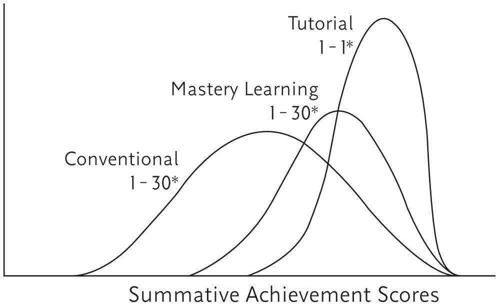


FIGURE 18.1
STANDARD DEVIATION

What is particularly striking is that the average tutored student score was above 98% of the students in the control class, meaning that the vast majority of students in this study have the capability to achieve a high level of learning under the right conditions (see Figure 18.2).

3 THIS IS ESPECIALLY THE CASE IN CHILDREN.

FIGURE 18.2 ACHIEVEMENT DISTRIBUTION FOR STUDENTS UNDER CONVENTIONAL, MASTERY LEARNING, AND TUTORIAL INSTRUCTION (FROM BLOOM, 1984)



The question then posed by Bloom is: Can we develop a way of achieving the same kind of results from the tutoring conditions under *group* teaching conditions? Bloom refers to this dilemma as the "2 sigma problem".

The elephant in the room here of course is the fact that modern societies can't afford to have 1:1 tutors for every single student. However, Bloom sensationally claims that if research on the 2 sigma problem can yield practical methods that the average teacher can learn in a short period of time with little more spending than there is on conventional approaches, then it would be "an educational contribution of the greatest magnitude". In a very real sense, Bloom is searching for the holy grail of education, so what does he suggest might be these practical methods?

ALTERABLE AND STATIC VARIABLES Things you can change and things you can't

Well Bloom makes a distinction between things you *can* change, which he calls "alterable variables", and things you probably *can't* change, which he terms "stable" or "static variables". Alterable variables are things like the quality of teaching, use of time, formative testing, rate of learning, and home environment (see Table 18.1). Stable variables are elements such as the personality of the teachers, measures of intelligence (though this is highly debatable!), the formal tests to be sat, and the socioeconomic status of families. However not all of these variables are equal. With the help of various meta-analyses, Bloom created a table of alterable variables, with 1:1 tutoring at the top with an effect size of 2 and things like cooperative learning lower down with an effect size of 0.8. His central claim is that there is a synergistic effect in the combination of these alterable variables put together. In other words, the right mix of things that you *can* do something about could have a dramatic impact on student learning. Put even more simply, though 1 + 1 usually equals 2, in this case it 1 + 1 might equal more than 2. The combination of two or more elements produces an effect greater than their individual components.

SYNERGISTIC EFFECT Cumulative interaction of two or more elements

So what is it about whole class instruction that makes it so inferior to 1:1 tutoring? Well for a start, Bloom suggests that many teachers are only getting feedback on what students are learning from a small sample of high achievers in the class, usually the ones who raise their hands. This

TABLE 18.1 THE EFFECTS OF SELECTED ALTERABLE VARIABLES ON STUDENT ACHIEVEMENT FROM BLOOM (1984) ADAPTED FROM WALBERG (1984)

		Effect size	**Percentile equivalent**
	D Tutorial instruction	2.00	98
	D Reinforcement	1.20	
	A Feedback-corrective (ML)	1.00	84
	D Cues and explanations	1.00	
(A)	D Student classroom participation	1.00	
	A Student time on task	1.00[a]	
	A Improved reading/study skill	1.00	
	C Cooperative learning	.80	79
	H Homework (graded)	.80	
	D Classroom morale	.60	73
	A Initial cognitive prerequisites	.60	
	H Home environment intervention	.50[b]	69
	D Peer & cross-age remedial tutoring	.40	66
	D Homework (assigned)	.30	62
	D Higher order questions	.30	
(D)	B New science & math curricula	.30[b]	
	D Teacher expectancy	.30	
	C Peer group influence	.20	58
	B Advance organisers	.20	
	Socio-economic status (for contrast)	.25	60

Note
[a] Object of change process:
A: Learner / B: Instructional material / C: Home environment or peer group / D: Teacher
[b] Averaged or estimated from correlational data or from several effect sizes.

can be contrasted with 1:1 tutoring where at every point, the learning is checked and more explanation and clarification given if needed. To address this, he advises strategies that are fairly commonplace today, such as getting feedback from a random sample of students in the lesson (often referred to as a "hands down policy" or "cold calling") but at the time these ideas would have been novel to many teachers. His main idea here was not to change the methods of teachers but rather to encourage them to teach to a cross-section of the class as opposed to the ones who are naturally more involved.

So what is the magic recipe? What things should be combined to achieve an effect as powerful as 1:1 tutoring? One thing Bloom is certain about is that one of them should be mastery learning, or what he terms the "feedback-corrective" process. Mastery learning is an instructional approach where students are tested on material learned and if they get less than 90% in a test then they are given additional instruction on that material until they get over 90% or until they have "mastered" the content. In Table 18.1, the variables are classified as A (the learner), B (the instructional material), C (the home environment), and D (the teacher and teaching process). Interestingly, Bloom speculates that two variables from different categories used together may be additive whereas two variables from the same categories might not be as effective. Variety is the spice of learning it seems.

"FEEDBACK-CORRECTIVE" PROCESS
Tutor identifies errors and provides explanation and clarification

Conclusions/implications of the work for educational practice

Essentially, Bloom is asking how we can teach whole groups of children in a way that essentially might be as effective as 1:1 tutoring. His solution to this is, first, that you need to combine a variety of different approaches, but not all approaches are equal. Although he advocates a variety of different techniques (some of which are vague discussions around critical thinking and student engagement), one firm suggestion is mastery learning as one of the methods to definitely be included. He then later suggests a method called cue-participation-reinforcement (Nordin, 1979, 1980) – an approach which seeks to provide better guidance to teachers on more effective cues (explanations) and to generate greater student engagement. The combination of these two approaches, Bloom suggests, might lead to an effect size of 1.7 on the higher mental processes (Tenenbaum, 1982). Although this is still short of solving the 2 sigma problem, it does at least come close.

CUE-PARTICIPATION-REINFORCEMENT
Behaviourist model of teaching to which Bloom added corrective feedback

The key idea in this article is that there are things that we can do something about in instruction and things we can do nothing about and that we should not only focus on the things we can do something about, but also focus on the two or three most effective things and do them together. Broadly speaking, Bloom is advocating for a more personalised form of learning where individualised instruction is tailored to the needs of individual students based on performance (which is the dynamic which makes 1:1 tutoring so effective), however the problem of opportunity cost still remains. Although mastery learning is possible with whole class conventional teaching, it's still time-intensive to have to go over material at different rates for different pupils. This is why Bloom's 2 sigma problem is cited as a guiding principle for the use of technology in personalised instruction. Despite the promises of Silicon Valley, however, it's a riddle that hasn't been solved yet and so the search for the holy grail continues.

How to use the work in your teaching

As well as a discussion on instructional methods, this article also discusses the nature of instructional materials used, for example the use of more sophisticated textbooks that take into account the sequential nature of topics and how they allow for schemata to be built. Also discussed are pre-organisers or advance organisers (see Chapter 11, What you know determines what you learn). The use of these materials has an effect size of 0.2, which is not likely to add much to solving the 2 sigma problem, however Bloom claims that it is likely that:

> a combination of advance organizers at the beginning of a new topic, further organizational aids during the chapter or unit, as well as appropriate questions, summaries, or other organizational aids at the end of the unit may have a substantial effect on the student's learning of that chapter.
>
> (p. 9)

Put simply, introducing knowledge organisers at the *beginning* of a topic of study is likely to be very beneficial for learning, not just as a revision resource at the end.

Parental engagement can greatly enhance attainment

Another alternative variable discussed is the home environment. Attention is paid to a number of studies which look at ways of fostering greater parental engagement. One study found that groups of parents meeting a parent educator for two hours, twice a month over a period of six months had a strong impact on student learning and effected significant changes in the home environment, although it is conceded that this approach is probably not very cost-effective. Bloom speculates that because mastery learning takes place in the school and parent support occurs in the home environment, these two approaches work in a sort of "pincer movement" and represent a strong solution to the 2 sigma problem, particularly if started early.

Interestingly, when the student learning in a regular class setting is compared to tutoring it is noted that approximately 20% of the students do equally as well as the tutored students. That is to say that these students would not do any better than if they had been individually tutored. However, another way of looking at that is that 80% of students in a regular classroom don't do as well as students who have been tutored 1:1. Bloom accounts for this by claiming that teachers treat students unequally in most classroom settings, with some students getting encouragement and praise while others are largely ignored. This results in the teacher getting feedback from a relatively small number of students and so is missing out on the kind of specific and actionable feedback and direction that one would get in an individual situation. The key thing here is to get feedback on the whole class learning from a random sample of students in the lesson rather than from confident individuals who give the impression everyone understands the material.

Teachers can tend to focus on a limited number of students

Ultimately, to solve the 2 sigma problem and deliver results that are as close to possible to 1:1 tutoring, teachers should use mastery learning approaches in combination with more active student participation so that teaching can be more responsive to all students, not just a minority. For Bloom, there is clearly a law of diminishing returns in whole class instruction and he offers no hard and fast rules for solving the problem but invites educators to pick up the challenge, a challenge still being wrestled with today.

Takeaways

- Most students can achieve high results given the right instructional approach.
- By combining different instructional techniques in different ways we might be able to enormously increase learning.
- When using knowledge organisers, *when* you use them is as important as *how* you use them.
- Parental involvement such as meeting the teacher or instructor twice a month could have a big impact.
- Instead of taking feedback from the same students, ask a random sample.
- Mastery learning is one part of the solution to the 2 sigma riddle and can achieve significant results.

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AVAILABLE FROM HTTPS://IA.EFERRIT.COM/EA/A6589CD862231ED3.PDF

SPOTLIGHTING THE BENJAMIN BLOOM TWO-SIGMA "PROBLEM", AS A STEP TOWARDS EDUCATIONAL REFORMATION TOWARDS WIDESPREAD MASTERY-BASED LEARNING.

AVAILABLE FROM HTTP://KAIROSFOCUS.BLOGSPOT.COM/2012/08/CAPACITY-FOCUS-55A-SPOTLIGHTING.HTML.

ADDRESSING THE "2 SIGMA PROBLEM": A REVIEW OF BILL FERSTER'S TEACHING MACHINES.

AVAILABLE FROM HTTPS://JITP.COMMONS.GC.CUNY.EDU/ADDRESSING-THE-2-SIGMA-PROBLEM-A-REVIEW-OF-BILL-FERSTERS-TEACHING-MACHINES/.

STANDARD DEVIATION – EXPLAINED AND VISUALIZED.

AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=MRQTXL2WX2M.

MASTERY LEARNING.

AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=GWA48XRNLH0.

19 PROBLEM-SOLVING

HOW TO FIND A NEEDLE IN A HAYSTACK

DOI: 10.4324/9781003395713-23

19 PROBLEM-SOLVING

PAPER "Human problem solving"[1]

QUOTE *"Problem solving was regarded by many, at that time, as a mystical, almost magical, human activity – as though the preservation of human dignity depended on man's remaining inscrutable to himself, on the magic-making processes remaining unexplained".*[2]

Why you should read this article

Back in the 1980s, every kid in my neighbourhood had a Rubik's cube. I can remember often picking one up and having several attempts at various solutions but I don't remember ever solving it. The challenge was both simple and complex: twist the cube until every face had nine panels of the same colour. Sounds straightforward until you learn that the cube had 3 billion combinations but only one solution as a 1980s TV commercial claimed.[3] How then could a child (or adult for that matter) solve such a problem with seemingly impossible odds?

As popular as the cube itself were the guides on how to solve it. In 1981, three of the top ten best-selling books in the US were books on how to solve the Rubik's cube (Singmaster, 1994). The solution cannot be found randomly and requires two key elements: first knowing *where* to start and second knowing *what* to do. A decade before, Newell and Simon came up with their theory of how people solve problems, using computer simulated problems which began to lift the lid on the mystical nature of problems like the Rubik's cube. They posited that people have "problem spaces", an internalised representation of the problem that looks very different than the external representation of the problem. What is so

PROBLEM SPACE
Internal conceptualisation of a problem

1 NEWELL, A., & SIMON, H. A. (1972). *HUMAN PROBLEM SOLVING.* ENGLEWOOD CLIFFS. NJ: PRENTICE-HALL.
2 IBID., P. 2.
3 TELEVISIONARCHIVES (OCTOBER 23, 2008). *RUBIK'S CUBE COMMERCIAL 1981*. RETRIEVED APRIL 10, 2019 – VIA YOUTUBE.

important about their work is that they managed to shine a light on those inner processes and demystify a lot of the "magic" of problem-solving.

Abstract of the article (abridged)

Problem solver is an information-processing system

Instead of tracing history here, we should like to give a brief account of the product of the history, of the theory of human problem-solving that has emerged from the research. The theory makes reference to an information-processing system, the problem solver, confronted by a task. The task is defined objectively (or from the viewpoint of an experimenter, if you prefer) in terms of a task environment. It is defined by the problem solver, for purposes of attacking it, in terms of a problem space. The shape of the theory can be captured by four propositions (Newell & Simon, 1972):

1. A few, and only a few, gross characteristics of the human information-processing system are invariant over task and problem solver.
2. These characteristics are sufficient to determine that a task environment is represented (in the information-processing system) as a problem space, and that problem-solving takes place in a problem space.
3. The structure of the task environment determines the possible structures of the problem space.
4. The structure of the problem space determines the possible programmes that can be used for problem-solving.

These are the bones of the theory.

The article

GESTALT PSYCHOLOGY
Holistic view of behaviour and the mind

Until relatively recently, the process of human problem-solving was largely a mystery. Behaviourists contended that problem-solving was reproductive in nature; in other words, people will *reproduce* something which worked before to solve a problem. Gestalt psychologists saw problem-solving in a very different way. For them the process is characterised by individuals reconstituting or shifting around elements of the problem mentally until they have a "Eureka!" moment where they suddenly "get it". However, in the early 1970s, Allen Newell and Herbert Simon explored the nature of problem-solving using computer programs (simulations) and found that humans solve problems in somewhat surprising ways.

A central idea in their work is the idea of "problem spaces". When encountering a problem to be solved, humans will represent this as a range of different solutions to be searched in internal memory (i.e. their long-term memory). This is distinct from the task environment, which is the way the problem looks externally. Essentially, when encountering a problem, we will represent the present state, the goal state, and a range of possibilities in between. However, problem spaces can be very large and searching through an index of possible problem solutions can be near impossible.

Consider the Hanoi Tower problem (Figure 19.1) where there are a number of circular blocks and three pegs and the aim is to move all the blocks to the right peg in their current order but only moving one block at a time, and the final kick in the teeth – you cannot put a bigger block on top of a smaller one. If there are four blocks, most humans can eventually solve this problem through trial and error. However if there are five or more blocks, the problem space contains a range of variables that are simply too large to search through, unless you have the right heuristic or "key" to use.

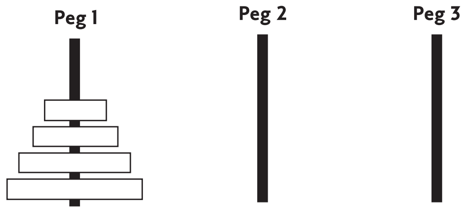

FIGURE 19.1
THE TOWER OF HANOI PROBLEM[4]

However, a key element of success in solving this problem is not searching the entire problem space, but rather searching within a smaller, pre-defined area that is much more manageable and likely to produce a solution. In other words, knowing *where* to look is as important as *what* to look for. As Newell and Simon put it, "We need not be concerned with how large the haystack is, if we can identify a small part of it in which we are quite sure to find a needle" (p. 151).

Structure is the opposite of randomness

Within these so-called knowledge spaces there are differing sources of information and structure. "Structure" as defined by Newell and Simon is the opposite of randomness. The presence or absence of random structures determine whether an individual will blindly search for an answer, trying every possible eventuality, or whether they search for a solution in a systematic way. The key difference here in terms of success is the ability to predict which areas to look at so you can search selectively rather than randomly.

Each knowledge state or "step" is defined as a node; for example having three blocks on the left peg is the starting node for the Hanoi Tower problem. The action one can take to reach the next node is defined as the "operator". So essentially there are two options available to the problem

4 WWW.MATHCS.EMORY.EDU/~CHEUNG/COURSES/170/SYLLABUS/13/HANOI.HTML (ACCESSED APRIL 11, 2019).

solver: *where* to begin solving the problem (node) and *how* to solve it (operator). A common method of achieving this is through means–ends analysis.

A problem solver must encode and decode a problem

An important point made by the authors is to do with representation and language. If we accept that a problem has both an internal representation and an external one, and that the human problem solver needs information in the form of text or images to encode and decode the problem, then a problem arises when trying to evaluate that translation process. In other words, it's very difficult to know the exact internal process of problem-solving, or as the authors put it: "It is a little like building a program to translate from English to Language X, where no one will tell us anything about Language X" (p. 157). The authors contend that this translation process or "Language X" will eventually be researched and explained.

Conclusions/implications of the work for educational practice

A key ability to solve problems is a heightened search ability that is largely determined by the presence or absence of knowledge – if you don't know what you're looking for, then how do you know what to look for and how do you know when you find it? As the authors point out, A. D. de Groot (1965) made an interesting observation of choice in chess players where the tree of move sequences did not look like a "bushy growth" but rather a "bundle of spindly explorations". After exploring each possibility, expert players would return to the base position to evaluate further possibilities for exploration, a process de Groot referred to as "progressive deepening". This method is intrinsically human in nature and accounted for by the limitations of working memory. This is an important difference between human problem-solving and computer programs which have a near infinite search functionality of different permutations. Taking into account the limitations of working memory (see Chapter 7, Take a load off me) it's clear that having a strong mental representation of a problem to be solved is useful for students and rather like the best-selling guides on how to solve the Rubik's cube, this means an expert giving explicit guidance to a novice. Encouraging students to "discover" a solution to the Rubik's cube might be fun for 10 minutes but will not allow them to solve it (unless they have 30,000 hours to randomly stumble across it). Similarly, having students work in groups to find a solution will be just as useless unless one of them has an internalised "problem space" with the solution.

PROGRESSIVE DEEPENING
When chess masters work out a series of moves and possibilities internally

How to use the work in your teaching

When showing students how to solve a particular problem, it's vital that they have the opportunity to independently solve that problem to put into practice what they have learned. This approach is often criticised as a "drill and kill" approach which can demotivate students but as Simon would later point out, this view is not supported by evidence:

The importance of practice

"DRILL AND KILL"?

[The] criticism of practice (called "drill and kill", as if this phrase constituted empirical evaluation) is prominent in constructivist writings. Nothing flies more in the face of the last 20 years of research than the assertion that practice is bad. All evidence, from the laboratory and from extensive case studies of professionals, indicates that real competence only comes with extensive practice (e.g. Hayes, 1985; Ericsson, Krampe, & Tesche-Romer, 1993). In denying the critical role of practice one is denying children the very thing they need to achieve real competence. The instructional task is not to "kill" motivation by demanding drill, but to find tasks that provide practice while at the same time sustaining interest.

(Anderson, Reder, & Simon, 2000)

A good example of this is the multiplication times tables. By committing these to memory from a young age, students can free up their cognitive bandwidth to creatively attack problems and find solutions. Furthermore, by using worked examples (see Chapter 22, Why discovery learning is a bad way to discover things) of how to solve particular problems and giving them plenty of time to practice them, instructors can endow students with internalised problem spaces that are invaluable when encountering new problems with similar underlying structures.

In addition, it is hugely important that students are searching for solutions selectively rather than randomly. In this sense, the teacher needs to monitor whether or not students have the right amount of knowledge to begin creatively exploring a problem. If their internal problem space is not sufficient, then they will be merely guessing; in other words, making sure that learners have the prerequisite prior knowledge (see Chapter 11, What you know determines what you learn). This might work for a simple problem with limited combinations but is useless for more complex problems. Modelling to students (see Chapter 29, Making things visible) where to start working on a problem is hugely important – asking students to find the proverbial needle in a haystack would be cruel, but narrowing *where* to begin and then a range of possible actions allows them a way to be successful and become more motivated in the future. An expert can see where they have taken a wrong turn, a novice can't; so when teaching someone such experiments in chemistry or physics, it's helpful to signpost the path for students so if they become lost, they can return to a particular node and start again from there.

Takeaways

- Problems to be solved are represented differently in our internal world than they look in the external world.
- Knowing *where* to start with a problem can be as important as knowing *how* to solve it.
- Having mental models of similar problems can help problem-solving. The teacher is the person best suited to model it.
- You can help novices by breaking down larger problems into smaller steps.
- Students are successful when they can search problem spaces *selectively* rather than *randomly*.

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A GOOD INTRODUCTION TO PROBLEM-SOLVING WITH USEFUL EXAMPLES IS

AVAILABLE FROM HTTP://PSYCHOLOGICALRESOURCES.BLOGSPOT.COM/2011/01/PROBLEM-SOLVING.HTML.

A BRIEF OVERVIEW OF NEWELL AND SIMON'S GPS (GENERAL PROBLEM-SOLVER) PROGRAMME IS

AVAILABLE FROM WWW.INSTRUCTIONALDESIGN.ORG/THEORIES/GENERAL-PROBLEM-SOLVER/.

AN INTERACTIVE VERSION OF THE HANOI TOWER PROBLEM IS

AVAILABLE FROM WWW.MATHSISFUN.COM/GAMES/TOWEROFHANOI.HTML.

20 ACTIVITIES THAT GIVE BIRTH TO LEARNING

MATHEMAGENIC ACTIVITIES

DOI: 10.4324/9781003395713-24

20 ACTIVITIES THAT GIVE BIRTH TO LEARNING

PAPER "The concept of mathemagenic activities"[1]

QUOTE *"You can lead a horse to water but the only water that gets into his stomach is what he drinks".*[2]

Why you should read this article

Ernst Rothkopf begins his 1970 article on how people learn with this metaphor: "You can lead a horse to the water, but the only water that gets into his stomach is what he drinks". For Rothkopf, while learning depends on what is offered (i.e. the water) it depends more on what the learner does with what is offered (i.e. what (s)he drinks). To learn, we must cognitively process what is offered. Whether and how we process the incoming information determines what we learn and remember. Rothkopf calls activities that promote learning *mathemagenic activities* (Greek: *manthanein* = that which is learnt + *gignesthai* = to be born). His theory of mathemagenic activities was one of the first theories that saw the learner as central to the learning process as opposed to the curriculum or the teacher.

MATHEMAGENIC That which gives birth to learning

You could say that students have veto power over their learning. If they read a text or listen to a lesson and are focused on the facts, then they'll learn and probably remember the facts. In contrast, if while reading or listening they think about how to use the information, then they'll – hopefully – learn how to apply it. And of course, if they don't do anything with the information, then they'll learn nothing. In other words, you as the teacher can offer everything, but in the end it's the learner who has the last word. The learner has to process the material that you offer and this process of processing is what ultimately

1 ROTHKOPF, E. Z. (1970). THE CONCEPT OF MATHEMAGENIC ACTIVITIES. *REVIEW OF EDUCATIONAL RESEARCH*, *40*, 325–336. DOI: 10.3102/00346543040003325.
2 IBID., P. 325.

determines what's learnt. That doesn't mean that you have nothing to add to the equation. You can be the driving force to stimulate students to carry out those activities that promote learning.

There are many activities that a student can carry out to process the material. Some have a positive effect on learning (are mathemagenic), some are neutral (they neither help nor hinder learning), and some even work counterproductively (they are called mathemathantic; *thanatos* = death; see Chapter 32, When teaching kills learning). For example, research shows that presenting learners with questions before or after the to-be-learnt materials or giving a quiz (see Chapter 26, Learning techniques that really work) induce specific *mathemagenic positive* activities. Other activities such as highlighting, underlining, or re-reading texts are, in principle, *mathemagenic neutral* activities.[3] Then there are activities such as attuning tasks to so-called learning styles or summarising something without having learnt to make a good summary. These activities are actually *mathemagenic negative*; that is, they interfere with learning. Rothkopf adds a fourth category, namely *mathemagenic unknown*.

MATHE-MATHANTIC
That which kills learning

Abstract of the article

Psychologists write from time to time in human language. Some years ago, I submitted the report of an experiment about mathemagenic behaviour to a journal. The article started with the sentence, "You can lead a horse to water but the only water that gets into his stomach is what he drinks". The editor, probably judging this alimentary (i.e., relating to nourishment or nutrition), deleted the sentence. I regretted this not only because the little phrase pleased me but also because the problem of the not-drinking horse was and is a useful metaphor for explaining why the study of mathemagenic activities is a challenging enterprise for the educational psychologist.

The proposition is simple. In most instructional situations, what is learned depends largely on the activities of the student. It therefore behoves those interested in the scientific study of instruction to examine these learning activities, i.e., the "drinking habits" of students.

The singular importance of certain learner activities first impressed me in connection with a theoretical analysis of frame formats programmed instruction. Student responses and the immediate feedback of knowledge of results had been interpreted in that context as having a direct effect on the acquisition of subject matter knowledge. Analysis

3 A NOTE NEEDS TO BE MADE HERE. THE ACTIVITIES THEMSELVES DON'T HELP OR HINDER. HOWEVER, IF THEY ARE CARRIED OUT INSTEAD OF MATHEMAGENIC POSITIVE ACTIVITIES, LEARNING WHAT COULD BE LEARNED ISN'T.

led to the rejection of this interpretation and to the belief that these operations affect the inspection activities of the students instead. The inspection activities then determine what is learned.

A similar conclusion was reached in attempts to understand attention-like phenomena in earlier experiments on learning from written sentences. This prompted me to coin the word mathemagenic to refer to attending phenomena derived from the Greek root *mathemain* – that which is learned and *gignesthai* – to be born. Mathemagenic behaviors are behaviors that give birth to learning. More specifically, the study of mathemagenic activities is the study of the student's actions that are relevant to the achievement of specified instructional objectives.

The concept of mathemagenic activity implies that the learners play an important role in determining what is learned.

The article

In order to get a grip on which activities are mathemagenic and which are not, Rothkopf posits that we first need to describe the activities precisely and then link them to a particular learning objective in a given situation. These last two aspects are extremely important because learning is a complex process. For him:

> any definition of mathemagenic activity that is broad enough to encompass all activities that produce any learning (or performance changes) in any situation is too broad to be useful … Performance changes in different situations may depend on different actions by the student … [distinguishing] … (a) instructional settings and (b) specific characterizations of instructional materials.
>
> (p. 327)

Rothkopf himself primarily studied written materials and distinguished three categories of mathemagenic activities:

THE THREE CATEGORIES OF MATHEMAGENIC ACTIVITIES:
- Orientation,
- Acquisition,
- Translation and processing

1. *Orientation*: Moving students towards what they have to learn. This includes attracting and retaining attention as well as controlling activities that distract or disturb others.
2. *Object acquisition*: Focusing the attention and studying of the student on certain things and in a certain way.
3. *Translation and processing*: This involves influencing what and how the student looks at the material, how it is translated into internal speech or representations, and the mental accompaniments of reading such as discrimination, segmentation, and the processing of the information offered in the brain.

We can observe the first two activities fairly directly. However whether the learner actually processes the information, and thus learns, can only be indirectly derived from other behaviours such as whether they can apply a concept after having been given application questions in the text. This third category includes three closely intertwined actions:

3a. *Translation*: Visually focusing on parts of the text and vocalisations of what is being read (which can sometimes be sub-audible).
3b. *Segmentation*: Syntactically analysing what has been read such that it is broken down into smaller units which are then related to each other. A typical way to "observe" this was to follow the intonation of the student when reading.
3c. *Processing*: Assimilating new information from the text into existing schemata and actions. This is difficult to "see", except by testing or questioning by the teacher or fellow students.

The sequence of mathemagenic activities carried out by the learner goes from less to more abstract; that is from certain physically observable behaviours (e.g. eye and muscle movement) to non-observable deeper processing. By examining mathemagenic activities and describing them as precisely as possible in behaviours, we can get a grip on what students have to do to achieve a certain learning goal in a particular situation. While Rothkopf only had rudimentary tools to follow these activities such as respiration (breathing patterns) and intonation (segmentation and intonation when reading), nowadays researchers have more precise ways to map out learning activities and thus see which activities are mathemagenic and which are not (see the box "The eye as portal to the brain").

THE EYE AS PORTAL TO THE BRAIN

THE VALUE OF EYE-TRACKING
Where one looks, for how long and in what sequence

Researchers can now precisely map our eye movements when they look at a text, picture, combination of the two, or situation with so-called eye- or gaze-trackers. These trackers allow us to see and follow exactly what someone is looking at, for how long, the pattern of fixations, where the eyes jump to, and so on. These eye-tracking measurements give us an impression of the thinking processes that take place in the learner's mind.

Kim, Aleven, and Dey (2014), for example, compared how novices and experts look at and solve geometry problems (see Figure 20.1). It's clear that completely different strategies are used.

(*Continued*)

(*Continued*)

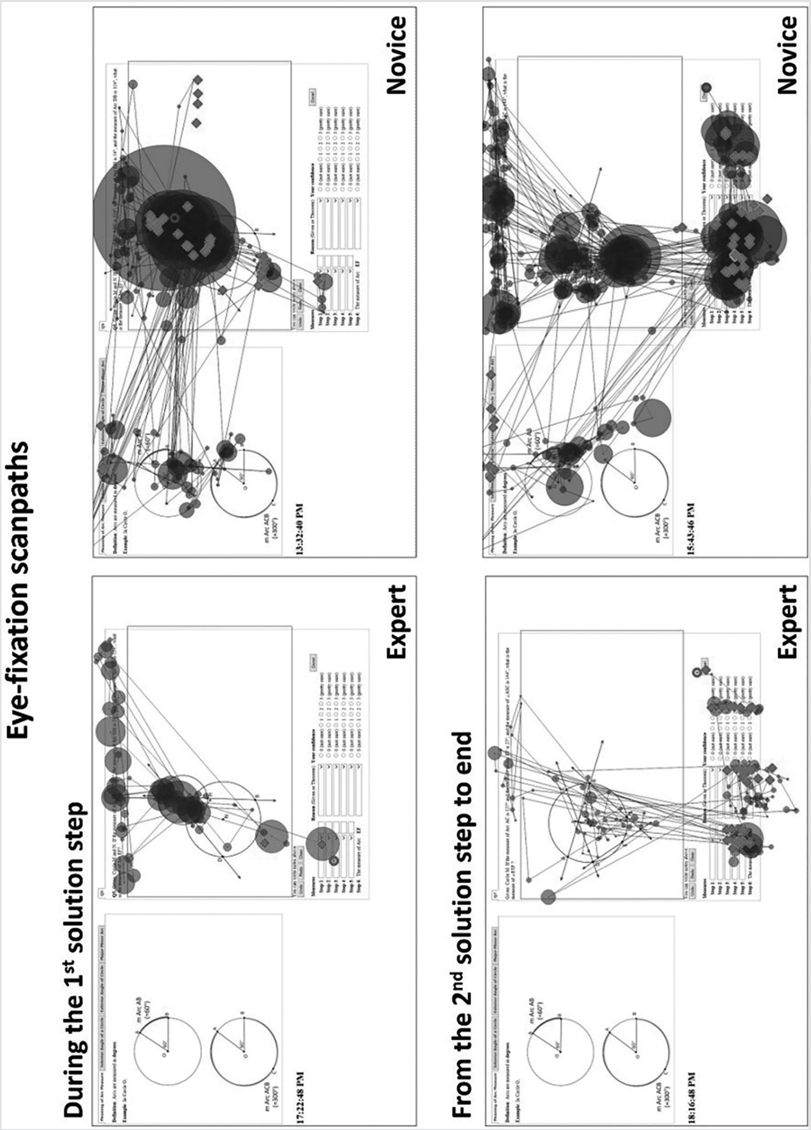

FIGURE 20.1 THE EYE MOVEMENTS OF EXPERTS AND NOVICES SOLVING A GEOMETRY PROBLEM (FROM KIM, ALEVEN, & DEY, 2014)

Also, because tracking devices are becoming smaller, more mobile, and cheaper, we can conduct research into what students see in certain situations. For example, research on eye movements of teachers-in-training (novices) and expert teachers when managing a classroom can yield insight into the strategies they use. In Figure 20.2 we can see that expert teachers look at (and process) what's going on in a classroom differently than teachers-in-training (Van Den Bogert, 2016).

(*Continued*)

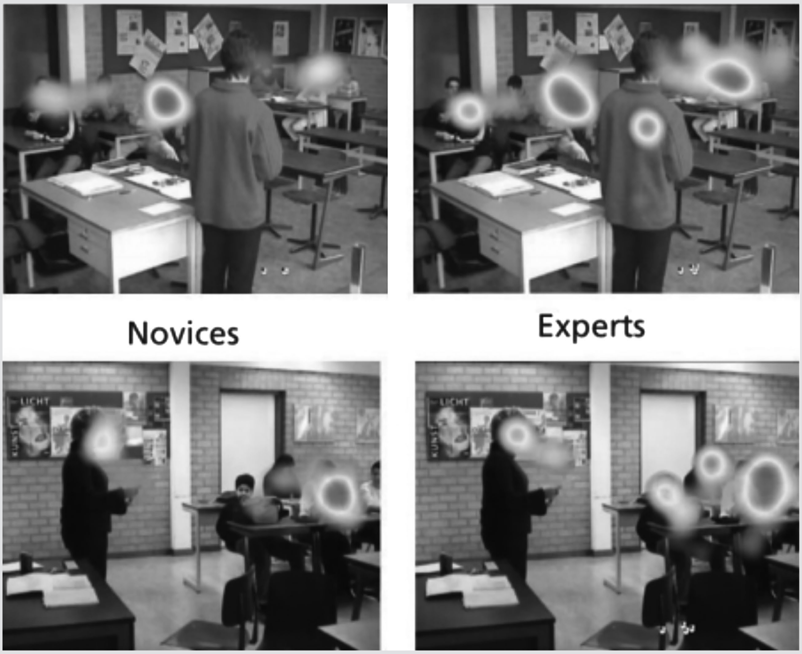

FIGURE 20.2 THE EYE MOVEMENTS OF AN EXPERT AND A NOVICE TEACHER IN THE CLASSROOM (THE LARGER THE SPOT THE LONGER THE GAZE; ALSO, THE OPACITY OF THE CENTRE GIVES THE INTENSITY; IN COLOUR THE SPOT GOES FROM GREEN TO AMBER TO RED LIKE A TRAFFIC LIGHT)

Conclusions/implications of the work for educational practice

Attending to mathemagenic activities has two concrete consequences for educational practice. The first is an emphasis on "investment in the instructional environment" (p. 334). Since 1970 we've seen radical changes in learning materials which are now seen as normal, but weren't then. Most textbooks were minimal. Attention guidance techniques such as interspersing questions in texts, presenting learning objectives prior to a chapter, and using prompting and focusing devices in multimedia are examples of this.

The paradox of Rothkopf's "student-centred" approach

The second consequence is that we now pay more attention to what students actually do. Rothkopf wrote: "Emphasis in instruction is on promoting those activities in the student that will allow him [*sic*] to achieve instructional goals with available materials. This is truly a student-centered approach" (p. 334). As a side note here, we see that Rothkopf called this promoting of mathemagenic activities in learners as student-centred! The view of learners as sponges that absorb information has shifted to learners as active participants in their own learning process. As a teacher you can be very focused on the curriculum, pondering questions such as: Which method should I use? What are the objectives of my lesson? In which order do I teach? Though all are important questions, to promote actual student learning you must also take into account the learning process. If you don't, your clever lessons fall on deaf ears. Rothkopf focuses on this learning process in his theory by looking at which learning and thinking activities the learner must undertake to learn from the offered subject matter. By paying attention to this when (shaping) your lessons, you support your students' learning. We'll give you some tips for this in the next section. While many of them will be pretty straightforward for many teachers, it still makes sense to be aware of the necessary processing activities for achieving specific learning objectives in specific situations. In doing so, it can offer a new perspective on how to teach.

How to use the work in your teaching

A positive classroom climate supports orientation and object acquisition

As a teacher, you can stimulate mathemagenic activities in different ways. Orientation and object acquisition (selection), for example, benefit from a quiet and orderly classroom. It's important that students are seated properly and that they can listen or read without disruption. Tom Bennett refers to this as creating a positive classroom climate. This also means that different distractors are not available such as mobile phones, tablets, or laptop screens when they are not necessary for the lesson. You can also encourage and help your students to focus on what they're doing. Think of making the objective crystal clear before starting on a lesson, implementing reward systems, or building quiet moments into your lessons. Though translation and processing are carried out in the students' minds, you can shape this. For example, making use of adjunct questions (Hamaker, 1986; Rothkopf, 1966, 1972) or other prompting techniques prior to, during, or after reading a text, listening to a presentation or a podcast (Popova, Kirschner, & Joiner, 2014), watching a video (Kirschner, 1978), and even working on a learning task or using a simulation can shape the way students think about the content or carry out their work. Adjunct questions and other similar prompts not only ensure proper orientation and object acquisition, but also have a major impact on processing. Questions can concern specific facts or concepts ("Where is X?" or "What is the definition of X?"), application of knowledge or thinking ("What is meant by X?" or "Where can you put X more to use?") or even stimulate thought ("Why does X work here and not here?" or "Why doesn't/won't X work in this situation?"). The last category of questions is known as epistemic questions or tasks (Ohlsson, 1995). By consistently asking a certain type of question or giving a specific type of assignment, you influence how students read/listen, translate, and process the information

ADJUNCT QUESTIONS Questions inserted into a text to draw attention and steer how one reads and learns (i.e. learning behaviour). They then have this question in mind when reading/listening, even when no question is asked.

Takeaways

- Learning is a combination of object orientation, selection, translation, and processing that takes place in the learner. A teacher can try to make the learning objects available, but what is learnt depends on what the learner does with them.
- The lessons that you prepare can be very sophisticated, but if your students don't do anything with them or do the "wrong" thing with them (e.g. memorise instead of apply), then they won't learn properly.
- With good use of questions, learning objectives, and assignments you can steer your students' learning in the direction that you want (e.g. to learn facts or to apply knowledge).
- Certain ambient factors such as appropriate student behaviour, classroom climate, and the appropriate use of technology are critical to stimulating mathemagenic activities. Get these right first.
- For those training teachers or line-managing teachers, it's helpful to focus less on "teaching" and more on the overall conditions that the teacher has set that engender student learning.

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Suggested readings and links

IN A 2005 INTERVIEW ERNST ROTHKOPF DISCUSSES HIS VIEW ON MATHEMAGENIC ACTIVITIES AND HIS MANY RESEARCH STUDIES ON THIS TOPIC:

ROTHKOPF, E., & SHAUGHNESSY, M. F. (2005). AN INTERVIEW WITH ERNST ROTHKOPF: REFLECTIONS ON EDUCATIONAL PSYCHOLOGY. *NORTH AMERICAN JOURNAL OF PSYCHOLOGY*, 7 (1), 51–58.

PART V

THE TEACHER

John Hattie assesses and discusses no fewer than 138 different influences on learning in his book *Visible learning*.[1] And what, or rather who, emerges as the most important for the learning process of students? Indeed, the teacher.

Noblesse oblige, and how! If teachers want to live up to their positive influence, they must be directive, authoritative, caring, active, and passionately involved in teaching and learning. On top of this, the teacher needs deep conceptual domain knowledge and skills necessary to be able to teach a subject and give meaningful feedback to each student. Finally, they need to top all of this off with the ability to precisely determine whether their lessons really work and the picture is complete. But then, in Hattie's words, it is also irrefutable that it is "what teachers know, do, and care about which is very powerful in this learning equation".[2]

In this part we give you some useful tips to help you achieve this ideal. For example, we discuss how you can give effective feedback, how you can best support learning, how direct instruction works and why, but also why discovery learning doesn't work.

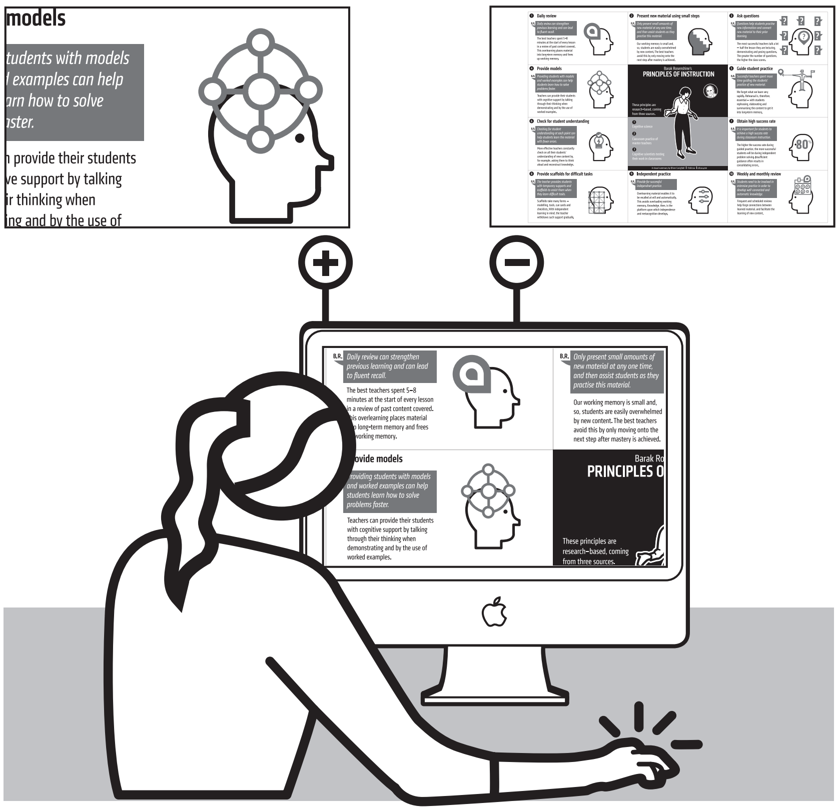
1 HATTIE, J. (2009). *VISIBLE LEARNING: A SYNTHESIS OF OVER 800 META-ANALYSES RELATING TO ACHIEVEMENT.* ROUTLEDGE.

2 HATTIE, J. (2003). TEACHERS MAKE A DIFFERENCE: WHAT IS THE RESEARCH EVIDENCE? *AUSTRALIAN COUNCIL FOR EDUCATIONAL RESEARCH: ANNUAL CONFERENCE ON BUILDING TEACHER QUALITY*. AVAILABLE FROM HTTPS://RESEARCH.ACER.EDU.AU/CGI/VIEWCONTENT.CGI?ARTICLE=1003&CONTEXT=RESEARCH_CONFERENCE_2003.

DOI: 10.4324/9781003395713-25

21 ZOOMING OUT TO ZOOM IN

ELABORATION THEORY OF INSTRUCTION



 DOI: 10.4324/9781003395713-26

21 ZOOMING OUT TO ZOOM IN

PAPER "The elaboration theory of instruction"[1]

QUOTE *"The simple-to-complex sequence prescribed by the Elaboration Theory helps to ensure that the learner is always aware of the context and importance of the different ideas that are being taught. It allows the learner to learn at the level of complexity that is most appropriate and meaningful to him or her at any given state in the development of one's knowledge".*[2]

Why you should read this chapter

As a young musician, Claude Debussy was greatly influenced by the German composer Richard Wagner and once considered his music to represent the birth of modern music, but in later years he began to feel that his work was not as significant as he previously thought and later referred to him as "a beautiful sunset that was mistaken for a dawn".[3]

The use of analogy is really a form of heuristic which aims to illuminate meaning by introducing a new concept and relating it to a concept already known to the learner. To someone who was not knowledgeable of the music of either composer, or indeed the genre as a whole, it would be impossible to discern whether Wagner was as ground-breaking as many thought he was but by using the comparison of a sunset and a dawn as an analogy, Debussy is able to illuminate the novice as to how that might make sense and orient them towards a deeper appreciation, or at least initiate them into a first stage of understanding of the debate.

1 REIGELUTH, C., & STEIN, F. (1983). THE ELABORATION THEORY OF INSTRUCTION. IN C. REIGELUTH (ED.), *INSTRUCTIONAL DESIGN THEORIES AND MODELS*. ERLBAUM ASSOCIATES. (PP.335–381)
2 IBID., P. 338.
3 DEBUSSY, C. (1971). L'INFLUENCE ALLEMANDE SUR LA MUSIQUE FRANCAISE. IN *MONSIEUR CROCHE* (P. 67). GAILLIMARD.

ELABORATION THEORY
Content should be ordered from simple to complex

The use of analogy is just one component of elaboration theory, a model for the sequencing and organising instruction on a course of content developed by Charles Reigeluth in the 1970s and 1980s. The organising structure for a particular course may be conceptual, procedural, or theoretical and requires various strategy components such as "epitomising" or giving the ultimate concrete examples of a particular concept and providing analogy to initiate the learner into a particular domain of knowledge. In the intervening years, elaboration theory has been well received by the community and has been highly influential in course design and the sequencing of instruction.

Summary of the article (adapted from the chapter)

SUBSUMPTIVE SEQUENCING
General to complex
SPIRAL CURRICULUM
Revisiting content with increasing complexity each time

The elaboration theory's prescriptions are based both on an analysis of the structure of knowledge and on an understanding of cognitive processes and leaming theories. As with other theories, goals form the basis for prescribing models. The most important aspect of all three models is a specific kind of simple-to-complex sequence, which is an extension of Ausubel's *subsumptive sequencing*, Bruner's *spiral curriculum*, and Norman's *web learning*. This sequencing pattern helps to build stable cognitive structures, provides a meaningful context for all instructional content, and allows for a meaningful context for all instructional content and meaningful application-level learning from the very first "lesson". Gagné's learning-prerequisite sequences are then introduced only as they become necessary within each lesson, and systematic integration and review are provided at the end of each lesson and unit. Also, each lesson is adjusted in certain ways to make it appropriate for the ability level of the students in relation to the complexity or difficulty of the content.

The article

LEARNING PREREQUISITES
Foundational knowledge needed to build new knowledge

Using an analogy, the authors liken the initial stage of elaboration theory to looking at a picture with a zoom lens. You begin with an overview or wide-angle view of things which allows you to see the component parts and how they relate to one another, however with no detail. From there you can zoom into the component parts and look more closely at its individual elements and their subtleties (in contrast to "cutting" to a detail). Then you zoom back out again and consider how those individual elements relate to the whole picture again. These smaller constituent parts are what Robert Gagné (1968, 1977) referred to as *learning prerequisites* which represent the fact that in order to acquire new knowledge, certain previous knowledge is needed to fully understand it (see also Chapter 11, What you know determines what you learn).

For example, when looking at Picasso's "Guernica" as a whole, it seems to be an abstract collection of unrelated images. However, when the viewer zooms in, they can see a bull, a horse, and numerous faces contorted with pain. When they learn that the bull and horse are significant images in Spanish culture and that Guernica was the site of a bombing during the Spanish Civil War where many civilians were killed, they can begin to attribute meaning where previously there was none. These elements of knowledge coalesce to form a deeper understanding and appreciation of the work through a process of zooming in and out and connecting various elements, previously unconnected.

Reigeluth (1979, pp. 8–9) summed this up as follows:

> A person starts with a wide angle view, which allows one to see the major part of the picture and the major relationships among those parts (e.g. the composition or balance of the picture), but without any detail.
>
> Zooming in at one level on a given part of the picture allows the person to see the major subparts.
>
> After having studied those subparts and their interrelationships, the person could then zoom back out to the wide-angle view to review the other parts of the whole picture and to review the context of this part within the whole picture.
>
> The person continues this pattern of zooming in at one level to see the major subparts of a part and zooming back out for context and review, until the whole picture has been seen at the first level of detail.
>
> The person follows the same zoom-in/zoom-out pattern for the second level of detail, the third level, and so on, until the desired level of detail is reached.

The seven components of elaboration theory

The authors' outline of elaboration theory features seven major strategy components: (1) an elaborative sequence, (2) learning-prerequisite sequences, (3) summary, (4) synthesis, (5) analogies, (6) cognitive strategies, and (7) learner control. The most important of these is the initial stage where the emphasis should be on introducing the overall topic or course with the aim of moving from simple-to-complex components in the instructional design. At this stage a key concept, procedure, or principle should be *epitomised* with additional layers of complexity being added appropriately later on. According to Reigeluth (1979), such an epitome is a "perfect example" of the to-be-learned material plus it also has what he calls "a single orientation" in that it emphasises only one kind of content. Simply stated, an epitome is the

EPITOME
The exemplary example

simplest and most fundamental example of an idea; the exemplary example. Epitomising is differentiated from summarising a topic by introducing a small element of the concept at a concrete level with applicable examples, which then allows the learner to build on those and relate them to subsequent concepts, procedures, or principles.

SYNTHESISER
Presentation device to help learners integrate new content

A *summariser* is a strategy component which gives a concise statement of what has been learned with typical easy-to-remember examples and a diagnostic test to be taken by the learner. A *synthesiser* will integrate what has already been learned with the bigger picture and aims to increase student motivation and agency by creating more continuity between new knowledge and the learner's prior knowledge. The use of analogy is recommended to relate new or difficult knowledge to familiar knowledge. For example, when teaching iambic pentameter in poetry, the teacher might use the analogy of rhythm in a contemporary song which may be familiar to the learners. *Cognitive strategies* are strategy components which explicitly harness the cognitive architecture of the brain by using less domain-specific elements such as diagrams, mnemonics, or paraphrases. However this component veers somewhat dangerously close to the idea of generic skills which is less supported by more recent evidence (Tricot & Sweller, 2014). The *learner control* component refers to the process where the learner has more agency over the entire domain of knowledge due to the knowledge they have acquired and are then best placed to use metacognitive strategies to decide where to focus their attention on what they wish to review or attend to more closely to plug any gaps they might have. A key element of this last component is that material will have been presented in a simple-to-complex sequence with various concepts clearly labelled so that the learner can choose where to select and review the relevant content.

Learner control supports agency of the learner

They also note that there are two fundamental types of sequencing strategies, namely a topical sequencing where a topic or task is taught to that level of understanding or competence which is necessary to go to the next level, and spiral sequencing where learners study the material in a number of rounds, going deeper or broader in each round. Within each of these two sequencing strategies, one can choose to go from simple to complex, general to detailed, or concrete to abstract.

Designing instruction according to the elaboration model has two major phases. The first phase is structuring the subject matter. This is done in the following six steps (see Figure 16.1):

1. Select how you want to organise the content based on what your instruction hopes to achieve. Should it be conceptual, procedural, or theoretical?

2. Develop an organising structure in the most detailed/complex version that the student needs to learn (i.e. detailed content analysis or task description).
3. Analyse the organising structure to determine which aspect(s) of content should be presented in the epitome and which in each level of elaboration. This is the "skeleton".
4. Put some meat on the skeleton by adding the other two types of content plus facts at the lowest appropriate levels of detail. For example, if you chose in the first step for a conceptual organisation, then add the necessary procedural and theoretical content.
5. Establish the scope and depth of each lesson that will comprise each level. How broad and deep do your students need to learn?
6. Plan the internal structure of each lesson. Determine what is prerequisite to what, what is needed to understand the whole, and what analogies, synthesisers, and summarisers you'll use. Finally, specify the content of each expanded epitome.

PHASE 1
Structure the subject matter

PHASE 2
Design the instruction

Having done this we can begin with phase 2, namely designing the actual instruction (Reigeluth, 1979; Reigeluth & Stein, 1983). First, we present the epitome. Having done this we present what is known as a level-1 elaboration, which provides detail of the aspect of the epitome that is most important or contributes most to an understanding of the whole structure. We follow this by a summariser with an expanded epitome, which is followed by another level-1 elaboration with a summariser and an expanded epitome until all aspects of the content in the epitome have been elaborated at that level. Then a deeper – level-2 – elaboration is presented and so forth until the level of detail/complexity specified by the objectives is attained in all aspects of the content. See Figure 21.2.

Reigeluth and Stein define a summariser as an additional instructional strategy component of elaboration theory which provides: (1) a concise statement of each concept, idea, or fact that has been taught; (2) a reference example or a relatively easy to remember example of that reference; and (3) some kind of self-test for each of the ideas.

EXAMPLE
Internal and within-set summarisers

Furthermore, there are two types of summariser: an internal summariser which appears at the end of each lesson and reviews only the content covered in that lesson, and a within-set summariser which covers all the material that has been taught up until this point in the "set of lessons" which refers to any single lesson and the lesson on which it elaborates in addition to the coordinate lessons that also elaborate on that lesson. For example, when studying a novel such as "The Great Gatsby" the teacher might use some form of advance organiser (see Chapter 11, What you know determines what you learn) featuring a definition of the American dream and an easy to understand example and then set a quiz on the

FIGURE 21.1 THE SIX-STEP DESIGN PROCEDURE FOR STRUCTURING THE INSTRUCTION IN ANY COURSE ENTAILING COGNITIVE SUBJECT MATTER (REIGELUTH & STEIN, 1983, P. 371)

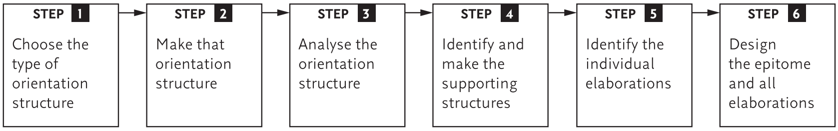
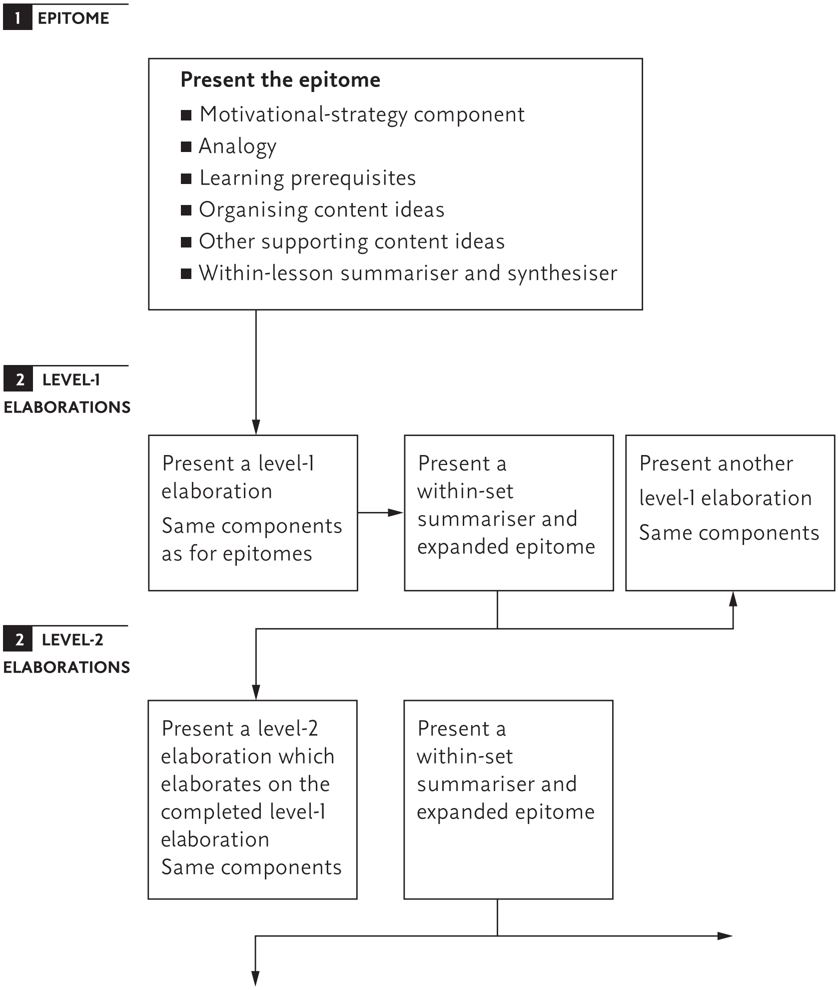


FIGURE 21.2 A DIAGRAMMATIC REPRESENTATION OF THE ELABORATION MODEL OF INSTRUCTION (REIGELUTH & STEIN, 1983, P. 367)



sequence of events and that relates to the American dream in Chapter 4 covered in that lesson. For homework, the teacher might set a quiz on all new vocab encountered in Chapters 1–4.

Space doesn't allow us to discuss all of the different aspects of this theory. We, however, strongly recommend going to the original sources (links are given in the references; Reigeluth, 1979; Reigeluth & Stein, 1983) as they present many examples of epitomes, sequences, and structures for using elaboration theory in many different fields (government, STEM, language, etc.).

Conclusions/implications of the work for educational practice

Reigeluth and Stein stress that elaboration theory is mainly to be used at a macro level and is most helpful when looking at the "big picture". Essentially it's a series of strategic components to be considered when planning the sequencing and organising of a course which borrowed from emerging cognitive psychology at the time.

The core idea in elaboration theory is a deceptively simple one: when designing a sequence of lessons units, content should be presented in a simple way at first and then with increasing complexity, but crucially the student must have a sound contextual understanding of the broad domain within which to process and assimilate new knowledge, skills, and concepts. This has many implications, particularly in terms of curriculum design; indeed Reigeluth notes that his work draws heavily on the concept of the spiral curriculum (Bruner, 1960) which asserts that no content is too "difficult" for students if it is presented in the right way. Bruner wrote: "We begin with the hypothesis that any subject can be taught effectively in some intellectually honest form to any child at any stage of development" (p. 33).

How to use the work in your teaching

As stated, the most important element of elaborative teaching is not just the sequencing of content from simple to increasingly complex, but the introduction of new content in relation to previously understood knowledge, skills, and concepts. Reigeluth and Stein provide a number of examples of how to provide epitomes at the outset of a course. For example, when introducing a course on economics one might begin instruction by selecting or "epitomising" the concept of supply and demand and then zooming in and out as necessary.

EXAMPLE
Using an epitome in Economics instruction

THEORETICAL EPITOME FOR AN INTRODUCTORY COURSE IN ECONOMICS:

Organising content (principles) – the law of supply and demand

a. An increase in price causes an increase in the quantity supplied and a decrease in the quantity demanded.
b. A decrease in price causes a decrease in the quantity supplied and an increase in the quantity demanded.

Supporting content – concepts of price, supply, demand, increase, decrease

There has been a recent shift towards carefully considering curriculum design, particularly in the UK where the government inspection body will now examine the ways in which schools are choosing, sequencing, and designing course content. One positive aspect of this is that it moves us away from the idea of learning as a single unit (a lesson) where teachers must demonstrate student progress within that unit. By considering how a particular "set" of lessons might link with and "elaborate" on previous lessons, we can begin to see how student learning takes place over many different phases and is cumulative in nature. Figure 21.3 gives a good model of what you can do to implement the elaboration theory in your teaching, particularly when considering the sequencing of content and the use of summarisers.

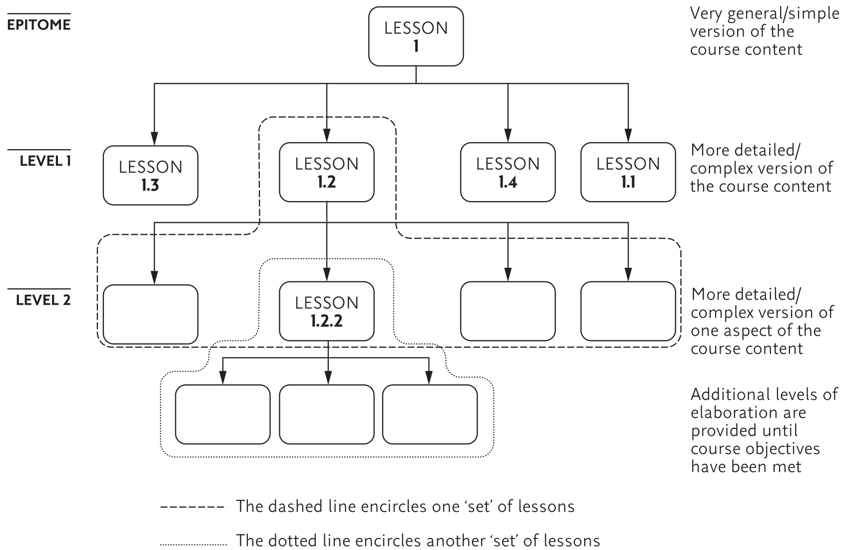


FIGURE 21.3 A DIAGRAMMATIC REPRESENTATION OF A SET OF LESSONS (REIGELUTH & STEIN, 1983, P. 359)

Takeaways

- Begin a course by "epitomising" a key concept or idea and then zooming in or out using it to build connections in the learner's knowledge base.
- Use summarisers at the end of a lesson to consolidate knowledge and relate to the "bigger picture" through quizzes.
- Use analogies to relate new knowledge to familiar concepts and ideas.
- Sequence your lessons/curricula either from simple to complex, general to detailed, or concrete to abstract.
- Once the learner has a sound understanding of a domain of knowledge, then allow them more control over which areas they need to zoom in on to consolidate knowledge.

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REIGELUTH, C. M., & STEIN, F. (1983). THE ELABORATION THEORY OF INSTRUCTION. IN C. REIGELUTH (EDS.), *INSTRUCTIONAL DESIGN THEORIES AND MODELS: AN OVERVIEW OF THEIR CURRENT STATUS* (PP. 335–381). ERLBAUM ASSOCIATES. AVAILABLE FROM WWW.RESEARCHGATE.NET/PUBLICATION/243768474_THE_ELABORATION_THEORY_OF_INSTRUCTION_19.

TRICOT, A., & SWELLER, J. (2014). DOMAIN-SPECIFIC KNOWLEDGE AND WHY TEACHING GENERIC SKILLS DOES NOT WORK. *EDUCATIONAL PSYCHOLOGY REVIEW*, *26*, 265–283.

Suggested readings and links

THE WEBSITE INSTRUCTIONALDESIGN.ORG GIVES A GOOD OVERVIEW OF ELABORATION THEORY.

AVAILABLE FROM WWW.INSTRUCTIONALDESIGN.ORG/THEORIES/ELABORATION-THEORY/.

USEFUL OVERVIEW OF ELABORATION THEORY: HTTPS://WWW.LEARNING-THEORIES.ORG/DOKU.PHP?ID=INSTRUCTIONAL_DESIGN:ELABORATION_THEORY.

IF YOU WANT TO KNOW MORE ABOUT HOW TO SEQUENCE ACCORDING TO ELABORATION THEORY, HERE'S A GOOD ARTICLE:

REIGELUTH, C. M., MERRILL, M. D., WILSON, B. G., & SPILLER, R. T. (1980). THE ELABORATION THEORY OF INSTRUCTION: A MODEL FOR SEQUENCING AND SYNTHESIZING INSTRUCTION. *INSTRUCTIONAL SCIENCE*, *9*, 195–219.

AVAILABLE FROM WWW.RESEARCHGATE.NET/PUBLICATION/226063833_THE_ELABORATION_THEORY_OF_INSTRUCTION_A_MODEL_FOR_SEQUENCING_AND_SYNTHESIZING_INSTRUCTION_11.

IMPORTANT CRITIQUE OF ELABORATION THEORY WITH SOME FURTHER RECOMMENDATIONS:

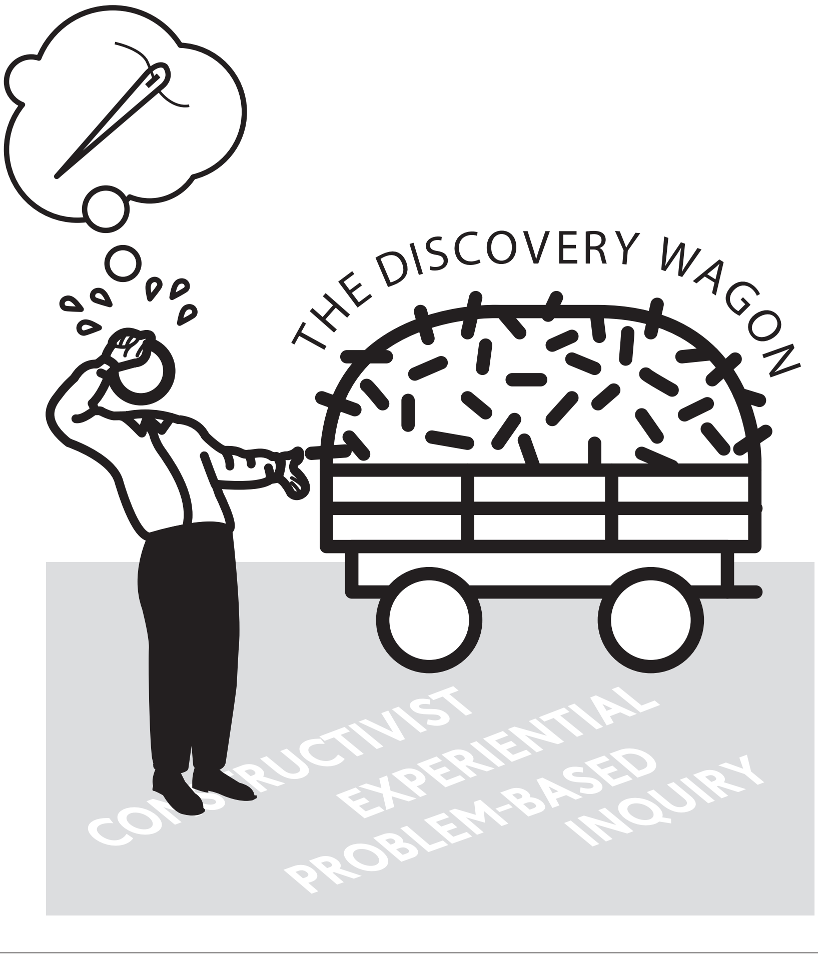
WILSON, B. & COLE, P. A. (1992). CRITICAL REVIEW OF ELABORATION THEORY. *ETR&D*, *40*, *63*. DOI: 10.1007/BF02296843.

A VIDEO WHICH GIVES AN OVERVIEW OF THE MAIN TENETS OF THE ELABORATION THEORY OF INSTRUCTION.

AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=8RPBANBKPAS.

22 WHY DISCOVERY LEARNING IS A BAD WAY TO DISCOVER THINGS

DISCOVERY LEARNING



DOI: 10.4324/9781003395713-27

22 WHY DISCOVERY LEARNING IS A BAD WAY TO DISCOVER THINGS

PAPER "Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching"[1]

QUOTE *"The aim of all instruction is to alter long-term memory. If nothing has changed in long-term memory, nothing has been learned".*[2]

Why you should read this article

LEARNING
A change in long-term memory

This paper poses a fundamental question, namely what do we mean by learning? Decades of evidence on how the brain actually works suggest that the answer is a relatively simple one: learning, simply stated, means that there has been a change made in one's long-term memory. Arising from this then is the question of how best to affect those changes through teaching. This seminal article makes the claim that if you use approaches where there is minimal guidance from the teacher and where students are encouraged to discover things for themselves, then you are ignoring the basic processes of human cognitive architecture. This article is important as it is one of the first to use developments in cognitive psychology to challenge a dominant orthodoxy in teaching, namely that direct instruction or teacher-led learning is a less effective approach than allowing learners to discover knowledge for themselves. This view has its roots in Jean-Jacques Rousseau's model of learning where the child should discover things for themselves and when you try to teach them, their "shining, polished brain reflects, as in a mirror, the things you show them, but nothing sinks in" (Rousseau, 1979). By looking closely

1 KIRSCHNER, P.A., SWELLER, J., & CLARK, R. E. (2006). WHY MINIMAL GUIDANCE DURING INSTRUCTION DOES NOT WORK: AN ANALYSIS OF THE FAILURE OF CONSTRUCTIVIST, DISCOVERY, PROBLEM-BASED, EXPERIENTIAL, AND INQUIRY-BASED TEACHING. *EDUCATIONAL PSYCHOLOGIST*, *46*(2), 75–86.
2 IBID., P. 77.

at recent research from cognitive psychology, specifically the claims of cognitive load theory and the limitations of working memory, this article has proven to be a *cri de coeur* for teachers who simply want to teach and students who want to learn.

Abstract of the article

Evidence for the superiority of guided instruction is explained in the context of our knowledge of human cognitive architecture, expert–novice differences, and cognitive load. Although unguided or minimally guided instructional approaches are very popular and intuitively appealing, the point is made that these approaches ignore both the structures that constitute human cognitive architecture and evidence from empirical studies over the past half-century, which consistently indicate that minimally guided instruction is less effective and less efficient than instructional approaches that place a strong emphasis on guidance of the student learning process. The advantage of guidance begins to recede only when learners have sufficiently high prior knowledge to provide "internal" guidance. Recent developments in instructional research and instructional design models that support guidance during instruction are briefly described.

The article

MINIMALLY GUIDED INSTRUCTION
The learner discovers what should be learnt
Explicit or direct instruction

In this conceptual article, Paul A. Kirschner, John Sweller, and Richard E. Clark confront the concept of *minimally guided instruction* (i.e. constructivist, discovery, problem-based, experiential, and inquiry-based teaching) head on. They dispute the two main assumptions underlying teaching using minimal guidance, namely that (1) having learners construct their own solutions to "authentic" problems or acquire complex knowledge in information-rich settings leads to the most effective learning experience and (2) knowledge can best be acquired through experience based on the procedures of the discipline (i.e. seeing the pedagogic content of the learning experience as identical to the methods and processes or the way experts gain knowledge within the discipline being studied; Kirschner, 1992). In such programmes, minimal guidance is offered in the form of process- or task-relevant information that is available if learners choose to use it. Advocates of this approach imply that instructional guidance that provides or embeds learning strategies in instruction interferes with the natural processes by which learners draw on their unique, prior experience and preferred learning approach to construct new, situated knowledge that will achieve their goals. They contrast the minimally guided approach with what they call *explicit instructional guidance* (also known as direct instructional guidance); an approach which provides information that fully explains the concepts and procedures that students are required to learn as well as learning strategy support that is compatible with human cognitive architecture.

Different types of instruction

> ***Minimally guided instruction*** is when teachers offer partial or minimal guidance so that learners are expected to discover some or all of the concepts and skills they are supposed to learn on their own. This approach has been given various names, including discovery learning, problem-based learning, inquiry learning, experiential learning, and constructivist learning.
> ***Explicit instructional guidance*** is when teachers *fully explain* the concepts and skills that students are required to learn. The provided guidance can be achieved through a variety of media, such as lectures, modelling, videos, computer-based presentations, and realistic demonstrations. It can also include class discussions and activities – if the teacher ensures that through the discussion or activity, the relevant information is explicitly provided and practised.

Their arguments are based on the premise that instructional procedures that ignore the structures that constitute human cognitive architecture are not likely to be effective or efficient. Human cognitive architecture is concerned with the manner in which our cognitive structures are organised, using Atkinson and Shiffrin's (1968) sensory, working, and long-term memory model as its base. As sensory memory is not relevant here, they only consider the relations between working and long-term memory, in conjunction with the cognitive processes that support learning. Long-term memory is viewed as the central, dominant structure of our human cognitive architecture, whereby learning is defined as "a change in long-term memory".

LONG-TERM MEMORY Where information is held indefinitely in schemata

WORKING MEMORY Where new information is processed

Working memory – where conscious processing occurs – has two well-known characteristics: when processing novel information, it's very limited in duration and in capacity. Almost all information stored in working memory and not rehearsed is lost within 30 seconds (Peterson & Peterson, 1959) and the capacity of working memory is limited to only a very small number of elements ranging from 7 according to Miller (1956) to 4±1 (Cowan, 2001).

These memory structures and their relations have direct implications for instructional design (e.g. Sweller, 1999; Sweller, van Merriënboer, & Paas, 1998). Inquiry- and problem-based instruction requires learners to search a problem space for problem-relevant information making heavy demands on working memory. This working memory load doesn't contribute to the accumulation of knowledge in long-term memory because while working memory is being used to search for problem solutions, it is not available and cannot be used to learn.

The article concludes that after about 50 years (now over 60) of advocacy for minimally guided instruction, there is no real body of research supporting the approach. In so far as there is any evidence from controlled studies, it almost uniformly supports direct, strong instructional guidance rather than constructivist-based minimal guidance during the instruction of novice to intermediate learners. Even for students with considerable prior knowledge, strong guidance while learning is most often found to be equally effective as unguided approaches. Not only is unguided instruction normally less effective, there is evidence that it may have negative results when students acquire misconceptions or incomplete and/or disorganised knowledge.

UNGUIDED INSTRUCTION
Can lead to misconceptions

Conclusions/implications of the work for educational practice

Based upon this article we can make a number of conclusions along with implications for teaching and learning.

First, when designing lessons we need to be mindful of the possibilities and limitations of our *human cognitive architecture*, and specifically working memory, long-term memory, and the interactions between them. Working memory (short-term memory) is extremely limited in both capacity and duration. Long-term memory stores a virtually unlimited amount of knowledge and skills on a more-or-less permanent basis, containing cognitive schemata that incorporate multiple elements of information into a single element.

COGNITIVE LOAD THEORY
The amount of mental effort required to perform a task

Intrinsic load versus extraneous load

Related to this is *cognitive load theory* which holds that optimal learning can only occur when instruction is aligned with human cognitive architecture. It concerns itself with techniques to reduce the load on working memory so as to facilitate the changes in long-term memory associated with schema acquisition. Instrumental here is the reduction of a learning task's extraneous load (i.e. the way the material is presented or the activities required of the learner) to allow optimal processing of a learning task's intrinsic load (i.e. the complexity of the task as determined by the number of novel learning elements and the interaction between those elements, and the expertise of the learner). It's also important to note that instructional methods should decrease extraneous cognitive load – that is, choosing an instructional approach that optimally supports and guides learning – so that the limited cognitive resources available can be devoted to effective and efficient learning. The support and guidance given minimises extrinsic load so that learners can focus their resources on the intrinsic demands of the learning.

Minimally guided instruction increases extraneous load

Constructivist, discovery, problem-based, experiential, and inquiry-based teaching, due to their inherent nature, tax working memory in such a way that it impedes effective and efficient learning. Such approaches require learners to search a problem space for problem-relevant information which makes heavy demands on working memory. Also, that working memory load doesn't contribute to the accumulation of knowledge in long-term memory because while it's being used to search for problem solutions, it's not available and cannot be used to learn.

The goal of instruction is not to have learners search for and discover information, but rather to give them specific support for guidance about how to cognitively manipulate information in ways that are consistent with a learning goal, and store the result in long-term memory. Approaches which achieve this are: modelling with and without explanations, worked/worked-out examples which are faded into partially worked examples and finally are faded into conventional tasks without support (see van Merriënboer & Kirschner, 2018), process worksheets, and so forth.

WORKED EXAMPLES Solutions to problems explicitly shown in solution steps

Finally, for students with considerable prior knowledge, strong support and guidance while learning is most often found to be equally effective to unguided and minimally guided approaches. And it's not only the case that unguided instruction is less effective and/or efficient, but there is evidence that this way of teaching may have negative results when students acquire misconceptions or incomplete and/or disorganised knowledge.

How to use the work in your teaching

Start with worked-out examples of a task where a full solution is shown and which students then have to apply to a new task. In other words, they follow the sequence of steps. Then move to completion assignments – also known as partially worked-out examples – where a partial solution is given and students must carry out the "empty" steps themselves to complete it. Subsequently remove – one by one – the presented steps until the learner is, eventually, left with a problem that (s)he has to solve without any support. In other words, begin with a model (a complete example), gradually remove completed steps which the learner has to complete independently, and finally leave just the to-be-solved problem or task. This approach acts as a form of *scaffolding*. Figure 22.1 gives an example of a simple visual worked-out example.

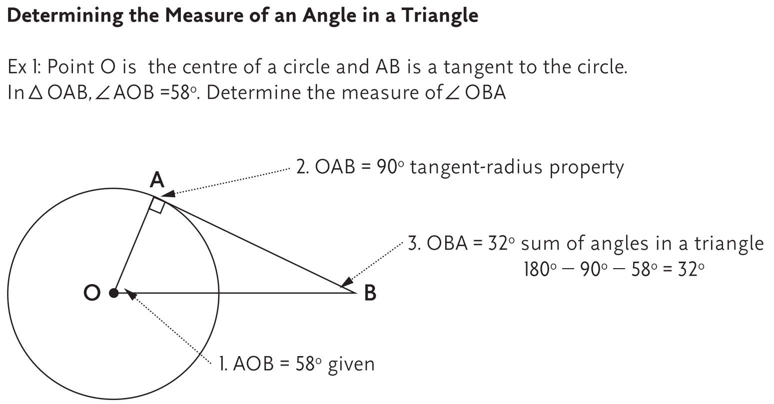


FIGURE 22.1 A GEOMETRY WORKED-EXAMPLE DEMONSTRATING THE TANGENT-RADIUS PROPERTY

Maximum guidance is provided by modelling examples or process-oriented worked examples because they confront learners with how to carry out a task, simultaneously explaining why the task is being carried out the way it is. A modelling example is, thus, similar to a worked-out example studied and evaluated by the learner, but it also pays explicit attention to the processes needed to reach an acceptable solution.

It is advisable to break down the subject content, sequencing delivery so that sub-tasks are taught individually before being explained together as a whole. The idea is to not overwhelm a student too early on in the introduction of new work. An example is that if you want to teach someone to play squash, don't instruct them to think about her/his footing, the way (s)he holds the racquet, the stroke of the racquet etc. all at once. Let her/him play first only concentrating on the footing. Once this has been mastered, shift the concentration to holding the racquet, and so forth. This is known as *emphasis manipulation*; learners carry out the whole task from beginning to the end, but different parts are emphasised as the learning progresses.

EXAMPLE
Emphasis manipulation

PROCESS WORKSHEET
Heuristic guidance through a task solution

A *process worksheet* provides learners with the phases to go through to carry out a learning task, heuristically guiding them through the process. The learner uses the process worksheet as a guide for carrying out the task. For each phase, rules-of-thumb are provided as to how to successfully complete the phase. These rules-of-thumb may be in the form of statements (e.g. when doing A, consider X, Y, and/or Z) or guiding questions (e.g. what aspect(s) of X, Y, and/or Z should you take into account doing A and why?). The latter form (also known as epistemic questions) had the advantage of triggering learners to think about what they need to do rather than just mechanically trying to carry out the instructions. An example of a process worksheet is the presentation of the series of steps (i.e. phases and sub-phases) that a student-chef needs to go through when planning a meal, along with rules-of-thumb such as: the amount of time needed to marinate and cook the meat is based on the surface area and not the weight.

Simple ≠ Easy
Complex ≠ Difficult

SIMPLE IS NOT THE SAME AS EASY, AND COMPLEX IS NOT THE SAME AS DIFFICULT.

Well-designed guided instruction ensures that learners are not overwhelmed by the complexity of a task. This means that the tasks are ordered from simple to complex with the necessary support and guidance given when needed. Important to note here is that simple is not the same as easy, and complex is not the same as difficult. The simplicity/complexity of a task is related to its intrinsic load; that is the number of new information elements contained in the task and the interactions between those elements. For example, a simple task in learning about electricity has few elements (one or two bulbs with a singular source of current either in series or parallel) whereas a complex task can have multiple elements combined in multiple ways.

Takeaways

- Learning is a change in long-term memory.
- Working memory is where conscious processing occurs. It is severely limited in duration and capacity.
- Long-term memory is virtually unlimited. It contains huge amounts of information concerning the area organised in schemata.
- Any instructional procedure that ignores the structures that constitute human cognitive architecture is not likely to be effective.
- Minimally guided instruction challenges working memory and, thus, inhibits/hampers effective and efficient learning.
- Explicitly (guided) instruction takes human cognitive architecture into account and, thus, supports/facilitates effective and efficient learning.
- While there is a substantial body of research supporting explicitly guided instruction, more than a half-century of promotion of minimally guided learning has not produced a body of research supporting its use.

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Suggested readings and links

MAYER, R. (2004). SHOULD THERE BE A THREE-STRIKES RULE AGAINST PURE DISCOVERY LEARNING? THE CASE FOR GUIDED METHODS OF INSTRUCTION. *AMERICAN PSYCHOLOGIST*, *59*(1), 14–19.

Richard Mayer posits that there is sufficient research evidence to make any reasonable person sceptical about the benefits of discovery learning – practiced under the guise of cognitive constructivism or social constructivism – as a preferred instructional method. He reviews research on discovery of problem-solving rules culminating in the 1960s, discovery of conservation strategies culminating in the 1970s, and discovery of LOGO programming strategies culminating in the 1980s. He concludes that, overall, learning is best supported by instructional methods involving cognitive activity instead of behavioural activity, instructional guidance instead of pure discovery, and curricular focus instead of unstructured exploration.

AVAILABLE FROM HTTP://TICTRABALHODEPROJECTO.PBWORKS.COM/F/SHOULD%20THERE%20BE%20A%20THREE-STRIKES%20RULE%20AGAINST%20PURE.PDF.

SWELLER, J. (2016). WORKING MEMORY, LONG-TERM-MEMORY, AND INSTRUCTIONAL DESIGN. *JOURNAL OF APPLIED RESEARCH IN MEMORY AND COGNITION*, *5*, 360–367.

John Sweller discusses the use of cognitive load theory to design instruction, making use of David Geary's theory of evolutionary educational psychology. The premises underlying the use of cognitive load theory assume that: (1) we have not specifically evolved to learn the topics taught in educational and training institutions; (2) these topics require learners to acquire domain-specific rather than generic–cognitive knowledge; and (3) we have not evolved to acquire domain-specific concepts and skills which require explicit instruction. For these reasons, cognitive load theory has been developed to provide techniques that reduce unnecessary working memory load when dealing with explicitly taught, biologically secondary, domain-specific knowledge.

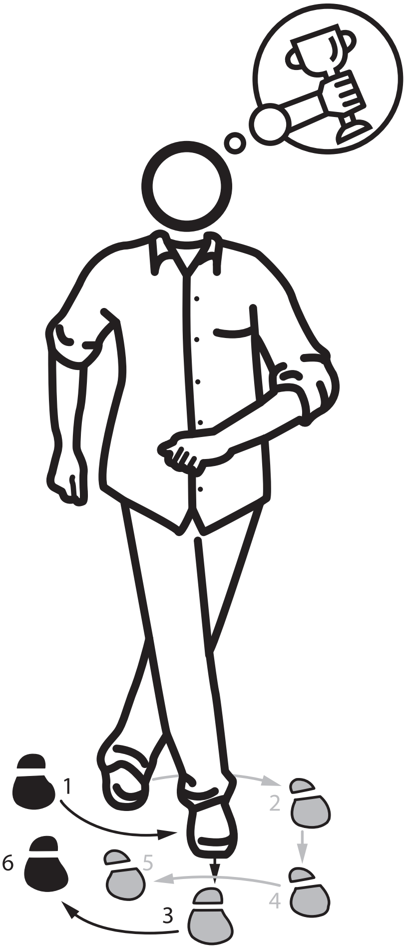
AVAILABLE FROM HTTPS://READER.ELSEVIER.COM/READER/SD/PII/S2211368115000935?TOKEN=D022673CEFD05BC9CDDEBFF63E6B6BD8B24906BC1D993C9253559A12CD14D537FF19CA47669D2464F1F897F1E50CF327.

A VIDEO EXPLAINING COGNITIVE LOAD THEORY.

AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=STJ-MKTGRFS.

23 DIRECT INSTRUCTION

DIRECT INSTRUCTION



DOI: 10.4324/9781003395713-28

23 DIRECT INSTRUCTION

PAPER "Principles of instruction. Research-based strategies that all teachers should know"[1]

QUOTE *"The most successful teachers spent more time in guided practice, more time asking questions, more time checking for understanding, and more time correcting errors".*[2]

Why you should read this article

Robert Pondiscio, Senior Fellow and Vice President for External Affairs at the Thomas B. Fordham Institute in the US, published a blog in which he called direct instruction the Rodney Dangerfield of curricula. Rodney Dangerfield was an American comedian who constantly complained that he didn't get any respect, no matter what he did. Poor Rodney.[3]

Engelmann's model of Direct Instruction (DI)

The same seems to be true for direct instruction. But before discussing the article by Barak Rosenshine, we need to say that there is Direct Instruction and direct instruction. Yes, there is not one, but rather two types! The first is Direct Instruction (with capital DI). This is a model for instruction that emphasises well-developed, carefully planned lessons, focusing on small learning steps with clearly defined and prescribed learning tasks. This model was developed by the American Siegfried Engelmann (Oregon University). His theory is that clear instruction should eliminate misconceptions and will/could lead to more effective and efficient learning. Educational/instructional techniques that are

1 ROSENSHINE, B. (2010) *PRINCIPLES OF INSTRUCTION*. INTERNATIONAL ACADEMY OF EDUCATION, UNESCO. INTERNATIONAL BUREAU OF EDUCATION. ROSENSHINE, B. V. (2012, SPRING). PRINCIPLES OF INSTRUCTION. RESEARCH-BASED STRATEGIES THAT ALL TEACHERS SHOULD KNOW. *AMERICAN EDUCATOR*, *36*(1), 12–19.

2 IBID., P. 16.

3 PARTS OF THIS CHAPTER LEAN STRONGLY ON TWO BLOGS WRITTEN BY THE FIRST AUTHOR AND MIRJAM NEELEN ON THEIR WEBSITE *3-STAR LEARNING EXPERIENCES* (HTTPS://3STAR-LEARNINGEXPERIENCES.WORDPRESS.COM/).

used with DI are, for example, working groups, participation labs, discussions, lectures, seminars, workshops, observation, active learning, practical assignments, and internships.

The second type of direct instruction (with lowercase di) was introduced by Barak Rosenshine in 1976/1979. He used the term direct instruction for a collection of variables that are significantly related to optimal learning.

Abstract of the articles

This article presents 10 research-based principles of instruction, along with suggestions for classroom practice. These principles come from three sources: (a) research in cognitive science, (b) research on master teachers, and (c) research on cognitive supports. Each is briefly explained in this article. Even though these are three very different bodies of research, there is "no conflict at all" between the instructional suggestions that come from each of these three sources. In other words, these three sources supplement and complement each other. The fact that the instructional ideas from three different sources supplement and complement each other gives teachers faith in the validity of these findings.

The article

Rosenshine's model of direct instruction (di)

Brophy (1979) summarised Rosenshine's "small di" as follows: instructors (1) emphasise academic goals, (2) ensure that learners are involved in learning, (3) select the learning objectives and monitor learner progress, (4) structure the learning activities and give immediate academically focused feedback, and (5) create a task-oriented yet "relaxed" learning environment. In essence, direct instruction:

- sets the stage for learning via introductions and review of what has been learnt,
- presents clear explanation of what to do,
- models the process/shows how to do something,
- guides practice in which the process is monitored,
- encourages independent practice, but only after the teacher is confident that the students will be successful,
- provides assessment of student progress and closure of the learning experience (i.e. reviews what the lesson was about).

In 2012, Barak Rosenshine, emeritus professor of educational psychology at the University of Illinois, published an article in *American Educator* magazine about instructional principles that have proven their

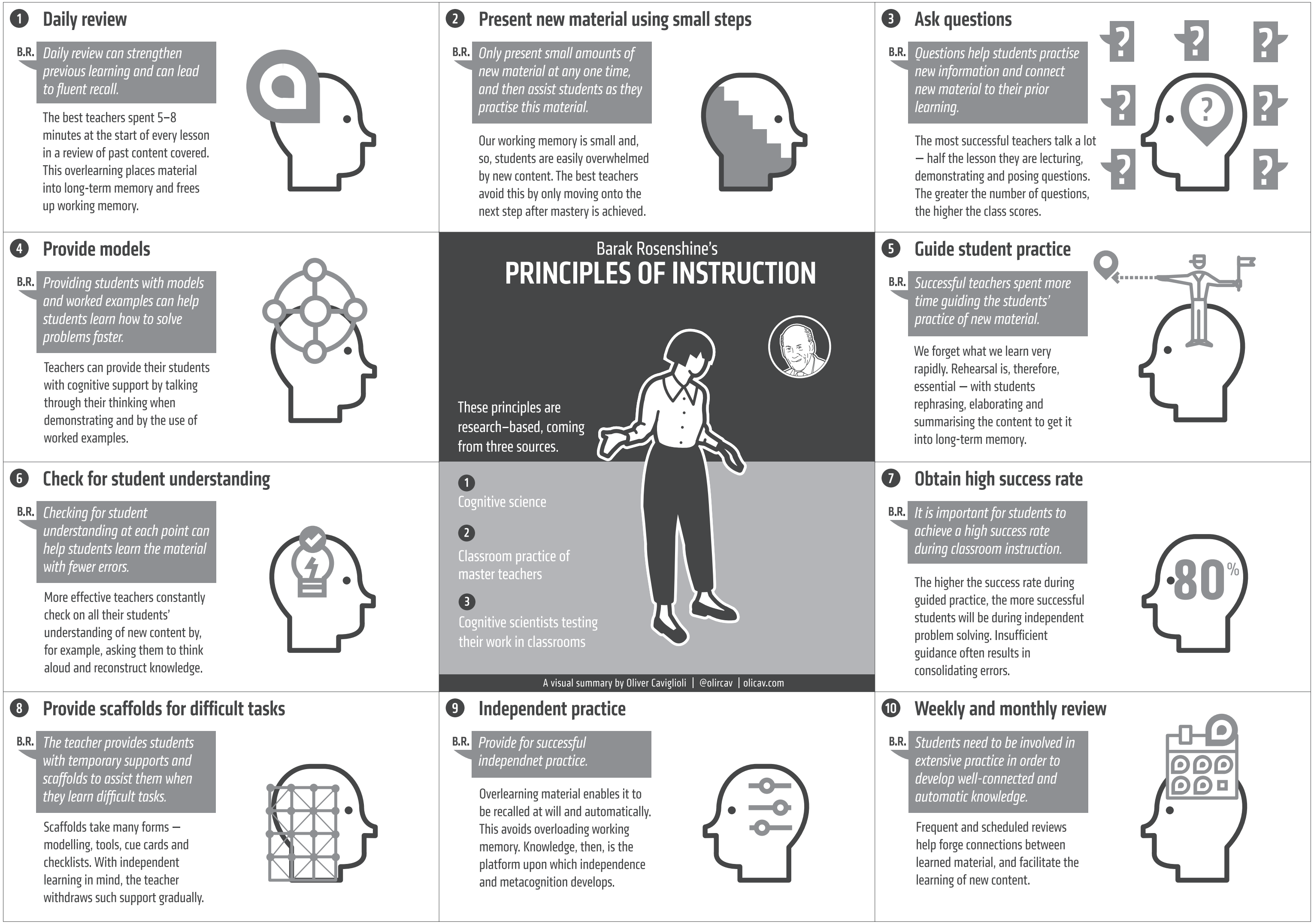


FIGURE 23.1
ROSENSHINE'S TEN GOLDEN PRINCIPLES

value time and again. The article was an adapted version of a report that he wrote in 2010 for UNESCO. In that article he extracted principles from research in cognitive science, research on master teachers, and research on cognitive supports for learning. The major strength of this synthesis is, even though these are three very different bodies of research, there is no conflict whatsoever between the instructional suggestions that they provide. Here are his ten golden instruction principles (see Figure 23.1).

Principle 1: Begin a learning experience with a short review of previous learning

PRIOR KNOWLEDGE
Establish connections

Reviewing what you've learnt reinforces learning and retention by establishing connections between what we already know and the new information that is coming. By beginning each session with a short review, we refresh our memory and activate our prior knowledge (see Chapter 11, What you know determines what you learn). Daily review is especially important for things that need to be used often as repetition helps automate the retrieval of that information. It allows for the effortless retrieval of words, concepts, procedures, etc. from our memory which we need to solve problems, carry out tasks, and understand new subject matter.

Principle 2: Present new learning material in small steps and help students practice with it

SMALL STEPS
Offer new information incrementally

Our working memory is very small: it can hold between four and seven pieces of new information at any one time. Those chunks are processed and stored in our long-term memory as schemata. Too much information overwhelms our working memory and the working memory will simply no longer process it. Always offer small amounts of information, then help students practice it, and only go to the next step if the previous one is mastered.

Principle 3: Ask a large number of questions to support connections between new materials and prior learning

RETRIEVAL PRACTICE
Ask lots of questions

Answering questions helps students to practise what has just been presented (i.e. new information) and then to make connections between that new information and with what they have already learnt. This is especially the case for "how and why" questions, so-called epistemic questions. The most successful teachers appear to spend more than half of their lessons teaching, demonstrating, and asking questions. Also, asking a teacher can also determine how well the students have learnt, whether they themselves taught properly, and whether further or different instruction is needed. To this end, it's also useful to ask students to explain how they came to the answer.

Principle 4: Provide models and worked examples; this supports learners to solve problems faster or better

COGNITIVE SUPPORTS
Worked examples and models

Or even better, be a model. Students need what Rosenshine calls "cognitive" support to learn how to carry out tasks and solve problems. By acting as a model and also telling them about what you're thinking, what you're doing, what working steps you're taking, and why you're doing what you're doing, you can show them how to do it properly.

Principle 5: Guide your students in practising with new learning material

QUESTIONING
Helps students understand and remember content

Simply offering new material isn't enough. In addition to review and repetition (Principle 1), sufficient and varied practice and testing are required. Pupils must spend time reformulating, expanding on, and summarising new material if you want them to store it properly in their long-term memory. This increases the retrieval strength of the information. Look at it this way: it's easy to store something in a drawer, but it can be very difficult to remember exactly where you left it. Practise helps us remember where it is! You as a teacher can help this rehearsal process by asking students questions, because good questions require them to process and review what they have learnt.

Principle 6: Check whether students have really understood what you've taught

UNDERSTANDING
Check for understanding often

Effective teachers very often check whether students are actually learning the new subject matter. They not only check the product, but also the process of learning. In this way, they not only promote the processing of the material, but they can also check whether students actually learn well and also whether they have actually understood the material. By the way, this also helps you to see whether the students have acquired misconceptions.

Principle 7: Obtain a high success rate

ENSURE SUCCESS
Success breeds confidence

It's important that students achieve success (small steps; Principle 2 helps this) as success breeds self-efficacy, a feeling of achievement, and ultimately the motivation to continue. Also, it's important that learners have mastered prerequisite knowledge for further learning.

Effective teachers check whether their students are successful often. This isn't for grading (assessment of learning), but rather as a learning strategy (assessment for learning). This is discussed in Chapter 24, Assessment *for*, not *of* learning, and Chapter 26, Learning techniques that really work. This last is what is known as retrieval practice. And although practice makes perfect, this is only if students or learners don't practise mistakes. If the practice doesn't lead to success, chances are that the student is practising the wrong thing. Ingrained errors – as well as misconceptions – are very difficult to eradicate.

Principle 8: Provide scaffolds for difficult tasks

EMPLOY SCAFFOLDING
Take away support as students become more independent

In addition to explaining things yourself (see Principle 4), you can also give your students temporary support that is used to assist them. These so-called scaffolds are gradually withdrawn as they become more competent. There are many types of scaffolds. Best known are worked (out) examples where the solution steps are gradually removed until the learner solves a problem or carries out a task without support or process worksheets where the process is laid out step for step and also is gradually diminished. In this way you offer students temporary cognitive support. Eliminating more and more steps, you break down the scaffold piece by piece, gradually guiding your students towards independent implementation.

Principle 9: Require and monitor independent practice

REMOVE GUIDANCE
Allow room for practising independently

You can't endlessly take your students by the hand; in the end they have to be able to do it themselves. Let them practise independently and check whether they can really do it or whether more and/or different (guided or unguided) practise is needed. Rosenshine (2010, p. 24) writes: "When material is overlearned it can be recalled automatically, and doesn't take up any space in our working memory. When students become automatic in an area, they can then devote more of their attention to comprehension and application".

Principle 10: Engage students in weekly and monthly review

Students need to practise extensively in order to develop well-connected and automatic knowledge. In other words, you need to activate what they have learnt regularly. It's important here to note that this review should

REVIEW OFTEN
Interleave and space student practice

be varied (i.e. interleaved) and spread over time (i.e. distributed) so as to help them develop strong and rich schemata. By returning to something that has already been learned often – but with the necessary time in between so that they can gain new knowledge in new and different situations – the connections in the schemata are strengthened and they become richer and more extensive.

Now the question is, does direct instruction (both the uppercase and lowercase version) work? The first real evidence of the efficacy of direct instruction was a very large scale study known as *Project Follow Through*. This project was a US government funded project meant to determine the best way to teach "at-risk children" from kindergarten through third grade. From 1968–1977, more than 200,000 children took part in this project which compared 22 different models of instruction ranging from open education through constructivism/ discovery learning to DI. The results were crystal clear. Siegfried Engelmann's DI method had the highest gains. Cathy Watkins (1997) writes:

> The Follow Through experiment was intended to answer the question "what works" in educating disadvantaged children. If education is defined as the acquisition of academic skills, the results of the Follow Through experiment provide an unequivocal answer to the question. The evidence provided by the Follow Through experiment clearly indicates that the instructional methods employed in the Direct Instruction and Behavior Analysis models are most effective in teaching the skills necessary for basic literacy and mathematical competence.
>
> (p. 42)

Not only did students who received DI have significantly higher academic achievement, but they also had higher self-esteem and self-confidence than students whose instruction followed any other programme. It is interesting that subsequent research found that the DI children continued to outperform their peers, were more likely to finish high school, and more likely to go on to higher education.

Stockard, Wood, Coughlin, and Khoury (2018) conducted a meta-analysis of studies on direct instruction. They included more than 400 studies that were carried out between 1966 and 2016. The research papers included subjects such as language, reading, maths, and spelling, as well as subjects that also focused on learning outcomes, affective outcomes (e.g. learner attitudes, confidence, self-esteem, and behaviour), perceptions from the instructor about the effectiveness of the process, and parent opinions. All effects of direct instruction were positive and

TABLE 23.1 WHAT DIRECT INSTRUCTION IS AND ISN'T (ADAPTED FROM GOEKE, 2018)

Direct Instruction *is*	**Direct Instruction *isn't***
• skill based with active student participation	• drill and practice
• holistic where the whole task is modelled	• limited to learning isolated facts and procedures
• when smaller learning units are integrated into meaningful wholes	• teaching basic skills in isolation from meaningful contexts
• developmentally appropriate; tailored to students' learning and attentional needs	• a one size fits all approach
• geared towards understanding where student progress is constantly monitored	• geared towards rote learning of facts and procedures
• usable in all different contexts and areas	• usable only for basic skills
• when students are allowed the opportunity to monitor and direct their own learning	• all teacher directed

DIRECTION INSTRUCTION
An overall positive effect

significant, except for the affective outcomes, which were positive but not significant. In other words, direct instruction: (1) has a positive effect on learning, (2) has instructors and parents feeling positive about it, and (3) doesn't hurt learner attitudes, confidence, self-esteem, and behaviour. That sounds hopeful to say the least, we'd say.

Furtak, Seidel, Iverson, and Briggs (2012) also carried out a meta-analysis, including experimental and quasi-experimental studies on discovery learning. They investigated 37 studies, completed between 1996 and 2006. The authors characterise this period as the decade in which curriculum innovation (especially in physics) clearly focused on discovery learning. They found an overall positive effect; however, the effect of the instructor-driven activities was much larger (effect size 0.40) than learner-driven activities. This might very well be the case because discovery learning over time has started to show many similarities to high quality direct instruction. In other words, discovery learning works *if* (and only *if*) the instructor provides clear guidance during the discovery process!

Last but not least, Andersen and Andersen (2017) investigated the possible (side) effects of learner-centred education on inequality. In this case, learner-centred education means an educational approach in which (1) learners set their own goals, (2) activities are tailored to the individual learner, (3) learners are responsible for (self-)directing their learning and seek help from the instructor at their own initiative, (4) learners are actively seeking knowledge, (5) educational methods are focused on individual learning and collaboration (often with ICT support), and (6) the instructors' role is to coach and facilitate. In a study with over 56,000 learners in 825 Danish schools, the effects of learner-centred education on academic achievement from learners with various socioeconomic backgrounds were analysed (its measurement was based on the highest educational degree from the parents, which is an often-used measure of socioeconomic status). The researchers found that overall learner-centred education had a negative impact on the academic achievement of the learners; however (and this is worrisome), that effect was larger for learners whose parents had a lower socioeconomic status. Therefore, the unfortunate conclusion is that learner-centred education appears to increase inequality in education.

Conclusions/implications of the work for educational practice

There are a lot of things that people think direct instruction is and isn't. Here is a handy table (see Table 23.1) to help understand this.

How to use the work in your teaching

The article has possibly the most directly implementable guidance for the classroom. The simplest way to explain how to use Barak Rosenshine's principles is to follow them.

Takeaways

We cannot say it better than Rosenshine (2010, p. 7) himself, so:

- Begin a lesson with a short review of previous learning.
- Present new material in small steps with student practice after each step.
- Limit the amount of material students receive at one time.
- Give clear and detailed instructions and explanations.
- Ask a large number of questions and check for understanding.
- Provide a high level of active practice for all students.
- Guide students as they begin to practice.
- Think aloud and model steps.
- Provide models of worked-out problems.
- Ask students to explain what they have learnt.
- Check the responses of all students.
- Provide systematic feedback and corrections.

- Use more time to provide explanations.
- Provide many examples.
- Re-teach material when necessary.
- Prepare students for independent practice.
- Monitor students when they begin independent practice.

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AVAILABLE FROM HTTPS://GRANITESCHOOLS.INSTRUCTURE.COM/FILES/64552171/DOWNLOAD?DOWNLOAD_FRD=1.

EXPLORING THE FOUNDATIONS OF EXPLICIT INSTRUCTION.

AVAILABLE FROM HTTPS://EXPLICITINSTRUCTION.ORG/DOWNLOAD/SAMPLE-CHAPTER.PDF.

THE NATIONAL INSTITUTE FOR DIRECT INSTRUCTION (NIFDI) IS THE WORLD'S FOREMOST DIRECT INSTRUCTION (DI) SUPPORT PROVIDER. THIS WEBSITE PROVIDES INFORMATION AND RESOURCES FOR ADMINISTRATORS, TEACHERS, AND PARENTS TO HELP THEM MAXIMISE STUDENT ACHIEVEMENT THROUGH DI.

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TOM SHERRINGTON – BARAK ROSENSHINE'S PRINCIPLES OF INSTRUCTION PAPER – RESEARCHED 2019.

AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=YR1DFO5XOPO.

EXPLORING BARAK ROSENSHINE'S SEMINAL PRINCIPLES OF INSTRUCTION: WHY IT IS THE MUST-READ FOR ALL TEACHERS.

AVAILABLE FROM HTTPS://TEACHERHEAD.COM/2018/06/10/EXPLORING-BARAK-ROSENSHINES-SEMINAL-PRINCIPLES-OF-INSTRUCTION-WHY-IT-IS-THE-MUST-READ-FOR-ALL-TEACHERS/.

DIRECT INSTRUCTION GETS NO RESPECT (BUT IT WORKS).

AVAILABLE FROM HTTPS://3STARLEARNINGEXPERIENCES.WORDPRESS.COM/2018/05/01/DIRECT-INSTRUCTION-GETS-NO-RESPECT-BUT-IT-WORKS/.

WILL THE EDUCATIONAL SCIENCES EVER GROW UP?

AVAILABLE FROM HTTPS://3STARLEARNINGEXPERIENCES.WORDPRESS.COM/2017/01/10/WILL-THE-EDUCATIONAL-SCIENCES-EVER-GROW-UP/.

24 ASSESSMENT *FOR*, NOT *OF* LEARNING

ASSESSMENT FOR LEARNING

DOI: 10.4324/9781003395713-29

24 ASSESSMENT *FOR*, NOT *OF* LEARNING

PAPER "Assessment and classroom learning"[1]

QUOTE *"Feedback should be more work for the recipient than the donor".*[2]

Why you should read this article

In thinking about education research and its relevance to the classroom, one helpful term to consider is that of "best bets". It seems self-evident that because teacher and pupil time is so precious and because of the elusive way in which learning happens, we should focus on what is more likely to yield the best learning gains based on the best available evidence. Possibly the strongest "bet" we know of is high quality feedback and over the last 20 years the practice of formative assessment, or "assessment for learning" as it would be later known, became one of the most influential approaches to classroom practice we know of.

FORMATIVE ASSESSMENT Allows teachers to respond to learner's needs

In this seminal article, Paul Black and Dylan Wiliam present a strong case for the use of formative assessment as a means of not just reducing the gap between pupil achievement and underachievement but for raising pupil achievement overall. Feedback is often cited as the most effective intervention there is, giving the most "bang for your buck", but surprisingly not all feedback is good. A review by Avraham Kluger and Angelo DeNisi (1996) found that while the overall effect size of feedback was powerful (0.4), there were huge discrepancies between the effects with around two out of every five showing a negative effect. In other words, some pupils would have been more successful if they had had no feedback at all. It's not the giving of feedback per se but rather the type of feedback given, possibly combined with the way it's given. The question is thus: what kinds of feedback are effective, and how can teachers use them?

FEEDBACK Not always a positive impact

1 BLACK, P., & WILIAM, D. (1998A). ASSESSMENT AND CLASSROOM LEARNING. *ASSESSMENT IN EDUCATION: PRINCIPLES, POLICY & PRACTICE*, *5*(1), 7–74.

2 WILIAM, D. (2011). *EMBEDDED FORMATIVE ASSESSMENT*. SOLUTION TREE PRESS, P. 131.

In the 1990s, Wiliam and Black reviewed a great number of studies on assessment completed between 1988 and 1998 (comprised of a total of 681 publications) and what they found was that assessment *for* learning as opposed to assessment *of* learning produced substantial improvement in student outcomes. This distinction (Gipps, 1994) claimed that approaches to assessment that were formative in nature, that is to say they were more focused on responding to a piece of work in a way that informed what the student and teacher needed to do next, and which viewed feedback as an interaction between teacher and pupil (*for* learning), were far more effective than summative feedback in the form of simply giving grades and comments (*of* learning).

Assessment *for* learning versus assessment *of* learning

Abstract of the article

This article is a review of the literature on classroom formative assessment. Several studies show firm evidence that innovations designed to strengthen the frequent feedback that students receive about their learning yield substantial learning gains. The perceptions of students and their role in self-assessment are considered alongside analysis of the strategies used by teachers and the formative strategies incorporated in such systemic approaches as mastery learning. There follows a more detailed and theoretical analysis of the nature of feedback, which provides a basis for a discussion of the development of theoretical models for formative assessment and of the prospects for the improvement of practice.

The article

In this article, the authors review studies published between 1988 and 1998 comprised of a total of 681 publications. The studies ranged from pupils aged 5 right up to undergraduates. The studies suggest that formative assessment practices are very powerful with typical effect sizes of formative assessment interventions recorded between 0.4 and 0.7. These are big gains. To put this in perspective, the authors note that:

EFFECT SIZE
Measure of an intervention's impact

> An effect size gain of 0.7 in the recent international comparative studies in mathematics would have raised the score of a nation in the middle of the pack of 41 countries (e.g., the U.S.) to one of the top five.
>
> (Black & Wiliam, 1998b, p. 141)

These findings would have big implications not just for the classroom teacher but for policy makers at a local, national, and indeed international level.

HOW LARGE IS THE EFFECT?

The most frequently mentioned magnitude of the effect of formative testing on learning is an improvement between 0.4 and 0.7. What these numbers mean exactly becomes clear when you express them in percentages (the so-called superiority percentage). These percentages indicate the likelihood that a random student from the formative assessment group will do better than someone from the control group (without formative assessment). For the effect size 0.4 that percentage is 61% and for 0.7 it is 69%. A meta-analysis by Neal Kingston and Brooke Nash from 2011 shows that this is an overestimation. The true effect size of formative testing is more in the direction of 0.25 or 57% (Kingston & Nash, 2011).

FORMATIVE ASSESSMENT
Modify teaching and learning activities

The term formative assessment has a long history in education, with it usually being attributed to Scriven (1967), however as Black and Wiliam state, formative assessment "does not have a tightly defined and widely accepted meaning" (1998a, p. 7). This points to a core problem in the implementation of the research, namely that it's often a kind of crystal ball through which anyone can see anything they want. They define formative assessment as "encompassing all those activities undertaken by teachers, and/or by their students, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged" (p. 7). In their view, formative assessment relates to a sequence of two actions: (1) the learners' perception that there is a gap between their goal and the present state of their knowledge, understanding, and/or a skill, and (2) what learners do to close that gap and attain the desired goal.

In reviewing the literature on teacher assessment practices, the authors found three major themes: first, formative assessment is not well understood by most teachers and is poor in practice. Second, the external pressure of local and national accountability exerts a strong influence on its efficacy. Lastly, to implement it properly requires substantial changes in teachers' perception of their own role and their classroom practice.

Another key point is that what students want and what *we want them to want* are often two completely different things. Many students "do not aspire to learn as much as possible, but are content to 'get by', to get through the period, the day or the year without any major disaster, having made time for activities other than school work" (Perrenoud, 1991, p. 92). The authors then lay out the challenge with formative assessment; not only do we aim for students to learn material and then know it at some time in the future, but we also want them to *know what they don't know* and then be able and motivated to do something about it, to put in place actions which will lead to a closing of the gap between aspired goals and outcomes. As a side note here: this prepares them for their futures without the need of twenty-first century skills hype.

Another issue is that students often don't recognise feedback as a first step for them to take towards success but rather as an overall judgement of ability (Tunstall & Gipps, 1996). The work of Purdie and Hattie (1996) in Japanese and Australian students showed a cultural difference in students' response to feedback; some saw it as a means to succeed and some just didn't want it. A key point here is that it's not just enough to *provide* feedback – students need to *want* the feedback. If the feedback is not desired, then it disappears into the ether (or the bottom of their book bags or backpacks). Furthermore, students with a more mastery-orientated approach to learning as opposed to a performance-orientated approach are far more likely to seek out, take on, and ultimately act upon feedback (see Chapter 13, Beliefs about intelligence can affect intelligence, and Chapter 16, Where are we going and how do we get there?). Thus, the authors are keen to emphasise the importance of self-concept on formative assessment.

Unwanted feedback is counterproductive

One more key point made in this article is that formative assessment practices are particularly effective for low-performing students and so reduces the gap in achievement and raises the level of achievement overall. This has significant implications as such students are often demotivated and can be disruptive for other students and can then go on to be "alienated from society and to become the sources and the victims of serious social problems" (Black & Wiliam, 1998b, p. 142)

In summing up, the authors state that formative assessment practices are hugely powerful and that the associated practices are not marginal changes in teacher practice and require additional support and guidance. Additionally, the kinds of significant gains are dependent on a wide range of factors that are often beyond the control of the classroom teacher such as managerial focus on summative data or the quality of the relationships between teacher and pupil for example.

Conclusions/implications of the work for educational practice

The central takeaway from this article is that assessment of pupil progress needs to have more than a summative function in order for it to affect learning; it must inform both the teacher and student *what*

Formative assessment informs rather than judges

to do next. One of the problems with the word "assessment", however, is that it has certain, often pejorative, connotations. Indeed Dylan Wiliam would later say in an interview in the *Times Educational Supplement* that "The big mistake that Paul and I made was calling this stuff 'assessment' … because when you use the word assessment, people think about tests and exams" (Stewart, 2012). In fact, he would later say that he wished he had called it "responsive teaching" as opposed to assessment for learning.[3] Also crucially, as stated earlier, there is an important distinction to be made between assessment *of* learning and assessment *for* learning (Gipps, 1994) which are two entirely different things. Black et al. (2002, p. i) define assessment *for* learning as:

> any assessment for which the first priority in its design and practice is to serve the purpose of promoting pupils' learning. An assessment activity can help learning if it provides information to be used as feedback, by teachers, and by their pupils, in assessing themselves and each other, to modify the teaching and learning activities in which they are engaged.

Feedback week as opposed to assessment week

The article has considerable implications, not just for the classroom teacher but also for school leaders in terms of the way in which they view the function of assessments. For example, many schools have an "assessment week" where year groups take tests and are given grades which are then recorded centrally and used for reports. But how many schools have a "feedback week"? A time where there is not just a stronger dialogue between teacher and student about the test but also a dedicated time given for the student to refine and improve and for the teacher to review and modify what they will teach next. In this way, assessments are truly responsive.

Essentially this article makes the claim that assessment which seeks to inform next steps is one of the most effective ways we know to improve pupil achievement (indeed the gains in using this approach are among the largest ever reported for educational interventions); however, they are at pains to state that a critical set of conditions need to be met in order to harness that effectiveness, which are a lot harder

3 WILIAM, D. (2013). EXAMPLE OF A REALLY BIG MISTAKE: CALLING FORMATIVE ASSESSMENT FORMATIVE ASSESSMENT AND NOT SOMETHING LIKE RESPONSIVE TEACHING. TWITTER BLOG AVAILABLE AT: HTTPS://TWITTER.COM/DYLANWILIAM/STATUS/393045049337847808 (ACCESSED JUNE 12, 2019).
IN A PERSONAL COMMUNICATION TO US, DYLAN WILIAM WROTE:

> BUT IN THE SOURCE CITED HERE, WE ALSO DISTINGUISHED BETWEEN ASSESSMENT FOR LEARNING AND FORMATIVE ASSESSMENT. ALSO, IT'S IMPORTANT TO REALIZE THAT THE REASON WE DID NOT USE THE TERM RESPONSIVE TEACHING IS BECAUSE IT FOCUSES TOO MUCH ON THE ROLE OF THE TEACHER, AND NOT ON THE ROLE OF THE LEARNER.

than one might think. Indeed it is interesting to note that some recent discussion has asked whether the subsequent use of assessment for learning over the last 20 years can be considered a success or failure (Christodoulou, 2017).

How to use the work in your teaching

Assessment for learning in practice

Following this article, Wiliam and Black worked with a wide range of schools in 1999 on putting the principles of assessment for learning into practice in the classroom. They explained the research and then collaborated with them on how to implement the findings into their own practice. Among the strategies identified (Black et al., 2003) were:

- Marking and feedback: handing back work to students with no grade, only comments. The idea here is to focus more on how to improve rather than how well they've done or gotten wrong.
- Questioning: instead of asking questions that are factual recall or guessing what's in the teacher's head, teachers should allow more thinking time for deeper understanding.
- Testing schedule: having tests two-thirds of the way through a unit as opposed to the end in order to allow students time to attend to miscomprehensions.
- Peer-assessment and self-assessment: allowing students to look at assessment criteria from exam boards and then use that criteria to evaluate their own work and that of their peers.

According to the researchers, the results were dramatic. By the end of that academic year, the performance on external tests by the students taught by the teachers using formative assessment practices was significantly higher than those not using them in the same school (Black et al., 2003).

Gradeless feedback

Possibly the most radical of these methods is giving back assessments or individual pieces of work with no grades on them. This is where there needs to be a serious conversation within a school about the purpose of assessment. A key question to ask is: does the assessment serve the learning or does the learning serve the assessment? If it's the latter then it's unlikely that students will be truly mastering a domain and it's possible that they are being taught to pass the test. It is also more uncomfortable to have to really think hard about work you have done, where you have gone wrong, and how to improve it than it is to look at a grade, but it is undoubtedly more effective. As Wiliam notes "feedback should be more work for the recipient than the donor" (Wiliam, 2011, p. 162). The key challenge facing educators is in creating a climate where those challenges are embraced and genuine learning is a central aspiration.

Takeaways

- Make a clear distinction between assessment *of* learning and assessment *for* learning.
- Formative assessment is particularly effective with lower-performing students.
- Don't always give a grade when handing back work, try comments only.
- Use questions to not only check understanding but to inform what to teach next.
- Give students rubrics, success criteria, and exemplar work and get them to peer-assess each other's work.
- The onus should be put on the student to respond to marked work.

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CHRISTODOULOU, D. WHY DID ASSESSMENT FOR LEARNING FAIL? FESTIVAL OF EDUCATION, WELLINGTON COLLEGE.

Assessment for learning is one of the most well-evidenced methods of improving education. Yet, after nearly two decades of intensive training and investment in its principles, educational standards in England haven't risen. Why? Daisy Christodoulou considers some possible explanations.

AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=QLPAALDAQQY.

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SLIDE PRESENTATION AVAILABLE FROM HTTPS://SLIDEPLAYER.COM/SLIDE/783910/.

A VIDEO OF DYLAN WILIAM EXPLAINING ASSESSMENT FOR LEARNING.

AVAILABLE FROM HTTPS://YOUTU.BE/Q-MYBW36_DA?SI=XRHNWVVKWF7MJDEE

LEARNING SCIENCES INTERNATIONAL (PUBLISHED ON SEPTEMBER 11, 2018).

Dylan Wiliam reviews the meaning of assessment for learning. He brings forward five helpful studies. Between them, five research reports synthesise the results of about 4000 research projects on feedback on assessment for learning in schools and colleges and in workplaces. Find out what the data has to say and what it reveals about learning assessment.

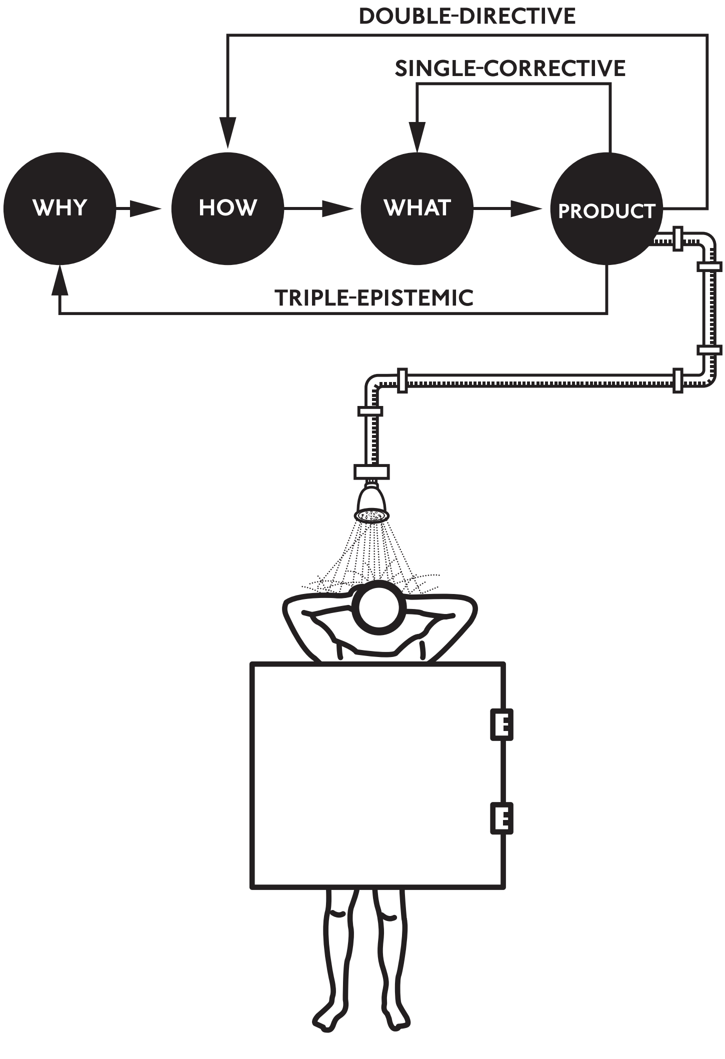
AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=Q-MYBW36_DA.

GETTING STARTED WITH ASSESSMENT FOR LEARNING.

AVAILABLE FROM HTTPS://CAMBRIDGE-COMMUNITY.ORG.UK/PROFESSIONAL-DEVELOPMENT/GSWAFL/INDEX.HTML.

25 FEED UP, FEEDBACK, FEED FORWARD

FEEDBACK



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25 FEED UP, FEEDBACK, FEED FORWARD

PAPER "The power of feedback"[1]

QUOTE *"Effective feedback must answer three major questions asked by a teacher and/or by a student: Where am I going? (What are the goals), How am I going? (What progress is being made toward the goal?), and Where to next? (What activities need to be undertaken to make better progress?)."*[2]

Why you should read this article

Do you remember the first time you learned how to ride a bike? For many of us that would have been with a parent and often resulted in many crashes before you finally took flight. Now if your parent said to you when you crashed "Oh you crashed there, okay now try it again but this time try not to crash", this input from the parent is technically a form of feedback in its broadest sense but is almost completely useless and more likely to put more pressure on the child. Instead, the parent might break down the global skill of "riding a bike" into its component parts and give specific instruction on how to push off, pedal at the right time, balance the frame, and guide the handlebars. This form of feedback is likely to result in success because it has a clear goal and provides clear steps on how to get there.

FEEDBACK
A definition
Shared responsibility of teacher and student

Kluger and DeNisi (1996) define feedback as "actions taken by an external agent to provide information regarding some aspect(s) of one's task performance" (p. 255). However a surprising thing about feedback is that it doesn't always lead to positive outcomes, indeed it often gets in the way of learning. The word feedback implies a responsibility on the teacher and certainly this is true, but what this article clearly shows

1 HATTIE, J., & TIMPERLEY, H. (2007). THE POWER OF FEEDBACK. *REVIEW OF EDUCATIONAL RESEARCH*, 77, 81–112.
2 IBID., P. 86.

is that students are most successful when they take responsibility for feedback. As Dylan Wiliam observes, "feedback should be more work for the recipient than the donor" (2011, p. 129).

In this article, Hattie and Timperley draw on a vast amount of evidence to make several important conclusions about the purpose and type of feedback. They invite us to view the process as a continuum of instruction and feedback and offer three central questions to be asked when providing feedback along with a four-part model with which to conceptualise the power of feedback.

Abstract of the article

Feedback is one of the most powerful influences on learning and achievement, but this impact can be either positive or negative. Its power is frequently mentioned in articles about learning and teaching, but surprisingly few recent studies have systematically investigated its meaning. This article provides a conceptual analysis of feedback and reviews the evidence related to its impact on learning and achievement. This evidence shows that although feedback is among the major influences, the type of feedback and the way it is given can be differentially effective. A model of feedback is then proposed that identifies the particular properties and circumstances that make it effective, and some typically thorny issues are discussed, including the timing of feedback and the effects of positive and negative feedback. Finally, this analysis is used to suggest ways in which feedback can be used to enhance its effectiveness in classrooms.

The article

The authors begin with a conceptual analysis of the meaning of the term feedback, which is more slippery than one might think. Possibly the best definition they give, which the authors describe as "an excellent summary", is from Winne and Butler (1994) who write that "feedback is information with which a learner can confirm, add to, overwrite, tune, or restructure information in memory, whether that information is domain knowledge, meta-cognitive knowledge, beliefs about self and tasks, or cognitive tactics and strategies" (p. 5740). This notion of a continuum or trajectory of learning, in which feedback and student agency are symbiotically linked, is a strong theme in this article.

META-COGNITION
Awareness and ownership of one's own learning

A key distinction made by the authors is that feedback and instruction are not the same thing. If students' knowledge of a particular domain is low then more instruction will be better than feedback. If you are learning to drive a car, it is no use for the instructor to tell you to "find the bite point" on the accelerator if you don't know how to use a clutch.

Feedback and instruction are not the same thing

As Kulhavy (1977, p. 220) points out "if the material studied is unfamiliar or abstruse, providing feedback should have little effect on criterion performance since there is not a way to relate the new information to what is already known".

As discussed in Chapter 24 (Assessment *for*, not *of* learning), the surprising thing about feedback is that some of it is not helpful at all. In Hattie's meta-analysis he also discovered a wide variability in the quality and impact of feedback. Simply providing more feedback is not always useful. The authors cite Kluger and DeNisi (1996) and their finding that the average effect size of feedback was 0.38 yet 32% of the effects were negative. The authors conclude from this that feedback is more effective when it builds on changes from previous trials and when goals are specific and challenging and task complexity is low. Significantly they claim that praise for task performance seems to be ineffective "which is hardly surprising because it contains such little learning-related information" (Hattie & Timperley, 2007, p. 86).

PRAISE
Good for lots of things but not for learning

A central theme of this article is that feedback needs to be directed at the appropriate level of student learning. (Considering again their model of feedback as a continuum between instruction and feedback is important to remember.) With that in mind, the authors use a three-part strategy based on three central questions:

1. *Where am I going*? (What is my goal? What am I trying to achieve?)
2. *How am I going*? (What is my current level of performance relative to my goal?)
3. *Where to next*? (What specific actions do I need to take to reduce the gap?)

FEEDBACK
Three questions to ask

They also refer to these three steps as "*feed up, feedback and feed forward*". In answering the first question, the authors state that it is vital to provide clear goals to students that are unambiguous and attainable, which attempt to close the gap between current understanding and goals: "Feedback cannot lead to a reduction in this discrepancy if the goal is poorly defined, because the gap between current learning and intended learning is unlikely to be sufficiently clear for students to see a need to reduce it" (Hattie & Timperley, 2007, p. 89). In terms of "How am I going?", there is not much guidance given apart from asserting that testing is perhaps not an ideal way of assessing current performance. The last question, "Where to next?", is a crucial one and may include "enhanced challenges, more self-regulation over the learning process, greater fluency and automaticity, more strategies and processes to work on the tasks, deeper understanding, and more information about what is and what is not understood" (Hattie & Timperley, 2007, p. 90).

Feed up, feedback, feed forward

Arising from this, the authors present a four-part model (Figure 25.1) which incorporates:

1. Feedback about the task (FT) is likely to be more powerful if it highlights misinterpretations of key concepts or terms instead of merely pointing out a lack of information.
2. Feedback about the process (FP) is aimed at outlining aspects of the process used to create a product or whatever was carried out.
3. Feedback about the level of self-regulation a student is using (FR) is aimed at providing guidance on how students might better assess how they can metacognitively reflect on their own learning, assess what they need to work on, and how to progress.
4. Lastly, feedback that is aimed at the self (FS) is aimed at personal aspects of the student such as saying, "Good girl, well done you are a top student".

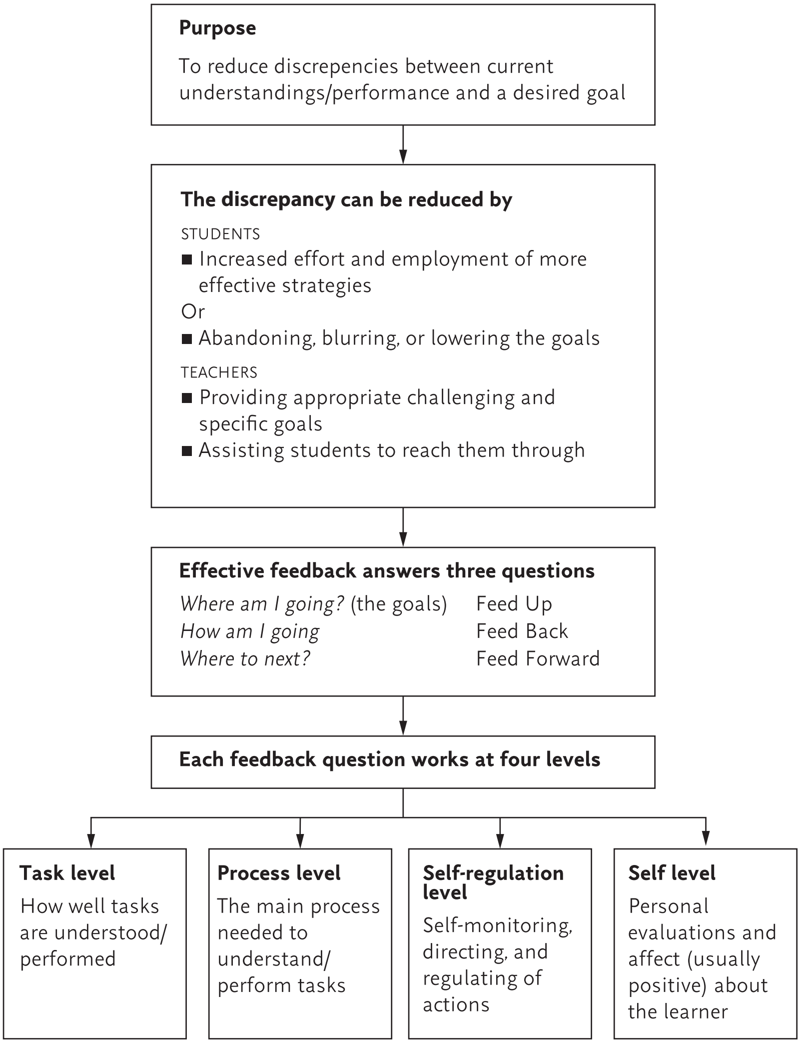

FIGURE 25.1 A MODEL OF FEEDBACK TO ENHANCE LEARNING (HATTIE & TIMPERLEY, 2007, P. 87)

A particularly important part of this model is the self-regulation level. Some students have low self-regulation levels and poor overall self-concept as they are conscious of the fact that "feedback", as they understand it, is a judgement of sorts. In this case, feedback is not always wanted or acted upon. Feedback is particularly powerful when it tells the student what they did well and how to expand on that, but as we saw in Chapter 15 (How you think about achievement is more important than the achievement itself), if overly positive praise or undeserved success is given to the student then the impact of this feedback can be negative as the student will not attribute their performance to effort but rather to external factors. Additionally, feedback can be really powerful when it disconfirms what a student thought they knew: "Feedback has its greatest effect when a learner expects a response to be correct and it turns out to be wrong" (Hattie & Timperley, 2007, p. 95).

Disconfirmation is important in learning

An additional problem is that some students view the entire process of feedback as the teacher's responsibility. They expect to be told what they need to achieve, how they are currently doing, and then how to get there. In the initial stages, there is certainly a responsibility on the teacher to provide this information but the students who are really successful will take more ownership of this process.

Conclusions/implications of the work for educational practice

Essentially, you want the student receiving feedback to act upon information provided to them and to do so they will need a clear picture of where they need to be. Getting students to "take on" this responsibility is key. If the teacher is working twice as hard as the student then something has gone wrong. Providing clear criteria for success, worked examples, and exemplars is particularly helpful. After all, it's impossible to be excellent if you don't know what excellent looks like. From there they need accurate information of their current performance and clear steps on how to reduce the gap between the current state and the aspired outcome.

Feedback works better when the learner has ownership

Additionally, feedback needs to be given in a context. Saying "you need to use more complex vocabulary and terms" is going to be ineffective if the teacher is not specific about what that specific context is. Too much "feedback" is really just information about what is wrong with the student's work. For example, in providing students with feedback on an essay on Shakespeare teachers often use the language of the exam board grade descriptors such as "extensive vocabulary should be used widely"; however, this is not useful information for a student who does not have that wide a vocabulary in the first place. Instructing the student to use terms such as “soliloquy” and “iambic pentameter” and pointing them to an area where they might expand on these terms is likely to lead to more learning.

Feedback should clarify *and* inform

In addition, the goals given to students need to be specific. If the feedback is unrelated to the goal then it is unlikely to reduce the gap between the current level of performance and the intended goal. For example, if the goal of a piece of student writing is to “create a mood in a story” and the student is given feedback on spelling and presentation then they are not likely to improve in their ability to create a mood where the focus might be on the use of tone and imagery which would better address the task.

How to use the work in your teaching

The authors of this article attempt to encourage teachers to view feedback as a continuum in which a productive dialogue occurs. The aim is to get students to think about, and act upon, the information they have been given. A helpful model of this is provided by Paul Kirschner, in a presentation in 2017 for the MBO Taalacademie (Vocational High School Language Academy) on “Effective, efficient and enjoyable feedback: Is that possible? And how?”. Kirschner distinguished three forms of feedback (see Figure 25.2). With *corrective feedback* you look at something, say whether it is right or wrong and what it should be. A student does not learn very much from this kind of feedback. This is called *single loop* feedback: it relates to the actions, behaviour, and visible effect or result (good/desirable or wrong/undesirable). A little better is *directive feedback*, in which the teacher tells the student what is wrong and how (s)he can correct it. This is called *double loop* and is about how the task was performed in which the student is told how it can or should be done better. The best type of feedback is knowledge development or *epistemic feedback*. This is called *triple loop* feedback. As a teacher, with this type of feedback you encourage the student to think about the who, what, why, when,

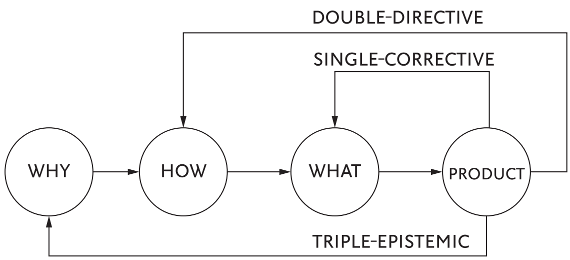

FIGURE 25.2
SINGLE, DOUBLE, AND TRIPLE LOOP FEEDBACK

and how of the task. You ask, for example, "Why did you choose this formula, Aisha? And what would you have done if the task was X? Would you have done it differently?"

Feedback is one of the most powerful forms of intervention in education but it is also one of the most misunderstood. Many teachers are now assessed against the progress of their pupils and how much marking is in their students' books, which can result in a situation where feedback is more about showing their own work as opposed to that of their students. To really harness the power of feedback it is vital to cultivate an environment where students have a clear sense of where they are going to, how they are currently doing against that goal, and what to do about it to close that gap.

Takeaways

- If the student doesn't know enough about a topic then they don't need feedback, they need more instruction.
- Feedback needs to be context specific, not general. Saying "use better vocab" is not helpful to students if they don't know what that domain-specific vocab is.
- If the teacher is putting more work into the process than the student, then progress is likely to be impaired.
- Students need to view the process of feedback as one they will ultimately take ownership of.
- Feedback needs to be non-threatening to students in terms of their self-concept.
- Praise that directs the student away from the task and towards the self is unlikely to be beneficial as it contains so little information on how to improve.
- Feedback on the task (FT) is most powerful when it addresses faulty conceptions as opposed to a complete misunderstanding.

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Suggested readings and links

A VIDEO OF JOHN HATTIE ON VISIBLE LEARNING AND FEEDBACK IS

AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=VPQ09EY4PZO.

DYLAN WILIAM'S "FOUR QUARTERS MARKING" – A WORKLOAD SOLUTION?

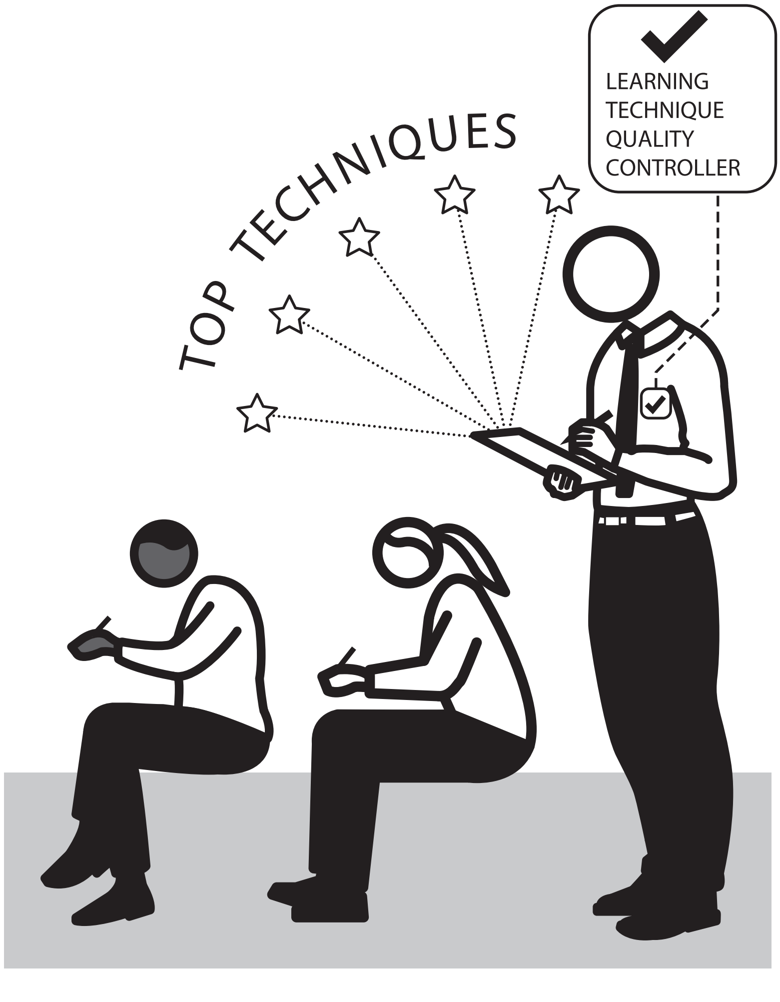
AVAILABLE FROM HTTPS://CHRONOTOPEBLOG.COM/2017/09/02/FOUR-QUARTERS-MARKING-A-WORKLOAD-SOLUTION/.

A SUMMARY OF THE ARTICLE WITH SOME USEFUL EXAMPLES OF APPLICATION IN THE CLASSROOM IS

AVAILABLE FROM HTTPS://ROBINBNEAL.COM/2015/04/24/THE-POWER-OF-FEEDBACK-SUMMARY-PART-ONE/.

26 LEARNING TECHNIQUES THAT REALLY WORK

LEARNING TECHNIQUES



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26 LEARNING TECHNIQUES THAT REALLY WORK

PAPER "Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology"[1]

QUOTE *"If simple techniques were available that teachers and students could use to improve student learning and achievement, would you be surprised if teachers were not being told about these techniques and if many students were not using them?"*[2]

Why you should read this article

You have to read and learn from some text. What's the best way to do this? Do you highlight the text with different colour markers? Do you underline in the text? Do you re-read the text? These are all "normal" study approaches, but it does not stop here. Learners often have very astonishing ideas about how they can best learn. Thinking back to our own school careers, we did things like putting a book under our pillow or playing a poem on an endless loop on the tape recorder so that the content could enter our brains during sleep. We've also heard of learners who thought that taking notes with a certain pen would ensure that the content would also appear during the examinations. Think of this as your own magical remember pen. Now these last three are very exceptional ideas and of course we know that they really don't work (especially the first and last ones), but the reason that students do these things is, in essence, good. At the very least they want to get a good grade on an exam and at best they really want to learn and master the substance (see

1 DUNLOSKY, J., RAWSON, K. A., MARSH, E. J., NATHAN, M. J., & WILLINGHAM, D. T. (2013). IMPROVING STUDENTS' LEARNING WITH EFFECTIVE LEARNING TECHNIQUES: PROMISING DIRECTIONS FROM COGNITIVE AND EDUCATIONAL PSYCHOLOGY. *PSYCHOLOGICAL SCIENCE IN THE PUBLIC INTEREST*, *14*, 4–58.

2 IBID., P. 5.

Chapter 13 on how beliefs can influence learning and Chapter 16, Where are we going and how do we get there?).

As a "calculating student" (nothing pejorative meant here), if there are certain study strategies or approaches that are more effective or efficient than others, then of course it's smart to use the most effective or efficient approach. The only problem here was that most students, and also many or even most teachers, don't have an accurate picture of the effectiveness of their study approach. We'd even venture to state that many don't even know the different effective strategies. After more than a hundred years of research into learning and memory, there are a few things that we know about good and less good approaches. Since the turn of this century, people have been trying to figure out how to remember as much as possible, how to ensure that we forget as little as possible, and how to do this in as little time as possible. The reason that we have our doubts with respect to teachers is because the findings that have emerged from this research aren't yet included in textbooks for teachers (both in research in the US, as well as in the Netherlands and Flanders; Pomerance, Greenberg, & Walsh, 2016; Surma, Vanhoyweghen, Camp, & Kirschner, 2018). This is one of the reasons why John Dunlosky and colleagues conducted an overview study of what is known about effective and efficient study approaches. With this knowledge, teachers can better choose between different approaches and apply the best in their education and also teach their pupils to do it themselves.

Students lack knowledge of most effective study methods

Abstract of the article

Many students are being left behind by an educational system that some people believe is in crisis. Improving educational outcomes will require efforts on many fronts, but a central premise of this monograph is that one part of a solution involves helping students to better regulate their learning through the use of effective learning techniques. Fortunately, cognitive and educational psychologists have been developing and evaluating easy-to-use learning techniques that could help students achieve their learning goals. In this monograph, we discuss 10 learning techniques in detail and offer recommendations about their relative utility. We selected techniques that were expected to be relatively easy to use and hence could be adopted by many students. Also, some techniques (e.g. highlighting and rereading) were selected because students report relying heavily on them, which makes it especially important to examine how well they work. The techniques

Easy-to-use study techniques

include elaborative interrogation, self-explanation, summarization, highlighting (or underlining), the keyword mnemonic, imagery use for text learning, rereading, practice testing, distributed practice, and interleaved practice.

To offer recommendations about the relative utility of these techniques, we evaluated whether their benefits generalize across four categories of variables: learning conditions, student characteristics, materials, and criterion tasks. Learning conditions include aspects of the learning environment in which the technique is implemented, such as whether a student studies alone or with a group. Student characteristics include variables such as age, ability, and level of prior knowledge. Materials vary from simple concepts to mathematical problems to complicated science texts. Criterion tasks include different outcome measures that are relevant to student achievement, such as those tapping memory, problem solving, and comprehension.

Five techniques received a low utility assessment: summarization, highlighting, the keyword mnemonic, imagery use for text learning, and rereading. These techniques were rated as low utility for numerous reasons. Summarization and imagery use for text learning have been shown to help some students on some criterion tasks, yet the conditions under which these techniques produce benefits are limited, and much research is still needed to fully explore their overall effectiveness. The keyword mnemonic is difficult to implement in some contexts, and it appears to benefit students for a limited number of materials and for short retention intervals. Most students report rereading and highlighting, yet these techniques do not consistently boost students' performance, so other techniques should be used in their place (e.g. practice testing instead of rereading).

The article

John Dunlosky and his colleagues Katherine Rawson, Elizabeth Marsh, Mitch Nathan, and Dan Willingham wrote this article to help students and teachers by looking at what was known from research in cognitive psychology and educational sciences on the effectiveness of different study approaches (they called them learning techniques). They knew from the literature that much was known about effective learning techniques, but that this information often wasn't found in teacher textbooks; both pre-service and in-service.

Dunlosky et al. document and discuss ten study techniques, namely: elaborative interrogation, self-explanation, summarisation, highlighting/underlining, keyword mnemonics, imagery for text, rereading, practice testing, distributed practice, and interleaved practice (see Table 26.1). They chose these ten because they're all relatively easy to use independently and would, therefore, be usable by many students. They also noted that a number of techniques (e.g. highlighting and rereading) are often used by students and so it was important to know if they actually worked. To this end, they searched the scientific literature for studies on the effectiveness of the different techniques. In addition to looking at whether the learning techniques actually led to better information retention, they also took into account whether the strategies could be used by different students (e.g. different ages, prior knowledge, verbal ability, self-efficacy), with different types of learning material (e.g. vocabulary, lecture content, narrative and expository texts, maps, diagrams), under different learning conditions (e.g. amount of practice, reading vs. listening, intentional vs. incidental learning, individual vs. group learning, listening vs. reading), and for different criterion tasks (e.g. cued recall, free recall, recognition, problem-solving, essay writing).

Highlighting and rereading don't work

Technique	Description
1 Elaborative interrogation	Generating an explanation for why an explicitly stated fact or concept is true
2 Self-explanation	Explaining how new information is related to known information, or explaining steps taken during problem solving
3 Summarization	Writing summaries (of various lengths) of to-be-learned texts
4 Highlighting/underlining	Marking potentially important portions of to-be-learned materials while reading
5 Keyword mnemonic	Using keywords and mental imagery to associate verbal materials
6 Imagery for text	Attempting to form mental images of text materials while reading or listening
7 Rereading	Restudying text material again after an initial reading
8 Practice testing	Self-testing or taking practice tests over to-be-learned material
9 Distributed practice	Implementing a schedule of practice that spreads out study activities over time
10 Interleaved practice	Implementing a schedule of practice that mixes different kinds of problems, or a schedule of study that mixes different kinds of material, within a single study session

TABLE 26.1 THE TEN LEARNING TECHNIQUES STUDIED BY DUNLOSKY ET AL. (2013)

The researchers were looking for techniques that could be used by as many students as possible (i.e. that were generalisable). Table 26.1 gives the ten study techniques with a short description. In the next part, we look at which ones came out the best.

Dunlosky and his colleagues produced a kind of report card for the different techniques including the generalisability requirements. Table 26.2 lists the assessments. As is apparent, the top two are practice testing and distributed practice. These learning techniques are, therefore, assessed as good (i.e. have high utility). Practice testing and distributed practice work regardless of learner, material, criterion task, learning context, and issues (problems) for implementation.

ELABORATIVE INTERROGATION Learner offers explanations for key facts asking "how?" and "why?"

Elaborative interrogation, self-explanation, and interleaved practice were judged to be of moderate, but sufficient, utility. There was less good news for summarisation, highlighting/underlining, keyword

TABLE 26.2 THE UTILITY ASSESSMENT AND GENERALISABILITY RATINGS OF THE LEARNING TECHNIQUES (DUNLOSKY ET AL., 2013)

Technique	**Utility**	**Learner**	**Material**	**Criterion tasks**	**Context**	**Implementation issues**
Elaborative interrogation	Moderate	P–I	P	I	I	P
Self-explanation	Moderate	P–I	P	P–I	I	Q
Summarization	Low	Q	P–I	Q	I	Q
Highlighting	Low	Q	Q	N	N	P
Keyword mnemonic	Low	Q	Q	Q-I	Q–I	Q
Imagery use	Low	Q	Q	Q-I	I	P
Rereading	Low	I	P	Q-I	I	P
Practice testing	High	P–I	P	P	P	P
Distributed practice	High	P–I	P	P–I	P–I	P
Interleaved practice	Moderate	I	Q	P–I	P–I	P

Note: A positive (P) rating indicates that available evidence demonstrates efficacy of a learning technique with respect to a given variable or issue. A negative (N) rating indicates that a technique is largely ineffective for a given variable. A qualified (Q) rating indicates that the technique yielded positive effects under some conditions (or in some groups) but not others. An insufficient (I) rating indicates that there is insufficient evidence to support a definitive assessment for one or more factors for a given variable or issue.

mnemonics, imagery use, and rereading; techniques which are very often recommended to and used by students. These all had low utility; that is they don't really help students learn. One of these may sound a bit weird, namely summarisation because it's actually a form of self-testing. The reason for this is simple: in order for summarisation to work, you have to be able to make a good summary. However, most students can't! The same might be true for underlining/highlighting. If you can't separate the wheat from the chaff, you'll highlight/underline too much or the wrong things.

The researchers conclude that (how can it be any different?) more research is needed. First, research should fully explore the degree to which the benefits of some techniques generalise to the variables studied (learner, material, etc.) including interactions among the variables that might limit or magnify the benefits of a given technique. Second, research on the benefit of most of the techniques needs to be carried out in representative educational settings.

Conclusions/implications of the work for educational practice

It's probably best to confine ourselves to a discussion of the two best techniques: practice testing and distributed practice.

DISTRIBUTED AND SPACED PRACTICE
Highly effective methods of learning
CRAMMING
Good in the short-term, bad in the long-term

Distributed practice (spaced practice) is a technique whereby you spread out the study and/or practice time instead of bundling it in one period in so-called blocked- or massed-practice sessions. Studying something in a few short sessions (e.g. four times 30 minutes) with a day or two between sessions works better than cramming on the night before a test for two hours. This is called the spacing effect (Cepeda et al., 2008). There is a caveat here: for immediate retention, cramming sometimes leads to equivalent or even slightly better learning, but for long-term retention spacing is significantly superior.

- For teachers: give small (homework) assignments that include both new and previously treated material frequently, give cumulative tests, plan short review sessions at the start of each lesson, implement a spiral curriculum, etc.
- For students: make exam schedules in which the study sessions are spread in time, practice basic skills repeatedly but in short intervals, etc.

THE SPACING EFFECT

The spacing effect is based upon what's known as the forgetting curve (see Figure 26.1), first discussed by Hermann Ebbinghaus in 1885! In essence, this means that we forget what we've read or learnt quickly and at a high rate (i.e. the curve is steep). By building retrieval moments into the learning process, we refresh what we know to 100% and also make the curve less steep.

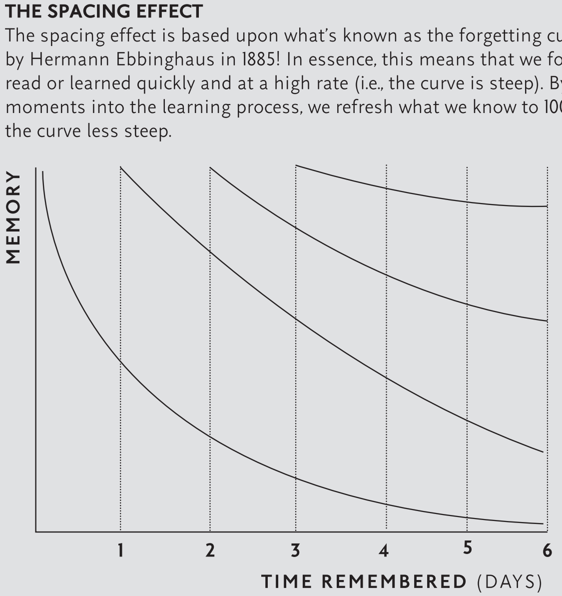

FIGURE 26.1 A TYPICAL FORGETTING CURVE (AFTER EBBINGHAUS, 1885)

The testing effect

Practice testing (retrieval practice) means that you are required to retrieve the information that was studied/learnt from long-term memory. This active recall/retrieval of information ensures that you remember this information better and for longer. This effect is called the testing effect (Roediger & Butler, 2011; Roediger & Karpicke, 2006).

- For teachers: use any instructional technique where your students are obliged to remember information such as quizzes, practice tests, and review questions.
- For students: use different forms of self-tests, such as flashcards, diagnostic exercises, quizzes. A great approach is what's known as Cornell notes (Pauk, 2001).

How to use the work in your teaching

Effective learning techniques are not just for students

When making use of the learning techniques that have been shown to have a high utility, you need to remember a few things. First, it's important that you lead by example. It's not enough to teach your students the techniques and then to tell them to use them. You need to use them yourself. You need to give them assignments in such a way that they are spacing their practice. You need to plan your exams in such a way that there's enough time for the kids to space their practice. And here's a sticky point: you need to coordinate this with your fellow teachers (at least if you're a secondary school teacher) since students can't spread their learning moments if there are a series of exams in different subjects planned close to each other. No child will study Monday evening for a test on Friday if there's a test Tuesday in a different subject.

Further, you need to make use of retrieval practice in your teaching. You can begin each lesson with a review in the form of a question, quiz, or whatever about what was studied or discussed the day before. In this way your students are required to retrieve what they have learnt. Barak Rosenshine (2010) moved this a step further saying that at the end of each week – or on the Monday of the new week – you should review in the form of a quiz the most important things that were handled the previous week and the same goes for each month. No big tests, just short quizzes to allow for retrieval. Finally, this also goes for starting a new unit: what was important in the previous unit for the new one?

More frequent practice tests are more effective than one big one

And all of this means that you need to teach how to use the techniques properly. As stated, certain techniques such as highlighting/underlining and summarising have potential, but don't fulfil that potential because most students have never really learnt how to write a good summary or learnt how to discern what the main points of a paragraph of text are. If they think that everything is of equal importance, then nothing is actually important. And don't think that this is only the job of the English teacher. The learning and use of these techniques needs to be integrated into all subjects!

Takeaways

- Most students don't really know the best way to study. As a teacher you need to teach them this!
- Most teachers also don't know what the best learning techniques are and often use ones that don't work or don't work well.

- Teach your students those techniques that have been proven to be effective and explain why they work well; discourage techniques that don't work well and explain why they don't.
- Teach your students how to summarise, highlight, etc., so that these techniques have a chance at working.
- Repeat/review the material from the day(s) before and check what your students still know and what they do and don't understand.
- Use different types of practice tests such as quizzes, flashcards, and open ended questions, epistemic tasks, review questions, and so forth.
- It's better to give your students a number of small (homework) assignments distributed over time than one large assignment.

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DOWNLOADABLE MATERIALS (E.G. POSTERS AND INSTRUCTIONAL MATERIALS) BY THE LEARNING SCIENTISTS.

AVAILABLE FROM WWW.LEARNINGSCIENTISTS.ORG/DOWNLOADABLE-MATERIALS/.

BLOG BY PAUL KIRSCHNER AND MIRJAM NEELEN ABOUT THE TESTING EFFECT.

AVAILABLE FROM HTTPS://3STARLEARNINGEXPERIENCES.WORDPRESS.COM/2018/06/19/AND-THE-WINNER-IS-TESTING/.

BLOG BY PAUL KIRSCHNER AND MIRJAM NEELEN ABOUT TOP AND FLOP LEARNING STRATEGIES.

AVAILABLE FROM HTTPS://3STARLEARNINGEXPERIENCES.WORDPRESS.COM/2015/07/14/LEARNING-THE-SMART-WAY-2/.

BLOG BY PAUL KIRSCHNER AND MIRJAM NEELEN ABOUT SPACED PRACTICE.

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BLOG BY PAUL KIRSCHNER AND MIRJAM NEELEN ABOUT HIGHLIGHTING.

AVAILABLE FROM HTTPS://3STARLEARNINGEXPERIENCES.WORDPRESS.COM/2019/01/08/LESS-IS-MORE-HIGHLIGHTING-AS-LEARNING-STRATEGY/.

POOJA AGARWAL'S GUIDES FOR RETRIEVAL PRACTICE AND SPACED RETRIEVAL PRACTICE ON *TRANSFORM TEACHING WITH THE SCIENCE OF LEARNING*.

AVAILABLE FROM WWW.RETRIEVALPRACTICE.ORG/LIBRARY/.

A VIDEO BY THE LEARNING SCIENTISTS ABOUT SPACED PRACTICE IS

AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=3WJYP98EYS8.

A VIDEO BY THE LEARNING SCIENTISTS ABOUT RETRIEVAL PRACTICE IS

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A VIDEO BY POOJA AGARWAL ABOUT MAKING THE MOST OF RETRIEVAL PRACTICE: SPACED PRACTICE IS

AVAILABLE FROM HTTPS://YOUTU.BE/5ZYIBPIISZW?SI=4KZT1HVDFFN675PS

PART VI

LEARNING IN CONTEXT

Learning is often seen as something cognitive, and that is definitely true. What we learn depends on how we process the information that we encounter and these processes take place in our brains. To learn, our brains must process new information and incorporate it into our existing knowledge or create new knowledge schemes. But this is not the whole story.

Learning is also a social event and thus the social environment – as with almost all our activities – also has a lot of influence on our learning. And that environment can greatly stimulate or stifle learning. Fellow students who do not participate in a group project can stand in the way of learning, while an expert teacher or classmates who cooperate constructively promote their own learning.

In this sixth part we deal with some aspects of that social learning environment. This section focuses on different social influences on learning such as situated cognition, cognitive apprenticeship, and communities of learners.

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27 WHY CONTEXT IS EVERYTHING

CONTEXT

DOI: 10.4324/9781003395713-33

27 WHY CONTEXT IS EVERYTHING

PAPER "Social learning theory: A contextualist account of cognitive functioning"[1]

QUOTE *"Learning is more than knowing* what *to do. It also involves knowing* how *to do it."*[2]

Why you should read this chapter

If you walk around the streets of Amsterdam, you hear lots of different languages spoken. Of course, much of what you hear is standard language spoken either by Dutch people or by tourists and landed immigrants. But there's also a language that you hear that's spoken primarily by Dutch youths that seems to bear resemblance to many languages, but can't be pinned down to any one standard language: street language. As Amsterdam has a large population of residents from the Netherlands itself, first and second generation residents from former colonies (e.g. Aruba, Bonaire, Curacao, Suriname), and children of former economic "guest workers" from primarily Turkey or Morocco who've remained in the Netherlands, what you hear is a rich street language which is a strange cocktail of all of those. This language isn't spoken at home nor is it taught in school, but is rather an example of social learning. This language is acquired either in action or from observing peers. And this isn't only the case for "cognitive" learning. Social learning plays a role in acquiring attitudes, behaviours, and values and even in acquiring physical skills. When a child sees another child receive a treat, either as a reward for behaving politely or as a placation of a tantrum, then the child will possibly imitate the other child in the hope of also getting a treat. When a teenager sees a peer smoking a cigarette or

Social context and individual behaviours

1 ZIMMERMAN, B. J. (1983). SOCIAL LEARNING THEORY: A CONTEXTUALIST ACCOUNT OF COGNITIVE FUNCTIONING. IN: C. J. BRAINERD (SERIES ED.) *SPRINGER SERIES IN COGNITIVE DEVELOPMENT, RECENT ADVANCES IN COGNITIVE-DEVELOPMENTAL THEORY: PROGRESS IN COGNITIVE DEVELOPMENT RESEARCH* (PP. 1–50). SPRINGER.

2 IBID, P. 20.

consuming alcohol, (s)he might be tempted to do the same, especially if these behaviours are likely to gain them more social acceptance.

This chapter shows that learning occurs socially in terms of the modelling and imitation of specific tasks and behaviours, but more importantly, it makes the claim that learning is highly contextual in nature (see also Chapter 28, The culture of learning) and is dependent largely on the prior knowledge of the learner and also on the way in which tasks are modelled. Put simply, social learning theory is the view that people learn by observing others. Though Albert Bandura published on social learning theory earlier than Barry Zimmerman, we chose his chapter as we feel it's more relevant to education. It was a toss-up and Barry won.

SOCIAL LEARNING THEORY
We learn by observing others

Abstract of the chapter[3]

Originating from the work of Albert Bandura, Social Learning Theory (SLT) posits that learning predominantly occurs through observation, interaction, and the replication of behaviours witnessed in others. In the educational context, SLT plays a pivotal role in shaping pedagogical strategies and classroom dynamics. Teachers, acting as primary models, influence students not only through direct instruction but more significantly through their behaviours, which students often emulate. Educational methodologies like peer learning capitalize on SLT by allowing students to observe and learn from their contemporaries. The rise of digital educational tools, such as interactive simulations, underscores the SLT principle by emphasizing learning through observation in virtual spaces. Moreover, immediate feedback in classrooms serves as reinforcement, bolstering the likelihood of behaviour replication. The environment of a classroom, where questioning and active discussions are promoted, roots learning in a social context, aligning with SLT principles. Additionally, the emphasis on boosting student self-efficacy—believing in one's capability to achieve—resonates with SLT's core tenets. In sum, SLT is foundational in understanding and enhancing learning dynamics within educational settings, highlighting the profound impact of observational learning and the social environment.

The chapter

Zimmerman begins the chapter (p. 2) by stating that social learning theory "grew out of the efforts of Bandura and Walters to explain how children acquired information and behavior by observing

3 'DUE TO COPYRIGHT ISSUES, WE WERE FORCED TO REPHRASE THIS ABSTRACT AND USED AI TO DO SO.

people in natural settings". It's often seen as a bridge between behaviourist and cognitive learning theories encompassing attention, memory, and motivation. It can be seen as a reaction to the two prevalent – classical – explanations of learning, namely behaviourist models which saw behaviour as an internal mechanism which could be affected by classical conditioning and operant conditioning and cognitivist theories that saw learning as something that occurred in the brain. Both saw learning as unrelated to its surroundings and independent of contextual factors. It also formed a shift away from studying cognition in laboratory settings to studying in more naturalistic settings broadly grouped under the category of "contextualism" (Jenkins, 1974; Labouvie-Vief & Chandler, 1978; Pepper, 1970). The central claims of contextualism are:

CLASSICAL CONDITIONING Involuntary stimulus and response
OPERANT CONDITIONING Voluntary stimulus and response

People interact with their environment

1. *Person–environment interaction*. Individuals make meaning through their interaction and relationship with the broader environment, where "environment" refers not just to the physical world but also the thoughts and actions of others (see Figure 27.1).

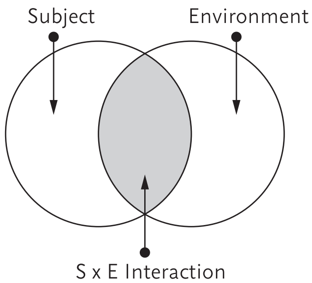

FIGURE 27.1 AN INTERACTIONIST VIEW OF SUBJECT AND ENVIRONMENTAL CONTRIBUTIONS TO CAUSATION OF EVENTS (ZIMMERMAN, 1983, P. 8)

Events are made up of strands and textures

2. *Events as holistic phenomena*. Events in the world are not experienced by the individual as discrete episodes but rather as "cognitively unified phenomenon" (p. 8). An event is broken down into elements called *strands* and the relationships between those strands are called *textures*. An example of this is sentence comprehension (Jenkins, 1974) where the individual words in a sentence can be understood as strands and their relationships as textures. If one person asks another "when will it come?", the meaning of this question is dependent on a range of other factors such as intonation, facial expression, the individual character of the person, and the location of the individuals. In this case we're speaking about a bus stop where an agitated pedestrian who's late for an appointment (intonation, facial expressions) refers to "it" (the bus as he's standing at a bus stop).
3. *Contextualism is comprehensive and dynamic*. William James observed that it's almost impossible to analyse cognitive process in an elemental way because the human mind is always reacting to its environment.

He suggested that "the human mind should be studied 'in motion' as a person adapted to changing environmental contexts" (p. 11). For the contextualist, the idea that psychological events can be reduced to a set of basic associations such as computer programs or logic, as early cognitivists did, needed to be rejected (Jenkins, 1974; Labouvie-Vief & Chandler, 1978; Neisser, 1976).

STAGE-THEORY
Belief that cognitive development is in stages and can be observed as such

Development is ongoing and diverse. Contextualists take issue with stage-theorists and their claims of the universal nature of cognitive development: that human development is universal, sequential, and hierarchical. They claim that social developments such as entering school or changes in their home life affect performance shifts with a greater degree of accuracy than age or a stage of development.

4. *Research methods and goals must be revised*. The contextualist view takes issue with traditional methods of research as "little attention is given to the confounding effects of historical and social context variables on age" (p. 14). Many researchers will compare research done in the laboratory with research done in the field, which raises the question of ecological validity or "the extent to which the environment experienced by the subjects in a scientific investigation has the properties it is supposed or assumed to have by the investigators" (Bronfenbrenner, 1979, p. 29).

Ecological validity

According to Zimmerman, contextualists "assume that reality is dynamic and continuous in flow and that knowledge is the ever-changing cumulative product of one's personal transactions with the proximal and distal environment" (p. 17). This contextualist worldview is often contrasted with what is called the realist worldview, which is often pejoratively characterised as a mechanistic, reductionist, or even cognitivist worldview. Table 27.1 summarises the differences between the two. We (the authors) must note here that a third worldview is often added here – the relativist worldview – but this falls outside of the scope of this chapter.

Based on the contextualist view, it is argued that the beginning of social learning theory starts with Bandura's social learning formulation (Bandura & Walters, 1959, 1963) in which Bandura argued that social modelling and experience has a determining influence on child development. Bandura's theory (1971) claimed that there were four subprocesses in human learning behaviour: two which are cognitive (attention and retention) and two which are noncognitive (motivation and motoric). As Zimmerman notes "for children to learn from models, they must perceive and attend to such models" (p. 19). "Cognitive rule learning" refers to the fact that individuals will form a hierarchy of rules through the observation of others performing the task. Social learning

Belief	Realist worldview	Contextualist worldview
Ontological: nature of reality and standards for judging truth	Reality is objective: truth corresponds to external reality and universal standards	There is no objective reality: truth is consensual based on negotiated standards
Epistemological: nature of knowledge and knowing	Knowledge and knowing is: ■ Objective and universal ■ Independent of knower ■ Relatively unchanging	Knowledge and knowing is: ■ Situational ■ Adapted by knower to fit contextual demands ■ Changes consensually
Pedagogical: nature of teaching and learning	Teaching and learning is: ■ Transmissive ■ Teacher-centred ■ Expert dissemination to passive but self-regulating recipients with little peer role	Teaching and learning is: ■ Transactional ■ Student and group-centred ■ Supportive co-collaborator and co-participant with self-regulating students and collaborative peers

TABLE 27.1 A COMPARISON OF THREE BELIEFS ACROSS TWO EPISTEMOLOGICAL WORLDVIEWS (BASED ON SCHRAW & OLAFSON, 2002)

theorists have noted that learning is possible without social models but that they are often inefficient as they depend on previous rule learning and naturalistic reinforcement.

COGNITIVE FUNCTIONING
Specific knowledge matters more than age

In terms of cognitive functioning, social learning theorists take the view that a child's level of task-specific knowledge is a critical factor rather than their age, and that this knowledge is based on their prior experience with family members and peers. Physical maturation is believed to have a lesser role in development since experience is dependent on the child's physical capabilities at a certain age. In other words, it is not so much the age of the child which determines their cognitive functioning but rather the social conditions in which they have been. Critically, what is expected of them at that particular age will determine how an adult will relate to them. For example, you would not expect a 2-year-old to read a Modernist novel but you would expect them to "read" a picture book. Zimmerman notes that Myers and Perlmutter (1978) conducted a study on word recall by 2-year-olds and 4-year-olds and discovered that "age-related improvements in recall were uncorrelated with the use of such general strategies as rehearsal, elaboration, or organization. They concluded that age differences in recall were due to the older children's superior content knowledge" (p. 28).

Zimmerman puts forward the hypothesis that where experience is unrelated to someone's age, the variable of experience is a strong predictor of learning.

EXPERIENCE
Degree of familiarity

"Experience" is more specifically defined as "*familiarity* with a task or object" (p. 28). This was explored in a study by Micki Chi (1978) where adults and 10-year-olds were tested on their predictive skills on chess tasks with the "twist" being that the 10-year-olds were chess experts and the adults were novices. Both groups were asked to examine an arrangement of chess pieces for 10 seconds and then recall it from memory and they were also asked to predict how many trials they would need to get it correct. Not only were the children better in recalling the chess pieces but they were also better at predicting how many attempts they would need to get it correct. The conclusion was that "specific task-related knowledge outweighed all other factors (including information processing capacity measures) in explaining age differences in recall" (p. 28).

In linguistic acquisition, several social elements are reported to be highly salient factors such as parent facial cues and reinforcement (Brown, 1976), which indicated that comprehension and imitation were highly dependent on the "specific dynamic experience" (p. 35) of observing others. A final key point made by Zimmerman is that universal theories of learning have become increasingly unsatisfactory as "evidence of the contextual dependency of children's knowledge continues to mount" (p. 39).

UNIVERSAL THEORIES OF LEARNING
A problem when context is taken into account

Conclusions/implications of the work for educational practice

The central idea from this work is that people learn through observing others and so it's of vital importance to educators to consider exactly what students will be observing. Learners need not only to see tasks being performed but learners, particularly novices, need to see the performance and execution of those tasks broken down into constituent parts, which is where teachers need to consider how they are sequencing and modelling curriculum content (see also Chapter 29, Making things visible). This chapter also illustrates a common theme in this book, namely that most learning does not happen in a context-free way and that generic skill approaches to learning are often ineffective. It is particularly important that a requisite amount of context-specific knowledge is gained before attempting most tasks.

THE IMPORTANCE OF CONTEXT-SPECIFIC KNOWLEDGE

EXAMPLE
Importance of prior knowledge

In 1988, Donna Recht and Lauren Leslie did a study in which they asked seventh and eighth graders to read a passage about baseball. They used four groups: one group had kids who were strong readers (top 30%) who knew a lot about baseball, one had struggling readers (bottom 30%) who knew a lot about baseball, one had strong readers who knew little about baseball, and one had struggling readers who knew little about baseball.

When, after reading a paragraph about baseball, the kids were asked a series of comprehension questions, Recht and Leslie saw results which they didn't really expect. Strong readers with a high knowledge of baseball performed best, but a close second were the struggling readers who knew a lot about baseball. These readers even outperformed their strong reading peers! Figure 27.2 shows how important context-specific knowledge is.

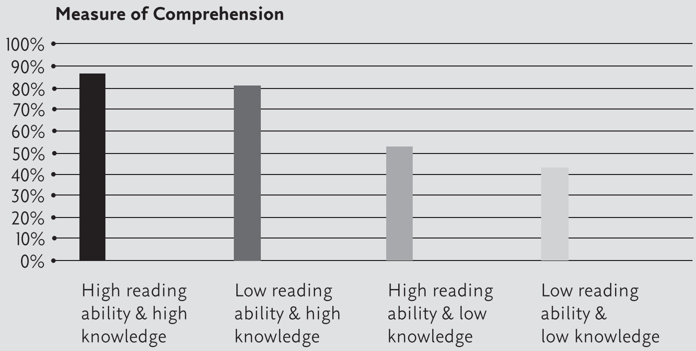

FIGURE 27.2 THE IMPORTANCE OF CONTEXT-SPECIFIC KNOWLEDGE FOR READING COMPREHENSION (RECHT & LESLIE, 1988)

Social learning is not as simple as it sounds

The term *social learning* implies that children learn in a social way as advocated by constructivists and while an element of this is true, an important factor often ignored is the previous knowledge of the child and the completeness of the modelled example. Social learning is not always positive; for example, unstructured experiences where children are engaging in low-level discussion about a play or even outright misconceptions of the parts of an atom are not useful at all. In that sense, it is vital that teachers consider the previous knowledge of the students and the types of modelling that are happening in their classroom; specifically whether real learning is actually happening or whether the students are just being busy. So the implication here is clear: children need clear modelled examples of how to succeed and second, they need a prerequisite of specific knowledge in order to "unlock" the skills from the specific task.

How to use the work in your teaching

Modelling does not just refer to the teacher instructing a student. Other powerful ways of harnessing the tenets of social learning theory include peer teaching, where one student will instruct another student in an area in which they are particularly proficient. Setting up a mentorship programme where certain students are paired with others can have

Students often pay more attention to peers than adults

a powerful effect on learning as children are most likely to imitate the behaviour of their peers, particularly if the outcomes are seen as favourable. Possibly the most straightforward and powerful way of enacting social learning is to ask students to read out a piece of work that is an exemplar model of how to solve a problem or express an idea. If this becomes a regular part of class feedback on classroom assessments, the gains can be significant as peers can frame the steps to success in a way that teachers sometimes can't.

One of the more subtle claims that this chapter makes is that modelling needs to be relatively complete in order to be effective and for children to learn the "rules" of a given task or objective. For example, Zimmerman and Rosenthal (1974) instructed preschool children in a new method of grouping pictures that differed from a spontaneous method used by the children. The older children were able to switch back and forth between methods but the 3- and 4-year-olds were unable to until they were shown a method that flexibly used both methods together. In other words, these children needed to have explicit modelling not just of both methods but of using them *interchangeably* in order to be successful; interestingly, individual differences between the children disappeared when this was done. The important point here is that when modelling something such as how to complete an equation or write an introduction to an essay, the crucial aspect is the *completeness* of the modelling. In cases where there are gaps in what is being modelled, the students with the stronger prior knowledge in these areas will be more successful. So, when teaching something (especially to novices) be as explicit as possible, otherwise you are just widening the gap between the students who have knowledge and those who don't

Modelling needs to be a complete model to function well

A good example of this is in teaching students to write well. English teachers can be particularly effective if they model ways in which students can learn vicariously. They can do this in two ways: first by actually explicitly modelling to the class by writing a full essay or creative piece themselves "live" in front of the class, where they break down exactly what choices they have made and why, either by using a visualiser or simply typing on a screen. Second, as mentioned earlier, they can facilitate peer teaching by asking one of their students to model to their peers how they constructed a particular piece of writing by handing out copies of a particularly good piece of writing and having them break it down to the rest of the class step by step.

Takeaways

- Social learning is highly contextual in nature and this is often ignored.
- Universal accounts of cognitive functioning are problematic.

- It's not so much a child's age that determines performance but rather their previous knowledge based on their social experience.
- When learning rules to complete a task, the key element for novices is the *completeness* of the modelling.
- Carefully sequenced and explicit modelling of tasks is more effective than unstructured, naturalistic modelling experiences.
- Techniques such as peer teaching, imitation, role playing, and so forth are good examples of ways to facilitate social learning.

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Suggested readings and links

A SHORT VIDEO ON THE IMPORTANCE OF BANDURA'S BOBO DOLL EXPERIMENT WHERE SOCIAL LEARNING IS ACHIEVED VIA MODELLING OF BEHAVIOUR IS

AVAILABLE FROM HTTPS://YOUTU.BE/ZERCK0LRJP8.

BANDURA'S FOUR PRINCIPLES OF SOCIAL LEARNING THEORY.

AVAILABLE FROM WWW.TEACHTHOUGHT.COM/LEARNING/PRINCIPLES-OF-SOCIAL-LEARNING-THEORY/.

A VIDEO EXPLAINING RECHT AND LESLIE'S (1988) BASEBALL STUDY IS

AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=QP6QPSRR3CG.

28 THE CULTURE OF LEARNING

CULTURE OF LEARNING

DOI: 10.4324/9781003395713-34

28 THE CULTURE OF LEARNING

PAPER "Situated cognition and the culture of learning"[1]

QUOTE *"The breach between learning and use, which is captured by the folk categories 'know what' and 'know how', may well be a product of the structure and practices of our education system".*[2]

Why you should read this article

Biologically primary and secondary knowledge (see Chapter 9)

As we saw in the chapter discussing David Geary's biologically primary and biologically secondary learning (see Chapter 9, An evolutionary view of learning), some things appear to be learnt almost "by themselves" without any real explicit instruction while other things take a lot of effort and are best learnt through proper instruction. Learning and communicating in our native language belongs to the former category. Children learn to communicate, first through simple sounds and gestures, and then through their native language by interacting – that is by listening and speaking with others in their direct environment. According to Miller and Gildea (1987), during their early years children acquire an average of 5000 new words per year (approximately 13 new words per day) by listening, speaking, and later reading. This process seems to be effortless and quick, especially if the child grows up in a rich linguistic environment. This is also the case for a second language, albeit to a lesser degree in families where multiple languages are spoken. But what happens when these same children go to school and try to learn new words in a foreign language there (or even new words in their own language from a vocabulary list)? Although we have no exact numbers here, we think that we can agree that the number is quite a bit lower and that it takes quite a lot of effort. Miller and Gildea put the number in the

1 BROWN, J. S., COLLINS, A., & DUGUID, P. (1989). SITUATED COGNITION AND THE CULTURE OF LEARNING. *EDUCATIONAL RESEARCHER, 18*(1), 32–42.
2 IBID., P. 32.

vicinity of 100 to 200 words. How does this happen? One would think that learning words in daily life doesn't differ that much from learning words at school. However, it does. As discussed in Chapter 7 (Take a load off me), one reason is that learning to communicate with others in our direct environment (let's call this our "culture") is an evolutionary necessity. In their article, John Seely Brown, Allan Collins, and Paul Duguid add a second dimension to this, namely that the context in which you learn makes a difference, and might even determine what you learn.

Abstract of the article

Many teaching practices implicitly assume that conceptual knowledge can be abstracted from the situations in which it is learned and used. This article argues that this assumption inevitably limits the effectiveness of such practices. Drawing on recent research into cognition as it is manifested in everyday activity, the authors argue that knowledge is situated, being in part a product of the activity, context, and culture in which it is developed and used. They discuss how this view of knowledge affects our understanding of learning, and they note that conventional schooling too often ignores the influence of school culture on what is learned in school. As an alternative to conventional practices, they propose cognitive apprenticeship (Collins, Brown, & Newman, 1989), which honors the situated nature of knowledge. They examine two examples of mathematics instruction that exhibit certain key features of this approach to teaching.

Knowledge is situated

The article

John Seely Brown and his colleagues distinguish between how students learn at school, which focuses on context-free rules, algorithms, well-defined assignments and answers, and how people learn in their work and everyday life, which focuses on contextualised experiences bound to different situations (i.e. situated learning) and with real, vaguely defined problems with multiple solutions.

In both, the learner responds to things from the environment; in school it's a sum in a book or on the black, green, white, or interactive whiteboard, and in real life (e.g. a kitchen) on a recipe for four that needs to be expanded to seven people. In each of these situations, the person doing the calculations must solve the problem within these environments. The student writes down numbers and signs in a notebook or on an electronic device and carries out the solution algorithm or script, while the cook weighs the ingredients, judges the size of the eggs or broccoli, and chooses the proper pots, pans, and cooking times. For Brown et al., how they solve the problem depends greatly on the situation or context in which they find themselves. For example, a student is usually not allowed the freedom to approximate and the cook does not have an algorithm for calculating temperatures and cooking times for a recipe and choosing pots and pans for a 75% increase in dinner guests. What's common to both is that each knows what the authors call the "cultural rules" that apply to these situations. They know what materials they have at their disposal and what is expected of them. They have learnt that calculating a sum in school is different from resizing a recipe in a kitchen.

CULTURAL RULES
Problem-solving is context specific

In contemporary education, the idea of situational or contextual learning is less earth-shattering than it was at the time this article was written. It has received much attention in schools, research, textbooks, and even standardised tests. More and more often, the material to be learnt is placed in an authentic context that pupils may also encounter in daily life. This, however, has also led to excesses. Realistic mathematics, discovery and enquiry learning, and so-called twenty-first century skills have focused so much on context and "realism" that some educators, schools, and even curricula have nearly banned the tuition and learning of facts, concepts, algorithms, heuristics, and the like.

ENCULTURATION
The gradual acquisition of cultural norms/customs

According to the authors, learning is contextual and is a process of enculturation in which one makes the rules and culture of a certain setting their own. Learning is not merely context-sensitive but is actually context-dependent. In their view, "by ignoring the situated nature of cognition, education defeats its own goal of providing useable, robust knowledge" (p. 32) for applying what is learnt in real-life practice. As a new cook you learn how to deal with different ingredients, what you can and can't do, and how to handle a recipe in the "right way". As a student, you learn how to use an algorithm or a script that you have to use to carry out the tasks prescribed by the teacher or the textbook, and how to perform them. Viewed in this way, learning at school might look similar to learning in everyday situations, but the problem is that in school, we're trying to teach things that the learners can use outside of school, while this is not always the case in practice. According to Brown and colleagues, this is because school and life have become[3] two different cultures with different sets of rules, and this means that students cannot simply apply what they've learnt in one culture to another. For example, a student can get a very good score on her geography test, but sitting next to her parents in the car she may have no idea where the cities are in relation to each other and the mountains between them! The authors feel that:

> we should abandon any notion that [concepts] are abstract, self-contained entities. Instead, it may be more useful to consider

3 AS YOU WILL READ IN CHAPTER 29 (MAKING THINGS VISIBLE) ON COGNITIVE APPRENTICESHIP, WHAT YOU LEARNED YOU LEARNED IN THE REAL-LIFE SETTING.

> conceptual knowledge as, in some ways, similar to a set of tools…It is quite possible to acquire a tool but to be unable to use it.
>
> (p. 33)

For Brown and his colleagues, the problem is that school learning has become divorced from the practice where it needs to be applied. Students learn to work with symbols and standardised strategies to gain abstract knowledge, based on the idea that they can then use it in other situations. According to them, nothing is less true. Because the cultural rules at school are so different from those in everyday contexts, transfer is problematic.

TRANSFER
The ability to use learning from one context in another

To solve this problem, they argue that school learning should look more like everyday learning. They call this *situated learning*. For them, knowing cannot be separated from doing because all knowledge is situated in activities that are bound to social, cultural, and physical contexts (i.e. all cognition is situated). To stimulate such learning in schools, they provide examples from arithmetic and vocabulary education. One example from Lampert (1986) concerns a math lesson on multiplication where students make use of coins. After mastering simple problems, the teacher then asks them to think of more maths money problems that deal with multiplication. Because the students think of and carry out many multiplication problems, they discover that multiplication happens in many different situations. Ultimately, the teacher teaches them the more abstract rules, concepts, and algorithms that are important in multiplication. In this way they also learn the "essence of multiplication", independently of a context, and they can also use this numeracy in new, unknown situations. First, a word of caution is needed here. Situated cognition isn't discovery learning. Instruction plays an important role here.

SITUATED LEARNING
Learning should be *situated* in the real world

Instruction is an important part of situated cognition

> Through this method, students develop a composite understanding of four different kinds of mathematical knowledge: (a) *intuitive knowledge*, the kind of short cuts people invent when doing multiplication problems in authentic settings; (b) *computational knowledge*, the basic algorithms that are usually taught; (c) *concrete knowledge*, the kind of concrete models of the algorithm associated with the stories the students created; and (d) *principled knowledge*, the principles such as associativity and commutativity that underlie the algorithmic manipulations of numbers.
>
> (p. 38)

Brown, Collins, and Duguid stress the use of authentic activities which they define as ordinary practices of the culture. These activities are framed by their culture and are meaningful, coherent, and purposeful. The parts are embedded in the whole activity so that the relationships are apparent. In this way it is very similar to what Van Merriënboer and Kirschner (2018) speak of when designing for complex learning.

FOUR COMPONENT INSTRUCTIONAL DESIGN AND COMPLEX LEARNING

Four component instructional design (4C/ID)

Jeroen Van Merriënboer and Paul Kirschner (2018) present a teaching/training blueprint (see Figure 28.1) based upon four interrelated components, namely:

1. *Learning tasks*: authentic whole-task experiences based on real-life tasks and situations that aim at integrating knowledge, skills, and attitudes.
2. *Supportive information*: information helpful for learning and performing the problem-solving, reasoning, and decision-making aspects of learning tasks, explaining how a domain is organised and how problems in that domain are (or should be) approached.
3. *Procedural information*: information prerequisite for learning and performing routine aspects of learning tasks. Procedural information specifies exactly how to perform the routine aspects of the task (i.e. how-to instructions) and is best presented just in time; precisely when learners need it.
4. *Part-task practice*: practice items provided to help learners reach a very high level of automaticity for selected routine aspects of a task.

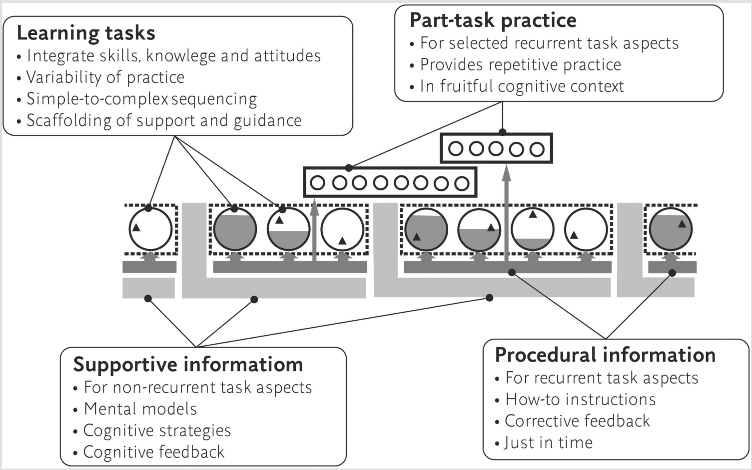

FIGURE 28.1 A SCHEMATIC TRAINING BLUEPRINT FOR COMPLEX LEARNING AND THE MAIN FEATURES OF EACH OF THE FOUR COMPONENTS OF INSTRUCTIONAL DESIGN (VAN MERRIËNBOER & KIRSCHNER, 2018)

This approach offers a solution for three problems, namely:

- *compartmentalisation*: teaching knowledge, skills, and attitudes separately which hinders complex learning and competence development,
- *fragmentation*: splitting a complex learning domain in small pieces which often correspond with specific learning objectives,

and then teaching the domain piece-by-piece without paying attention to the relationships between pieces, and

- the *transfer paradox*: using instructional methods that are highly efficient for achieving specific learning objectives (e.g. blocked practice), but that are not efficient for reaching transfer of learning.

Conclusions/implications of the work for educational practice

To make situated cognition and learning possible, learning experiences must become less abstract and more embedded in authentic tasks and contexts. To do this, you need to build your lessons, as in the maths lesson example, from authentic, context-specific practice to a more abstract level. In this context the authors speak of cognitive apprenticeship (see Chapter 29, Making things visible). In cognitive apprenticeship, the teacher is a (role) model who applies or uses what (s)he knows and can do to teach and guide students through authentic learning activities. If students have gained some confidence and have become somewhat familiar with the material, the teacher then challenges them to apply what they know and can do in different situations. This is often done in teams or in whole-class dialogues so that the students create a common language pertaining to the knowledge, skills, and attitudes to elevate it to a more abstract, conceptual level. To this end, collaboration is important. While working together, pupils must articulate their thinking and sense/meaning-making becomes social. After all, when they work together they have to look for a solution with each other and need to agree on what is needed to solve a particular problem in a particular situation. This is very similar to how people solve problems and gain knowledge in everyday situations, facilitating the transfer of school knowledge to everyday situations.

How to use the work in your teaching

Instruction, and especially direct instruction, has almost become a dirty word, which is not what Brown, Collins, and Duguid proposed. It has also led to standardised tests, for example in mathematics, that test reading and text-interpretation to the detriment of students from different cultures and/or with other first languages than the predominant language.

FUTUREPROOF LEARNING?

Twenty-first century skills aren't twenty-first century

There's a lively debate at the moment on twenty-first century skills. While many are finally aware of the fact that twenty-first century skills are the emperor's new clothes, this myth remains strong in some educational circles. First off, twenty-first century skills aren't twenty-first century; we've worked together, solved problems, been creative, and so forth since "the birth of civilization" in Mesopotamia around the sixtieth century BCE. They are presented as generic skills (like communication and problem-solving) which don't exist as all skills are domain specific. At best we can learn domain-general procedures (how to organise a report or article, the steps in dissecting a problem, etc.), but knowing the procedure for doing something isn't the same as having a skill to do it. Finally, many of the so-called twenty-first century skills are actually character traits and not skills (e.g. flexibility, leadership, perseverance) whose development can be stimulated or inhibited, but cannot be taught. Be this as it may, politicians, businesses, and worst of all eduquacks insist on building curricula around this myth. Kirschner and Stoyanov (2018) present a way to help students and workers to learn in a future-proof way so as to acquire the skills and attitudes necessary to continue to learn in a stable, lasting way in our rapidly changing world.

Teaching in context

Making your teaching more contextual is a good way to ensure that your students can use what they learn in your classroom in their daily lives. For example, in vocabulary education, don't offer single words, but teach in the context of a sentence or situation in which the words are often used. Then have the students practise the new words by inventing sentences and contexts themselves. With geography ask students to map out routes through the places they have learnt, and not only on traditional maps but also on maps where the terrain is visible (a mountain will add a lot of travel time if there's no tunnel). And so on.

Finally, make good use of authentic whole tasks, but don't forget to present students with the necessary supportive and procedural information and knowledge needed to carry out those tasks. Don't make them discover it themselves as that doesn't work (see Chapter 7, Take a load off me, and Chapter 22, Why discovery learning is a bad way to discover things). Only in this way can you guide students towards substantive understanding.

Takeaways

- Typical learning in schools is often devoid of the context (and thus the culture) in which the knowledge acquired is abstract and difficult for students to translate into everyday situations.
- Contextualised authentic learning environments help students translate what they are learning from school to the world.
- Authentic whole tasks allow for such contextualisation and, thus, help avoid compartmentalisation and fragmentation of learning.
- Discussion, collaboration, and extensive practice promote situational cognition and learning.
- Many so-called "twenty-first century skills" are actually traits that cannot be taught.

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VAN MERRIËNBOER, J. J. G., & KIRSCHNER, P. A. (2018). *TEN STEPS TO COMPLEX LEARNING (THIRD EDITION)*. ROUTLEDGE.

Suggested readings and links

SITUATED COGNITION. LEARNING THEORIES PROVIDES A SHORT SUMMARY OF SITUATED COGNITION.

AVAILABLE FROM WWW.LEARNING-THEORIES.COM/SITUATED-COGNITION-BROWN-COLLINS-DUGUID.HTML.

SITUATED COGNITION AND LEARNING ENVIRONMENTS: ROLES, STRUCTURES, AND IMPLICATIONS FOR DESIGN.

AVAILABLE FROM HTTP://TECFAETU.UNIGE.CH/STAF/STAF-E/PELLERIN/STAF15/SITUACOGN.HTM.

A PRESENTATION ON THE ESSENTIALS OF SITUATED COGNITION AND ITS RELATION TO OTHER LEARNING THEORIES IS

AVAILABLE FROM HTTPS://PREZI.COM/FHCFJSKNEMWA/SITUATED-COGNITION-AND-SITUATED-LEARNING-ACTIVITIES/.

29 MAKING THINGS VISIBLE

MAKING THINGS VISIBLE

DOI: 10.4324/9781003395713-35

29 MAKING THINGS VISIBLE

PAPER "Cognitive apprenticeship: Making thinking visible"[1]

QUOTE *"Cognitive apprenticeship is not a relevant model for all aspects of teaching … [but rather] a useful instructional paradigm when a teacher needs to teach a fairly complex task to students".*[2]

Why you should read this article

THE GUILD SYSTEM
Experts overseeing their trade or craft

Beginning in the late Middle Ages and up through the beginning of the twentieth century, it was perfectly normal for children to get an education or be trained in a profession by being apprenticed to masters in their workplace. This was part of what is known as the guild system where experienced and confirmed experts in a field or craft (i.e. master craftsmen) hired new employees who began as apprentices and received their education or training in exchange for food, lodging, and, of course, work. The apprentice began by observing the master craftsman at work – for example a weaver, blacksmith, or printer – and learnt to look and practice under her or his (almost always his) tutelage. After a period of training under the eyes of the expert, the apprentice progressed to the level of journey who was considered to be competent and was authorised to work in that field. This journeyman could work for and with other master craftsmen within the guild. At a certain moment the journeyman would submit a master piece of work to the guild for evaluation which certified her or him as a master. The training was mostly about practical actions; the usefulness of what had to be learnt was clear, and there were clearly defined end products such as a cloth or tapestry, a knife, or a book. Also, the learning environment was social.

Apprentice, journeyman, master

1 COLLINS, A., BROWN, J. S., & HOLUM, A. (1991). COGNITIVE APPRENTICESHIP: MAKING THINKING VISIBLE. *AMERICAN EDUCATOR*, *15*(3), 6–11, 38–46.
2 IBID., P. 45.

Today, most children learn in schools, with the teacher replacing the master craftsman, though some schools and professions still make use of at least part of this approach. An example of this is the vocational high school or even medical colleges where students spend a part of the week in the workplace or longer periods as interns there. Also, learning materials and assignments are now more abstract and independent of the context in which they'll ultimately be used. As a result, unless the teacher for example uses modelling as an educational approach, students may not have a good idea of how to carry out their assignments as they can no longer copy how an expert works and thinks. In their article, Allan Collins, John Seely Brown, and Ann Holum make a case for a form of instruction that resembles the former master–apprenticeship relationship. They call this method of instruction *cognitive apprenticeship*.

COGNITIVE APPRENTICESHIP
A return to the master–apprenticeship relationship

Abstract of the article

In ancient times, teaching and learning were accomplished through apprenticeship: We taught our children how to speak, grow crops, craft cabinets, or tailor clothes by showing them how and by helping them do it. Apprenticeship was the vehicle for transmitting the knowledge required for expert practice in fields from painting and sculpting to medicine and law. It was the natural way to learn. In modern times, apprenticeship has largely been replaced by formal schooling, except in children's learning of language, in some aspects of graduate education, and in on-the-job training. We propose an alternative model of instruction that is accessible within the framework of the typical American classroom. It is a model of instruction that goes back to apprenticeship but incorporates elements of schooling. We call this model "cognitive apprenticeship".

While there are many differences between schooling and apprenticeship methods, we will focus on one. In apprenticeship, students can see the processes of work: They watch a parent sow, plant, and harvest crops and help as they are able; they assist a tradesman as he crafts a cabinet; they piece together garments under the supervision of a more experienced tailor. Apprenticeship involves learning a physical, tangible activity. But in schooling, the "practice" of problem solving, reading comprehension, and writing is not at all obvious – it is not necessarily observable for the student. In apprenticeship, the processes of the activity are visible. In schooling, the processes of thinking are often invisible to both the students and the teacher. Cognitive apprenticeship is a model of instruction that works to make thinking visible.

The article

MAKING THINKING VISIBLE
Explicit modelling

For learners to learn something, it's necessary for the teacher to make the reasoning and strategies needed to perform a task explicit. Otherwise, learners learn to solve these specific assignments, but they do this as a trick which they learn by heart. As a result, they won't get a grip on the required thinking processes and they'll have difficulty deploying what they have learnt, both with respect to content and strategies, in different contexts. The key to overcoming this is what Collins and his colleagues call *making thinking visible*.

But how do you make thinking visible? First, Collins, Brown, and Holum say we need to know what learners need to do a task and how we can transfer it. Cognitive strategies are central to the integration of skills and knowledge and certainly to abstract knowledge areas such as reading, writing, and arithmetic. These strategies are in their view best communicated through contemporary apprenticeship education: learners should see from an expert (teacher or more advanced fellow student) and hear how they solve the task, which strategies the expert uses and why. The student can then practice under supervision.

Learning as an apprentice

Collins et al. write that in:

> traditional apprenticeship, the expert shows the apprentice how to do a task, watches as the apprentice practices portions of the task, and then turns over more and more responsibility until the apprentice is proficient enough to accomplish the task independently.
> (p. 8)

MODELLING
Explicit demonstration of a skill or task

SCAFFOLDING
Support and guidance that's slowly removed

The authors see four important aspects of traditional apprenticeship, namely modelling, scaffolding, fading, and coaching, which are also applicable to cognitive apprenticeship. In *modelling* an expert demonstrates the different parts of the to-be-learnt behaviour. In cognitive apprenticeship, this is accompanied by the expert explicitly explaining what (s)he is thinking and why (s)he is doing certain things while carrying out a task (i.e. thinking aloud).

Scaffolding, as we saw in Chapter 17, is the support and guidance the teacher provides while the students are carrying out the behaviour. As the student proceeds, the support and guidance are slowly removed – *faded* – as the student becomes able to carry out the task her-/himself. This increases the independence and responsibility of the student. Finally, *coaching* is the thread running through the entire apprenticeship experience; the expert diagnoses encounter problems, provide feedback, and generally oversee the learning.

The interplay of all four of these aspects aids the student in developing self-monitoring and correction skills as well as in integrating the skills and conceptual knowledge needed to look critically at their own progress and learn further. In all of this, observation is critical. By seeing experts carrying out authentic whole tasks, students build conceptual models of the task: they see the entire task before getting started and follow the progress of all of its constituent parts through to its completion. As a result, they don't endlessly practice isolated skills without seeing the bigger picture. In this way, the four component instructional design model (4C/ID; Van Merriënboer, 1997; Van Merriënboer & Kirschner, 2018) can be seen as leaning on the idea of cognitive apprenticeship.

Since teaching and learning take place in schools and not in the real world with real tasks, the model of traditional apprenticeship needs to be translated to cognitive apprenticeship for three reasons. First, in traditional apprenticeship the process of carrying out a learning task is usually easily observable. In cognitive apprenticeship, however, we need to deliberately make the thinking involved in carrying out more abstract school tasks visible. "By bringing these tacit processes into the open, students can observe, enact, and practice them with help from the teacher and from other students" (p. 9). Second, in traditional apprenticeship, the tasks come up in the same way as they do in the real world; in the school, teachers are working with a curriculum which is "divorced from what students and most adults do in their lives. In cognitive apprenticeship, then, the challenge is to situate the abstract tasks of the school curriculum in contexts that make sense to students" (p. 9). Finally, in traditional apprenticeship, the skills to be learnt are specific to the tasks themselves. A carpenter learns to make a table leg, but doesn't need to learn to make a button hole or a bookbinding. This isn't the case in school where students need to be able to transfer what they learn to other tasks and areas. In cognitive apprenticeship, teachers need to "present a range of tasks, varying from systematic to diverse, and to encourage students to reflect on and articulate the elements that are common across tasks" (p. 9). To this end, Collins et al. note that for cognitive apprenticeship, teachers need to:

Learning in school is often not domain specific

- identify the processes of the task and make them visible to students;
- situate abstract tasks in authentic contexts, so that students understand the relevance of the work; and
- vary the diversity of situations and articulate the common aspects so that students can transfer what they learn.

IF EYES COULD TALK

A promising field with respect to making thinking visible is the field of eye-tracking (sometimes also called gaze tracking). Halszka Jarodzka et al. (2013) did research that builds on the work of Collins, Brown, and Holum, specifically with respect to identifying the processes of the task and making them visible (see Figure 29.1). She recorded the eye movements of experts with an eye-tracker while they performed a task on a screen. Then she asked the experts to explain what they were doing, what they were looking at, and why. She then made instructional videos showing a model explaining and executing a task, while the attentional focus of the model is displayed in the form of her or his eye movements, which were presented to students as lessons. With these eye-movement modelling examples, students can gain insight into the actions and thinking of an expert, albeit through a slightly more modern approach than traditional apprenticeship.

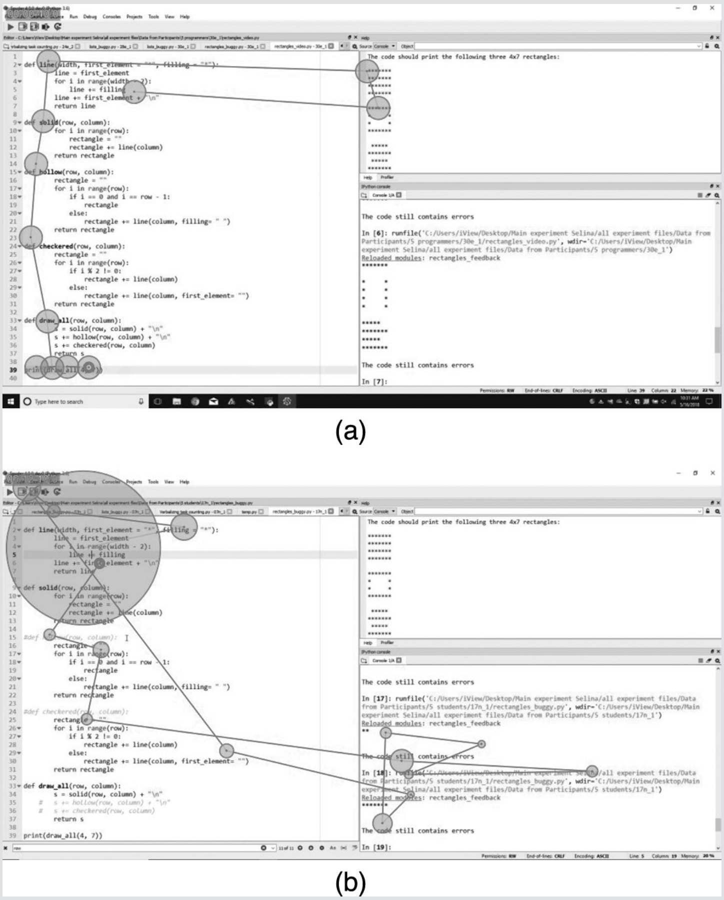

FIGURE 29.1 EYE MOVEMENTS OF A NOVICE SOLVING A CODING PROBLEM (TOP) AND AN EXPERT DOING THE SAME (BOTTOM). CIRCLES ARE FIXATIONS; THE SIZE OF THE CIRCLE REPRESENTS THEIR DURATION. THE LINES BETWEEN THE CIRCLES ARE SACCADES (I.E. THE JUMPS MADE BY THE EYES) (EMHARDT ET AL., 2019)

A social environment (i.e. the class) is an important aspect of cognitive apprenticeship. The class offers students continuous access to examples of others at varying degrees of expertise so that they can model their behaviour against those others and seek advice. This way they learn that more answers are often possible. After all, every expert will perform the task in his (or her) own way. Moreover, they see their peers at different levels of expertise, which "encourages them to view learning as an incrementally staged process, while providing them with concrete benchmarks for their own progress" (p. 9).

Switching roles/peer teaching and learning

The authors give expansive examples of cognitive apprenticeship in teaching reading, writing, and mathematics. For reading, they use Palincsar and Brown's (1984) reciprocal teaching of reading. This means that students in a class alternate in taking on the role of teacher. The procedure is as follows: the teacher and the students silently read a paragraph. The person who plays the role of teacher then summarises the paragraph, clarifies the text where necessary, formulates a question about the text, and then predicts what the next paragraph will be about. They do this after their real teacher has presented these four strategies and then practised them with the students with much guidance. Ultimately, the role of the actual teacher will become less visible and the students increasingly assume this role themselves. They then continue presenting an example of learning to write based on Marlene Scardamalia, Carl Bereiter, and Rosanne Steinbach (1984) who used contrasting models of novice and expert writing strategies to provide explicit procedural supports, in the form of prompts, to help students adopt more sophisticated writing strategies. Finally, they present an example of learning to solve maths problems based on Alan Schoenfeld's (1983, 1985) method for teaching mathematical problem-solving.

Conclusions/implications of the work for educational practice

APPRENTICESHIP FRAMEWORK
Content, method, sequence, sociology

Collins, Brown, and Holum present a framework for designing cognitive apprenticeship learning environments. This framework (see Table 29.1) consists of four dimensions: content, method, sequence, and sociology.

The *content* should give learners a solid grounding in facts, concepts, and procedures. Having this they can learn to apply heuristics ("rules-of-thumb") making use of acquired control (i.e. metacognitive) strategies. Finally, students need to acquire learning strategies with which new concepts, facts, and procedures can be learnt. Cognitive

TABLE 29.1 PRINCIPLES FOR DESIGNING COGNITIVE APPRENTICESHIP ENVIRONMENTS (COLLINS ET AL., 1991, P. 43)

Principles for designing cognitive apprenticeship environments
CONTENT Types of knowledge required for expertise
Domain knowledge Subject matter specific concepts, facts, and procedures
Heuristic strategies Generally applicable techniques for accomplishing tasks
Control strategies Generally approaches for directing one's solution process
Learning strategies Knowledge about how to learn new concepts, fact, and procedures
METHOD Ways to promote the development of expertise
Modelling Teacher performs a task so students can observe
Coaching Teacher observes and facilitates while students perform a task
Scaffolding Teacher provides supports to help the student perform a task
Articulation Teacher encourages students to verbalise their knowledge and thinking
Reflection Teacher enables students to compare their performance with others
Exploration Teacher invites students to pose and solve their own problems
SEQUENCING Keys to ordering learning activities
Global before local skills Focus on conceptualising the whole task before executing the parts
Increasing complexity Meaningful tasks gradually increasing in difficulty
Increasing diversity Practice in a variety of situations to emphasise broad application
SOCIOLOGY Social characteristics of learning environments
Situated learning Students learn in the context of working on realistic tasks
Community of practice Communication about different ways to accomplish meaningful tasks
Intrinsic motivation Students set personal goals to seek skills and solutions
Cooperation Students work together to accomplish their goals

apprenticeship teaching *methods* "should be designed to give students the opportunity to observe, engage in, and invent or discover expert strategies in context" (p. 43). The *sequencing* should structure learning but preserve the meaningfulness of what the learner is doing. Their ideas on sequencing are very similar to Reigeluth's elaboration theory (see Chapter 21, Zooming out to zoom in). Finally, cognitive apprenticeship takes place in a *social* environment, situated in meaningful tasks, working with others.

These methods come into their own in a class in which students work together with a teacher and with each other. By repeatedly articulating what they see, their thinking processes become visible, not only for themselves, but also for the teacher. In this way the teacher knows what students can do and where they still need guidance.

Finally, the authors also note that this model can be a useful tool at certain moments in the classroom, but it certainly does not suit all forms of instruction and learning. Reading a book or watching a documentary can also be very useful ways of learning, especially when it comes to learning factual knowledge.

How to use the work in your teaching

With cognitive apprenticeship it's important that you make your own thinking steps visible to your students and that you go from lots of guidance and support to minimal or even no guidance and support. Important rules of thumb for this are:

- List important thinking processes and procedures and make them transparent, for example by systematically thinking aloud when something happens.
- Show that a task is useful by placing it in an authentic context, for example, by linking it to the everyday environment of the students and making them clear on when they should apply this task.
- Apply the task in different contexts so that students discover what the underlying core is, for example, by showing that a certain strategy can be used in multiple situations.

First perform an entire task, supervise it, and then let the students do more and more themselves so that the students oversee the entire task and can safely try it themselves.

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A NICE WEB SITE WITH A VERY UNDERSTANDABLE DISCUSSION OF COGNITIVE APPRENTICESHIP WITH LOTS OF LINKS TO OTHER SOURCES.

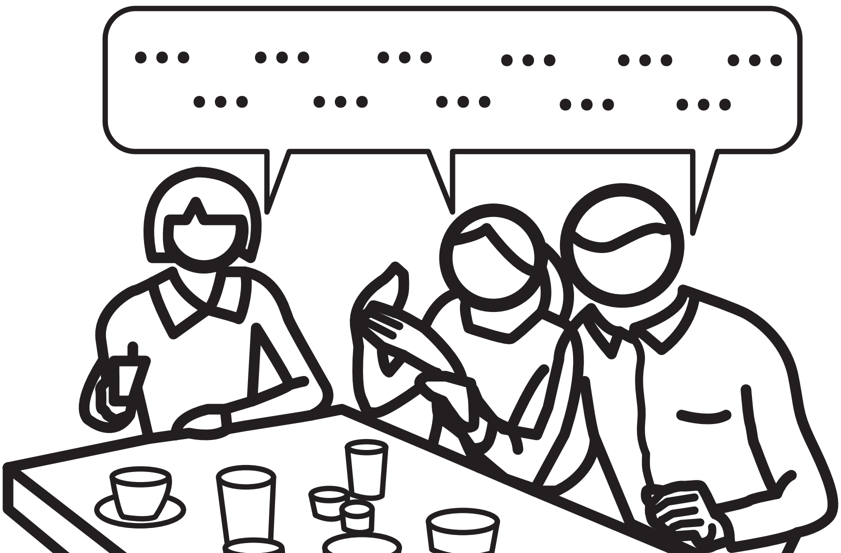
AVAILABLE FROM WWW.LEARNING-THEORIES.ORG/DOKU.PHP?ID=INSTRUCTIONAL_DESIGN:COGNITIVE_APPRENTICESHIP.

SHORT VIDEO ON COGNITIVE APPRENTICESHIP AND TEACHING

AVAILABLE FROM HTTPS://YOUTU.BE/PAXD4AG5LVI?SI=Y7BUAWQ7LQ2KUSTJ

30 IT TAKES A COMMUNITY TO SAVE $100 MILLION

COMMUNITIES OF PRACTICE



DOI: 10.4324/9781003395713-36

30 IT TAKES A COMMUNITY TO SAVE $100 MILLION

PAPER "Communities of practice and social learning systems"[1]

QUOTE *"Since the beginning of history, human beings have formed communities that share cultural practices reflecting their collective learning: from a tribe around a cave fire, to a medieval guild, to a group of nurses in a ward, to a street gang, to a community of engineers interested in brake design. Participating in these 'communities of practice' is essential to our learning. It is at the very core of what makes us human beings capable of meaningful knowing."*[2]

Why you should read this article

The Xerox corporation used to train their employees in a fairly orthodox way. They would provide manuals and training for their technicians who fixed the machines in order that they could meet the needs of the customer. Anyone having problems with their printer or photocopier would call a customer service rep who would send out a "trained" technician who would then fix the problem with the help of error codes. Sounds straightforward but in reality it didn't work like that.

First, the machines were highly unpredictable and often didn't malfunction in the way prescribed in the manual (anyone frantically flicking through the "troubleshooting" section of a computer manual will be familiar with this). There were usually a myriad of overlapping problems that were not covered by the manual or by training and the knowledge needed to fix them represented what Michal Polanyi (1958) refers to as "tacit knowledge", meaning things that we know, yet are difficult or that we are even unable to express. In other words, the way to fix the machines was not covered in manuals or training; it was often

TACIT KNOWLEDGE
Implicit knowledge that's hard to explain

1 WENGER, E. (2000). COMMUNITIES OF PRACTICE AND SOCIAL LEARNING SYSTEMS. *ORGANIZATION*, 7, 225–246.
2 IBID., P. 229.

contained in a collective wisdom about the machines that was borne out of direct experience in fixing them.

So how did they get anything done? Researcher Julian Orr spent time with the employees and noticed that many of them would meet for breakfast and discuss the problems they were facing while having coffee before work. They would share specialist knowledge of particular machines they had worked on and the various ways in which they could break down and the solutions they used to address the problem. He discovered that the employees would often share their stories and learn from each other in an informal way that the manuals and training did not cover.

Xerox then created a knowledge management system of this tacit knowledge called Eureka, which was initially rolled out in France and then worldwide, where workers would input problems and solutions to a database which other workers could then access and learn from. As one worker notes:

> Eureka isn't so much an end, as a beginning. Someone will call over the radio with a fault code like, 'I'm having 12–142s', and I can look it up in Eureka and scroll through common causes. It's faster to find it in Eureka than it is to go in and fire up the documentation CD for the repair procedures there.
>
> (Bobrow & Whalen, 2002, p. 55)

Eureka made its debut in 1994, and in 12 years of its implementation it saved Xerox over $100 million in service costs (Whalen & Bobrow, 2011). What Xerox had created was a unique social learning system and a very good example of the power of a community of practice.

Abstract of the article

This essay argues that the success of organizations depends on their ability to design themselves as social learning systems and also to participate in broader learning systems such as an industry, a region, or a consortium. It explores the structure of these social learning systems. It proposes a social definition of learning and distinguishes between three "modes of belonging" by which we participate in social learning systems. Then it uses this framework to look at three constitutive elements of these systems: communities of practice, boundary processes among these communities, and identities as shaped by our participation in these systems.

The article

In 1991, Jean Lave and Etienne Wenger published a hugely influential book, claiming that learning is not a solitary enterprise but rather is formed through one's cultural and historical context (Lave & Wenger, 1991). Three elements need to be in place in order to be what they called a community of practice: the domain, the community, and the practice.

In this 2000 article, Wenger develops this idea and begins by making the case that learning is essentially “an interplay between social competence and personal experience” (p. 227); that is to say there are certain competencies or skills that are socially recognised, such as being a qualified plumber, and then there are the personal experiences of plumbers within that social structure. Wenger argues that whenever there is tension between the two and one starts to pull against the other, learning takes place.

Three modes of belonging

What does it mean to “belong” to a community? There are three modes of belonging offered by the author: (1) *engagement*, where we do things together such as enter into dialogue or produce artefacts, (2) *imagination*, how we construct an image of ourselves; for example, conceiving of ourselves as a nation or that the earth is round are acts of imagination, and (3) *alignment*, where our activities chime with or are in sync with a broader set of processes such as the scientific method or obeying the law. These different modes help distinguish what a community is and how it functions in the sense that a community of imagination such as nation is very different from a community of engagement such as a team of electricians.

Communities of practice then are collectives which have a shared set joint enterprise, feature mutual engagement, and will have produced a shared repertoire of resources such as language, artefacts, narratives, etc., and have ready access to these. Communities of practice have been around for centuries in the form of medieval guilds and are now popular in the form of online communities, and although they are focused on learning, they are not always positive entities. For example, the Witch trials of the nineteenth century were a community of practice that had “learned not to learn” (p. 230) and had become more of a closed circuit fuelled by dogma and fear rather than a flourishing network informed by evidence and dialogue. We see this today on the internet, where virulent dogmatic communities troll and threaten others who don’t see the world as they do and dare to say so.

Communities of practice are not always positive

LIMINAL SPACE
A boundary or threshold

Boundaries are an important idea within communities of practice as they suggest a liminal space (what Turner (1969) calls a “betwixt and between space”) where competence and experience converge and knowledge becomes expanded. For example, a group of educators who are largely concerned with philosophical aspects of education might come into contact with a community of cognitive scientists and learn more about the architecture of the brain, which might inform and even challenge preconceived ideas and thus expand their knowledge base.

This process might even work the other way, with the cognitive scientists reconceiving their knowledge base and practice through the lens of various philosophical questions. In this way, a more cross-disciplinary approach can be enacted within organisations and institutions where different groups can meet, share, and exchange ideas with boundaries seen as a fruitful place of creation as opposed to rigid defensive boundaries to be protected.

Another key element of social learning systems is individual identities. Wenger claims that "we define ourselves by what we are not as well as by what we are, by the communities we do not belong to as well as by the ones we do" (p. 239). For example, we do not stop being a parent when we go to work or stop being a science teacher when we're not teaching science. We carry multiple identities as we move across boundaries from community to community, creating bridges as we do so. There are three elements to an identity: *connectedness*, *expansiveness*, and *effectiveness*. *Connectedness* refers to the kinds of enduring social relationships through which an identity gains depth. A robust identity has deep connections with others through shared history and experience and mutual commitments. *Expansiveness* refers to the fact that an identity will initially be defined in a local sense, but it will then cross multiple boundaries and will seek a range of experiences and direct participation in a range of other communities. *Effectiveness* asks whether an identity enables action and involvement and represents a vehicle for social participation. A healthy identity is empowering, not marginalising. Navigating the tensions between these different elements is a crucial aspect of forming a healthy identity within a social learning system.

ELEMENTS OF IDENTITY
Connectedness, expansiveness, and effectiveness

COMMUNITIES OF PRACTICE AND LEGITIMATE PERIPHERAL PARTICIPATION

> For communities of practice, it requires a balance between core and boundary processes, so that the practice is both a strong node in the web of interconnections – an enabler of deep learning in a specific area – and, at the same time, highly linked with other parts of the system – a player in systemwide processes of knowledge production, exchange, and transformation.
>
> (Wenger, 2000, p. 243).

Important here is the concept of *legitimate peripheral participation*, which describes how newcomers to a community of practice become experienced members and eventually old timers of

LEGITIMATE PERIPHERAL PARTICIPATION
Meaningful interaction between new and old members

that community. It sees learning as a social phenomenon that occurs in a context which is achieved through participation in a community. In this way we can see it as a form of situated learning (see Chapter 28, The culture of learning). Newcomers become community members by participating in simple, often low-risk tasks that are nevertheless both productive and necessary and which further the goals of the community. Through peripheral activities, novices become acquainted with the tasks, vocabulary, and organising principles of the community's practitioners. In time, as newcomers become old timers and gain a recognised level of mastery, their participation takes forms that are more and more central to the functioning of the community. Legitimate peripheral participation suggests that membership in a community of practice is mediated by the possible forms of participation to which newcomers have access, both physically and socially.[3]

Conclusions/implications of the work for educational practice

While all of the other articles in this book deal primarily with learning and teaching, this article possibly is more suited – in our opinion – to teachers and the community of practice that is the school.

In terms of how to use the ideas outlined in Wenger's article, he suggests that a community of practice should look at things like: events, leadership, connectivity, membership, projects, and artefacts (see Table 30.1). Events bring together members of a community and must decide on the rhythm of these events; too many and members stop coming, too few and the community doesn't gain momentum. The community also needs internal leadership and multiple forms of active membership such as networkers, thought leaders, and administrative workers. It's also important for members of this community to be able to connect with each other through multiple forms of media (e.g. face-to-face, social media, computer-based environments) and to deepen their shared commitment by working on a range of projects together such as a literature review, empirical research, community projects, and so forth. Finally, a community should produce a set of artefacts such as documents, stories, tools, websites, etc., which will remain practically useful as the community grows and evolves.

Technology has afforded communities more opportunities

A good example of this in practice is the ways in which certain educators choose to engage with the wider research about their own

3 HTTPS://EN.WIKIPEDIA.ORG/WIKI/LEGITIMATE_PERIPHERAL_PARTICIPATION.

TABLE 30.1 COMMUNITY DIMENSIONS (ADAPTED FROM WENGER, 2000, P. 231)

Enterprise: learning energy	Mutuality: social capital	Repertoire: self-awareness
Engagement		
What are the opportunities to negotiate a joint inquiry and important questions? Do members identify gaps in their knowledge and work together to address them?	What events and interactions weave the community and develop trust? Does this result in an ability to raise troubling issues during discussions?	To what extent have shared experience, language, artifacts, histories, and methods accumulated over time, and with what potential for further interactions and new meanings?
Imagination		
What visions of the potential of the community are guiding the thought leaders, inspiring participation, and defining a learning agenda? And what picture of the world serves as a context for such visions?	What do people know about each other and about the meanings that participation in the community takes in their lives more broadly?	Are there self-representations that would allow the community to see itself in new ways? Is there a language to talk about the community in a reflective mode?
Alignment		
Have members articulated a shared purpose? How widely do they subscribe to it? How accountable do they feel to it? And how distributed is leadership?	What definitions of roles, norms, codes of behaviour, shared principles, and negotiated commitments and expectations hold the community together?	What traditions, methods, standards, routines, and frameworks define the practice? Who upholds them? To what extent are they codified? How are they transmitted to new generations?

practice in the form of journal reading groups where teachers will meet weekly or monthly to discuss a research paper they have read and then discuss how it applies to their own immediate context. In this way, these communities then act as a sort of "brokerage" between research and practice and create a more evidence informed community.

How to use the work in your teaching

In many cases, communities of practice are typically used as a template for subject-specific associations where groups of English or maths teachers will create a network to share domain-specific knowledge about teaching particular exam units or address changing requirements of exam boards and government policy changes. When teachers get together and share ideas and experiences in this way, the results are often profoundly useful to the members of that community and are far more practical than the "official" advice given by exam boards. Nuanced knowledge such as how to teach Shakespeare to specific age groups in specific contexts can provide powerful instances of professional development with huge benefits to not just teachers but the students in their charge.

COMMUNITIES OF PRACTICE IN ACTION

Using this book to form a community of practice

Traditional knowledge management approaches attempt to capture existing knowledge within formal systems, such as databases. Yet systematically addressing the kind of dynamic "knowing" that makes a difference in practice requires the participation of people who are fully engaged in the process of creating, refining, communicating, and using knowledge (Wenger, 1998, p. 2). In this respect, you as reader might consider using this book as a starting point for a community of knowledge and practice within your school or section. Each of the chapters could be the basis of thinking and discussion on the content, the theory, its use in the school and class, etc. Here's how: every week or two one member of the community takes the time and makes the effort to thoroughly read a chapter (including some of the referenced materials); (s)he is the expert. The other teachers "just" read the chapter. Then, in a short (let's say one hour) meeting the expert presents the content, after which a discussion ensues about the research, its usefulness, and – probably most importantly – how the school or section can best implement it and where. Finally, this is all brought into a shared document, wiki, or whatever so that there is documentation where (1) new teachers can go to begin their membership in the community and (2) new thoughts, information, and uses can be added, growing the database. Kind of like Eureka, which was implemented at Xerox!

researchED International community sharing education research between researchers and practitioners

In education we are currently seeing very far-reaching communities of practice form around education research, in the form of large networks such as researchED, but also more local ones in schools with the advent of research journal groups where teachers get together in their own time and read a particular article, literature review, or book and then discuss ways in which that research is significant to their own context. The notion of communities of practice has particular resonance for all levels of educational institution, such as leadership, for example, where head teachers often create networks to share and address specific problems that often only other school leaders can help with.

By allowing communities of practice to not only form and collaborate but also to flourish beyond the borders of their own boundaries, educational institutions can harness a very powerful and old form of knowledge creation and also empower their own members at the same time. Unlike the Xerox corporation they may not save $100 million (impact is far more difficult to quantify in education) but the knowledge created can have far-researching benefits to both teachers and students alike.

Takeaways

- Communities of practice are systems of learning where participants come together in shared process of human endeavour.
- Communities of practice can create and share domain-specific knowledge that more formal systems cannot.
- The boundaries of such systems should not be closed and protected but rather should seek to connect with other communities to further knowledge.
- Communities of practice require three elements: domain, community, and practice.
- Belonging to a community of practice means having engagement, imagination, and alignment.
- Communities of practice allow for legitimate peripheral participation where all members (newbies and old sods) can meaningfully participate.

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Suggested readings and links

FREQUENTLY ASKED QUESTIONS ABOUT COMMUNITIES OF PRACTICE, NETWORKS, AND SOCIAL LEARNING SET UP BY ETIENNE AND BEVERLY WENGER-TRAYNER ARE

AVAILABLE FROM HTTP://WENGERTRAYNER.COM/FAQS/.

A CHAPTER WRITTEN BY ETIENNE AND BEVERLY WENGER-TRAYNER: LEADERSHIP GROUPS, A PRACTICE FOR FOSTERING LEADERSHIP IN SOCIAL LEARNING CONTEXTS, IS

AVAILABLE FROM HTTPS://WWW.WENGER-TRAYNER.COM/WP-CONTENT/UPLOADS/2022/10/13-11-25-LEADERSHIP-GROUPS-V2.PDF

USEFUL PAPER ON USING COMMUNITIES OF PRACTICE IN HIGHER EDUCATION

AVAILABLE FROM HTTPS://FILES.ERIC.ED.GOV/FULLTEXT/EJ1259432.PDF

A GOOD DEFINITION OF LEGITIMATE PERIPHERAL PARTICIPATION IS

AVAILABLE FROM WWW.IGI-GLOBAL.COM/DICTIONARY/LEGITIMATE-PERIPHERAL-PARTICIPATION/17026.

PART VII

CAUTIONARY TALES

We close this book with four cautionary tales because, as they say in Dutch, a person forewarned counts double. We discuss whether learners really know what's best for them, when teaching kills learning, what the ten dubious reasons for using multimedia are, what the ten deadly sins of education are, and the deadly dozen lethal mutations.

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31 | DID YOU HEAR THE ONE ABOUT THE KINAESTHETIC LEARNER …?

URBAN LEGENDS

DOI: 10.4324/9781003395713-38

31 DID YOU HEAR THE ONE ABOUT THE KINAESTHETIC LEARNER …?

PAPER "Do learners really know best? Urban legends in education"[1]

QUOTE *"The beliefs that a person holds persist in the face of data that disproves or even contradicts those beliefs."*[2]

Why you should read this article

Did you hear the one about the little old lady (why is it always a little old lady?) who after walking her toy poodle in the rain wanted to dry it quickly? To this end, she put the poodle in the microwave oven – it used to be the clothes dryer – and mistakenly cooked it? Or how about the one about the grandparents who brought a cute little alligator home from their trip to Florida for their grandson [*sic*]? Well, as it grew the mother began to have qualms about it and flushed it down the toilet. Years later, a sewer worker in New York was killed and eaten by a 5 metre long alligator who flourished in the warm and food rich sewer system. Such stories are known as urban legends or myths; a story or description (often fictitious) that's broadly circulated, often told, seen by the narrator and listener as true, and that we want to believe but that there's no real proof for. Many books have been written about them. My favourite is *The vanishing hitchhiker: American urban legends and their meanings* by Jan Harold Brunvand. I read it when it first came out in 1981 and I was hooked.

URBAN LEGEND
Dubious story widely circulated

You might think that such myths are harmless, but that's not always the case. The field of education is rife with myths which are undermining the learning of our children. There are so many myths in education that Paul, together with Pedro De Bruyckere and Casper Hulshof, has filled two complete books with them. Many myths can be dismissed as

1 KIRSCHNER, P. A., & VAN MERRIËNBOER, J. J. G. (2013). DO LEARNERS REALLY KNOW BEST? URBAN LEGENDS IN EDUCATION. *EDUCATIONAL PSYCHOLOGIST*, *48*(3), 169–183. DOI: 10.1080/00461520.2013.804395.

2 IBID., P. 180.

tangential or exotic (e.g. listening to Mozart makes you or your baby smarter), but there are quite a few pernicious ones. Take the idea that the brains of different generations are different and thus that teaching should accommodate this. The current generation is often referred to as *Generation Z*, *digital natives*, *homo zappiëns* … because they grew up in a digital environment surrounded by the internet, smartphones, tablets, and the like. Playfully, without effort, they've been said to have acquired the ability to independently discover and learn, are knowledge builders and sharers, and so forth. In addition, as they're connected to all knowledge of the world via the internet they are assumed not to need to acquire factual and procedural knowledge or domain-specific skills. Paul and Jeroen van Merriënboer make short work with these myths about this supposedly exceptional generation.

DIGITAL NATIVE
Incorrect claim that today's kids are different to previous generations

Abstract of the article

This article takes a critical look at three pervasive urban legends in education about the nature of learners, learning, and teaching and looks at what educational and psychological research has to say about them. The three legends can be seen as variations on one central theme, namely, that it is the learner who knows best and that she or he should be the controlling force in her or his learning. The first legend is one of learners as *digital natives* who form a generation of students knowing by nature how to learn from new media, and for whom "old" media and methods used in teaching/learning no longer work. The second legend is the widespread belief that learners have *specific learning styles* and that education should be individualized to the extent that the pedagogy of teaching/learning is matched to the preferred style of the learner. The final legend is that learners ought to be seen as *self-educators* who should be given maximum control over what they are learning and their learning trajectory. It concludes with a possible reason why these legends have taken hold, are so pervasive, and are so difficult to eradicate.

LEARNING STYLES
Disproven theory that learners learn best in a particular style

The article

If you see kids with a tablet, you might think they really know what they're doing. They search for videos, effortlessly use all types of social media, and seem to remember passwords better than us. People call them digital natives and us (parents and teachers) digital immigrants. According to Marc Prensky (2001) who coined the term, these *digital natives* cannot learn in our present current educational system and thus should be taught in a different way because they think and process information fundamentally differently from their predecessors "as a result of this ubiquitous [digital] environment and the sheer volume of their interaction with it" (p. 1). Without ever making the effort to actually study this, he concluded that they (1) really understood what they were doing, (2) used their digital devices effectively and efficiently, and (3) needed a new type of education designed to accommodate this. Veen and Vrakking (2006) took this a step further and introduced the *homo zappiëns*; a new generation of learners who learn significantly differently from their predecessors who develop – on their own and without instruction – the metacognitive skills needed for inquiry-based learning, discovery-based learning, networked learning, experiential learning, collaborative learning, active learning, self-organisation and self-regulation, problem-solving, and making their own implicit (i.e. tacit) and explicit knowledge explicit to others.

Kirschner and Van Merriënboer question this. Playing with tablets is different from learning via tablets, and Instagramming each other is different from communicating and collaborating to learn. They question, thus, whether these children really know how to use the technology to learn. Along with this, they discuss two other things attributed to this generation, namely that children need instruction that caters to their specific learning styles and that they should have complete control over their own learning.

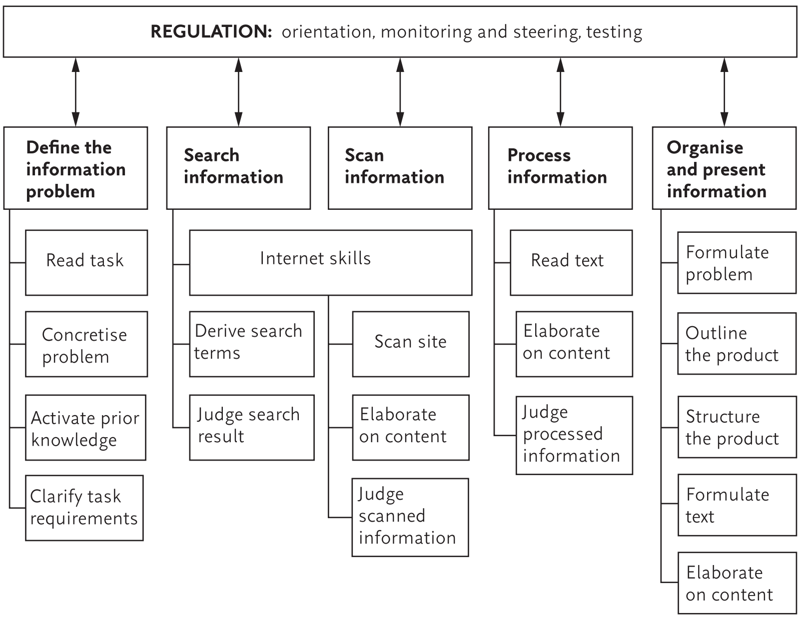

FIGURE 31.1 SKILLS NEEDED TO SOLVE AN INFORMATION PROBLEM (BRAND-GRUWEL, WOPEREIS, & WALRAVEN, 2009)

It's true that children can search for practically everything online, but there is also a lot of misinformation, disinformation, and even sheer nonsense online. They must therefore also be able to first formulate a proper search question and when the results are presented, they need to assess the information found with respect to its usefulness, reliability, truth, and so on. All of the hours children spend with new technology has not led to acquisition of these necessary skills (also known as *media literacy* or *information problem-solving skills*; Brand-Gruwel, Wopereis, & Walraven, 2009; see Figure 31.1).

"JUST GOOGLE IT"
A real problem without knowledge of what to trust

Kirschner and Van Merriënboer also point to another risk of using such technology, namely that many researchers have found that children use the information they find very passively; mostly cutting and pasting, and fluttering via hyperlinks from one "interesting" piece of information to the next without understanding the underlying structure of the content. This is very similar to what is known as continuous partial attention (Stone, 2007) where we try to pay simultaneous attention to a number of sources of incoming information. When we try to do this, the result is paying attention at a superficial level with all of the consequences associated with this. They may remember some "interesting" facts, but don't really learn. Salomon (1998) called this the *butterfly defect*. An extra note here is that by simply cutting and pasting – and not even literally transcribing what is read with pen and paper or keyboard – learners don't process the information and, thus, don't learn from it!

CONTINUOUS PARTIAL ATTENTION
Superficial focus through repeated distraction

The second thing the authors warn of is differentiation based on the different learning styles. The idea is that in order to teach well, as a teacher, you need only determine the learning style of each pupil and then teach according to that style. This is what people call the meshing hypothesis (Pashler, McDaniel, Rohrer, & Bjork, 2008). This means that you first need to determine what style each learner has. In the last half century, many different learning styles have been thought up. For example, we can use the VARK in which people are subdivided into four learning styles: visual, auditory, read/write, and kinaesthetic. On the other hand, you could use Kolb's four styles, where you divide learners into divergers, assimilators, convergers, and accommodators. Or you could choose to divide your students into holistic or analytical learners, impulsive or reflective learners, analytical, practical or creative learners, and so on. Frank Coffield and his colleagues (2004) investigated how many learning styles existed in the literature and came to no fewer than 71 different learning styles!

MESHING HYPOTHESIS
Claim that instruction should match learning style

ONE LEARNING STYLE PER CHILD?

Suppose you want to use learning styles to differentiate in your classroom. How would that work? First you test whether Mary is a diverger, assimilator, converger, or accommodator (Kolb). She appears to be a diverger (according to the test). Good start, but unfortunately you don't know if she's visual, auditory, read/write, or kinaesthetic diverger. You now test her for this and she turns out to be a visual diverger, one of the now 16 possible styles (four Kolb times four VARK). But is she a holistic or an analytical visual diverger? You test her again and now we are on 32 different learning styles and she turns out to be an analytical visual diverger. Are you there yet? No! You don't know if she's an impulsive or reflective analytical visual diverger. Now we've reached 64 different learning styles and unfortunately you can continue for a while (remember, you've only tested for 4 of the 71). That's not only impossible, it also makes no sense at all.

Evidence for learning styles doesn't exist

And then a second, more serious problem: from overview studies of empirical studies of the effects of learning style on learning (e.g. Coffield, Moseley, Hall, & Ecclestone, 2004; Pashler, McDaniel, Rohrer, & Bjork, 2008) it appears that matching subject matter to learning style actually doesn't lead to better learning.

If better learning was the case, pupils with an auditory learning style, for example, would learn better if allowed to listen to the instruction and less well or not at all if they had to read the instruction. This is the opposite for a pupil with a visual learning style (and we've purposely left out visual and kinaesthetic). This expected interaction between learning style and subject matter is shown in Figure 26.2. There has been a frantic

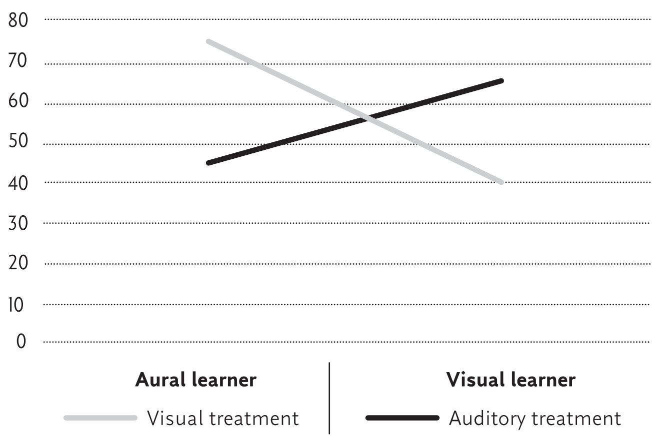

FIGURE 31.2 AN INTERACTION EFFECT, ACCORDING TO PASHLER, MCDANIEL, ROHRER, AND BJORK (2008), IS THE ONLY ACCEPTABLE EVIDENCE FOR THE MESHING HYPOTHESIS

search in the literature to confirm this interaction, but unfortunately none has been found.

A third problem with learning styles is that most instruments used to determine learning styles (actually almost always self-response questionnaires) aren't reliable. One week, the person is classified as an assimilator and the next week as a converger. Allied to this problem is that the questions used are valid (i.e. do they measure what they purport to measure?) for determining one's preference for a certain way of learning. But one's preference doesn't say anything about whether a person actually learns better using a preferred type of presentation. Do students really know what's good for them? Ask people about their favourite food and most tell you something that is fatty, and/or salty, and/or sweet. Is this eating preference (eating style) also the healthiest?

A final problem becomes clear with the following question: How do you explain to a pupil in an auditory way how crimson red and brick red look? Or how do you kinaesthetically explain how a blackbird sings? In other words, it's actually the subject matter and the learning goal that should determine how one teaches and not a preference or a non-existent learning style.

Content should be the determining factor in instructional design

So why are learning styles so popular? Part of the answer is psychological: every teacher would like to have a way to differentiate between pupils. Another reason is that there's good money in the learning style hype. Think about all of the providers of tests, materials, books, workshops, conferences, advice, and so on. Finally, it can be a welcome excuse for the child or parent to explain why the learning is not going well, and thus to tell the teacher or school that they are teaching wrong.

Third, Kirschner and Van Merriënboer discuss the often voiced idea – especially by those who are fans of Richard Ryan and Edward Deci (2000; self-determination theory) – that for students to learn best, they need control over their own learning process. In this way of thinking, they can make their own choices about what they want to learn, when they want to learn it, and how. By giving them control of (or autonomy with) their own learning process, they become more motivated and subsequently learn and perform better. A problem here is that students find it difficult to accurately estimate their own performance; they often think that they are better than in reality (see Chapter 12, Why independent learning is not a good way to become an independent learner).

Also, we see that if pupils are given the opportunity to make their own choices, they often choose the things that they find easy. For example, they choose assignments that they already know they can do. In this way they do not challenge themselves, while this is exactly what we, as teachers, want them to do. They need our help. We have to support and guide them in making good choices and gradually reduce this support and guidance so that pupils can eventually do it by themselves (i.e. we must properly scaffold their learning choices; see Chapter 17, Why scaffolding is not as easy as it looks).

Learners are poor judges of their own learning

Conclusions/implications of the work for educational practice

The insights from this article help us to reflect on the role of digital technology in education, differentiation, and independent learning. We can't ignore the technology that surrounds us, but we can teach our students to actively and responsibly deal with digital information and make them media savvy. It's good to critically look at when and how to use a smartphone, tablet, or laptop; when it is effective and efficient for learning and when it isn't. Research will help us decide when and how technology will be of added-value in our teaching (see also Chapter 33, The medium is NOT the message).

As Kirschner and Van Merriënboer clearly show, learning styles don't exist. They therefore aren't a meaningful basis for differentiation. In fact, they are rather counterproductive because our memory benefits from instruction being presented in more than one modality and this applies to all pupils (see Chapter 10, One picture and one thousand words, and Chapter 33, The medium is NOT the message). Teachers, thus, don't need to spend time determining each person's learning style and changing their teaching accordingly. There are many other, more effective ways to differentiate, but this falls outside of the scope of this book.

Self-determined and directed learning must be learnt!

Finally, independent self-determined and directed learning is *not* something students can do spontaneously. They need support and guidance in making their choices and you, as teacher, are the perfect person to do this. You can't begin early enough with helping children to make good choices, but remember: it's not productive to do this too soon.

How to use the work in your teaching

What about in your classroom and at your school? Do you and your colleagues believe in learning styles or even work with them? It's really hard to say goodbye to an idea that sounds so logical and even sympathetic; after all, aren't all human beings different and special? It's also hard to "reject" your own preferences when you may have elevated them to truths about how you learn best. But learning styles lack any scientific foundation and can even be counterproductive. Talk to colleagues who swear by learning styles. These kinds of conversations can be difficult, precisely because people have invested a lot in the method they use but in the end every teacher wants to do what is best for students.

Challenging established beliefs through evidence

Using technology can be very valuable for learning, after all most kids look like they're proficient in using it, but aren't. They're finger-fast but knowledge-poor. Don't be fooled into thinking that they possess the information problem-solving skills necessary for effectively using the internet. They need to learn to use it properly and you need to teach them/help them to learn to use it. Also remember that students can get distracted by working online. They are butterflies that flutter from link to link when they're not doing something else that's completely irrelevant to learning while online. Technology can be a blessing, but it's also a Pandora's box. Use it wisely.

From pre-school onwards, you can give children some control over their learning process. It starts with letting children choose in which corner of the room they want to work and play. Make sure they don't just choose to do what they know and can do; get them to try to do new things that challenge them. Of course the school is there to help children learn to better do that which they already can, but the primary job of the school should be to teach them to do things they can't! In higher grades you can continue to expand the choices they can make themselves, but under supervision. In maths, for example, first you determine how many addition problems and at what level they have to complete. Later you can slowly allow them to decide for themselves. You teach them not to look at what they like or dislike, but at what they themselves need to do to learn and achieve success. Let them see the effect of their choices on their learning and achievement.

Effective learning means taking on challenge

Takeaways

- Stop propagating the myths of learning styles and *digital natives*. Both don't exist and teaching according to them is a waste of time and is often bad for the student!
- Be careful with self-determination, including self-directed and self-determined learning. Students must acquire these skills with your support and under your guidance.
- Work with students when searching for information on the web and teach them how to judge the reliability and validity of what they find.
- Learners are often the worst judges of how they "learn best".
- Schools should consider the role of a "research lead" to act as a buffer against urban myths in education.

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Suggested readings and links

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AVAILABLE FROM WWW.DANIELWILLINGHAM.COM/LEARNING-STYLES-FAQ.HTML.

KIRSCHNER, P. A., & DE BRUYCKERE, P. (2017). THE MYTHS OF THE DIGITAL NATIVE AND THE MULTITASKER. *TEACHER AND TEACHER EDUCATION*, *67*, 135–142. DOI: 10.1016/J.TATE.2017.06.001.

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PROFESSOR DANIEL WILLINGHAM DESCRIBES RESEARCH SHOWING THAT LEARNING STYLES ARE A MYTH.

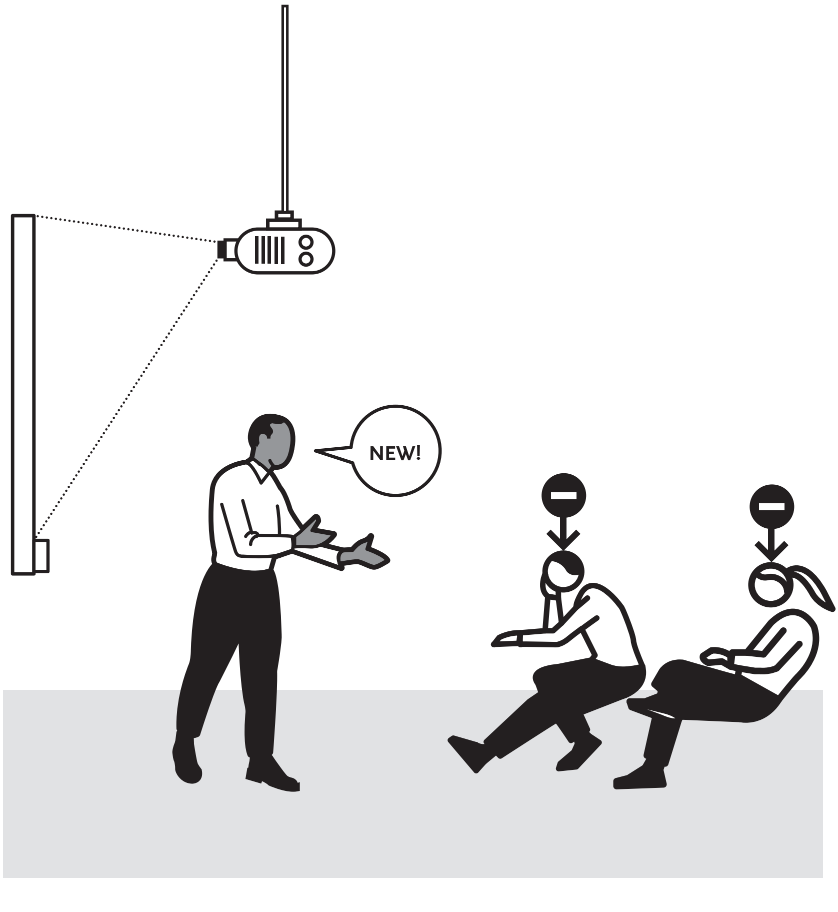
AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=SIV9RZ2NTUK.

LEO LAPORTE AND DANAH BOYD, AUTHORS OF *IT'S COMPLICATED: THE SOCIAL LIVES OF NETWORKED TEENS*, TALK ABOUT HOW THE IDEA OF "*DIGITAL NATIVES*" IS A MISNOMER.

AVAILABLE FROM WWW.YOUTUBE.COM/WATCH?V=S0K-RX4SHT8.

32 WHEN TEACHING KILLS LEARNING

WHAT DOESN'T WORK



DOI: 10.4324/9781003395713-39

32 WHEN TEACHING KILLS LEARNING

PAPER "When teaching kills learning: Research on mathemathantics"[1]

QUOTE *"A central objective of educational research is to identify 'mathemagenic' instructional methods (i.e. those that 'give birth' to learning). Yet there has been increasing evidence for 'mathemathantic' effects in instructional research (i.e. where instruction 'kills' learning)."*[2]

Why you should read this article

THE COBRA EFFECT
Law of unintended consequences

Nothing ventured, nothing gained. There's no harm in trying. What doesn't kill me makes me stronger.[3] How often have you heard these maxims? But is this really the case? As far as Richard Clark is concerned, with respect to education, the answer is *no*. Sometimes, research shows that a certain classroom intervention, no matter how well-intentioned, didn't have the intended effect. This is somewhat similar to the *cobra effect*[4] in policy and/or economics where an attempted solution to a problem makes the problem worse. What is often the case is that there was no effect for the intervention in comparison to the control condition (usually the "standard" teaching practice). It may have taken more effort by the teacher or learner or required more resources, but the kids learnt as well as the control, so no harm done (in any event with respect to learning). If we know this, then we don't have to spend the extra time, effort, and/or money on something that doesn't work. But sometimes

1 CLARK, R. E. (1989). WHEN TEACHING KILLS LEARNING: RESEARCH ON MATHEMATHANTICS. IN H. MANDL, E. DE CORTE, N. BENNETT, & H. F. FRIEDRICH (EDS.), *LEARNING AND INSTRUCTION. EUROPEAN RESEARCH IN AN INTERNATIONAL CONTEXT* (VOL. II). PERGAMON.
2 IBID., P. 1.
3 THE GERMAN PHILOSOPHER FRIEDRICH NIETZSCHE WROTE "*WAS MICH NICHT UMBRINGT MACHT MICH STÄRKER*". IT COMES FROM THE "MAXIMS AND ARROWS" SECTION OF NIETZSCHE'S BOOK, *TWILIGHT OF THE IDOLS* (1888).
4 THE BRITISH GOVERNMENT IN INDIA OFFERED A BOUNTY FOR DEAD COBRAS TO DECREASE THEIR NUMBERS. SOME PEOPLE SAW A CHANCE AND BEGAN BREEDING COBRAS TO MAKE MONEY. WHEN THE BRITS REALISED THIS AND SCRAPPED THE PROGRAMME, THE BREEDERS SET THE NOW-WORTHLESS SNAKES FREE, RESULTING IN AN INCREASE IN THE COBRA POPULATION.

something else happens. Sometimes, the students who received the new approach actually performed worse than the students in the control group and/or performed worse after the intervention than before. In educational research we find few publications about these types of results (i.e. what doesn't work or works worse) because many people think that the goal of educational research is only to discover robust instructional methods that do work. This so-called publication bias (the distortion that arises when only positive results are published, but not the negative results) is a shame because we can also learn a lot from what doesn't work. In this article, Clark draws attention to the fact that what doesn't work also tells us something about the relationship between learning and instruction. He shows how certain learning activities can be counterproductive to learning. These so-called "mathemathantic activities" (cf. mathemagenic, Chapter 20; *manthanein* = learning + *thanatos* = death), a term first used by Richard Snow in an address to the American Educational Research Association in 1972, are instructional methods that unintentionally create conditions whereby pupils learn less well or even lose knowledge through the offered material (Snow, 1972). The theory of mathemathantic activities clearly shows why differentiation is also important for the more gifted pupils; after all, these students have something to lose – their existing knowledge.

MATHE-MATHANTIC ACTIVITIES
Activities that kill learning

Abstract of the article

Instructional research is reviewed where teaching failures have produced students who are less able to use learning skills or had less access to knowledge than before they were taught. Three general types of "mathemathantic" (i.e. where instruction "kills" learning) effects are hypothesized, theoretical explanations for each effect are examined and representative studies in each area are described. The three types of effects described are where instruction serves to: 1) substitute learning procedures (e.g. novel learning strategies are hypothesized to interfere with the learning of higher general ability learners and inadequate learning strategies are provided to those with lower general ability); 2) impose less desirable motivational goals on learners (e.g. when teaching methods lead constructively motivated learners to believe that failure avoidance has replaced achievement directed goals and, conversely, when defensively motivated students believe that achievement directed goals have replaced the opportunity to avoid failure); and 3) substitute student control for system control over instructional method (e.g. by allowing lower cognitive load instructional methods to be chosen by high general ability, constructive students and/or by allowing higher cognitive load methods to be chosen by defensive students who have low general ability).

The article

MATHEMAGENIC ACTIVITIES Activities that give birth to learning

The holy grail of educational research is to invent and/or identify instructional methods that are *mathemagenic* (see Chapter 20, Activities that give birth to learning). If the idea, theory, or hypothesis fails, they generally expect that the achievement or skills of the participants either remain at pre-experiment levels or are the same as those who didn't take part in the study. Clark was triggered to write this article by what he called "increasing evidence for 'mathemathantic' effects in instructional research" (p. 1).

He operationally defined a mathemathantic effect as when an intervention has one of four different effects. First, we see such an effect when the control group – the group of students that doesn't receive the intervention – significantly outperforms the experimental group that did. That is to say, instruction without the intervention led to more learning than with. The second is when pre-test scores for the intervention group are significantly higher than their post-test scores. Here, the intervention led to a loss of knowledge or skill. The third is when there are "significant disordinal interactions between student's aptitudes and instructional treatments" (p. 2); that is, an aptitude-treatment interaction (Cronbach & Snow, 1977) is observed. In plain terms, this is when one intervention leads to better learning in a certain type of learner but to poorer results for another. In Figure 32.1, a contrast of student-centred (i.e. unstructured, discovery) and teacher-centred (i.e. directed, monitored) instruction with students with different levels of anxiety is shown. Higher anxiety students profited from the greater structure provided by a teacher-centred approach while lower anxiety students profited more from a student-centred approach. Finally, we see a mathemathantic effect when increasing amounts of some approach to instruction produces significantly negative correlations with learning; that is "more is worse".

Aptitude-treatment interaction is similar to learning styles

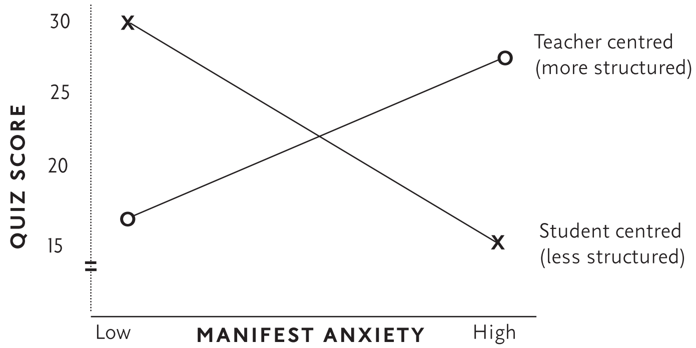


FIGURE 32.1 DISORDINAL INTERACTION WITH ANXIETY PREDICTING QUIZ SCORES UNDER MORE AND LESS STRUCTURED TREATMENTS FOLLOWING DOWALIBY AND SCHUMER (1973)

In Clark's view, the interpretation of negative research results (i.e. mathemathantic effects) requires analysing the role that individual differences play in learning from instruction. "What is mathemathantic for one aptitude level may be mathemagenic for another" (p. 2). This means that when offering instruction, we must take a good look at the match or possible mismatch between the instruction and individual learner. Clark focuses on two possible areas where a mismatch can arise, namely learning strategies and learning environments. What the mismatch looks like depends on the prior knowledge and abilities of the learner.

Learning strategies mismatch

STRATEGY SUBSTITUTION
Effective methods for ineffective ones

When implementing an instructional treatment where the learner replaces an effective strategy that (s)he already uses with a new and often unfamiliar one, learning is often depressed. This *strategy substitution* can take two forms. First, substituting an existing strategy with a novel strategy mainly affects higher aptitude students as they often replace an automated effective strategy with a less familiar one. These novel strategies interfere with these learners' existing skill repertoires. However, the same strategies that are mathemathantic for higher aptitude learners often benefit low aptitude students who lack an effective approach (see the following text box, *Prior knowledge and expertise reversal*).

EXAMPLE
Introducing an inadequate strategy

The second is where inadequate strategies are introduced that provide learners with unsuccessful and/or incomplete learning procedures. This is, for example, the case for discovery learning which might work by experts but not by novices (see Chapter 6, A novice is not a little expert). Such strategies negatively affect lower aptitude students as they're often too abstract and are based on partly automated knowledge which beginners don't possess. Clark gives an example where math teachers discourage using concrete "finger counting", a strategy that slower math learners use while performing arithmetic operations, and encouraging more "abstract" learning strategies was mathemathantic for lower aptitude or younger learners. These inexperienced learners not only know less, but their cognitive schemata – how their knowledge, skills, and strategies are stored in their brains – are also very different from experienced ones. As a result, the information they receive isn't complete and their learning process falters.

Instruction must consider learner prior knowledge

PRIOR KNOWLEDGE AND EXPERTISE REVERSAL

If the instruction works better for more expert learners than for beginners – or vice versa – we speak of an "expertise reversal effect", a concept introduced by Kalyuga, Ayres, Chandler, and Sweller (2003), and Kalyuga (2007). As prior knowledge is the most important factor in learning (see Chapter 11, What you know determines what you learn), it's clear that instruction should take the learners' prior knowledge into account. Instruction and/or guidance that's essential for beginners (for example what is given in worked examples) can hamper learning in more experienced learners by making them do things that are contrary to what they already can effectively do, especially if these learners can't ignore or otherwise avoid the redundant information and guidance. In the same way, what works for more experienced learners hampers beginners who need the explicit support and guidance. To optimise cognitive load in each student (see Chapter 7, Take the load off me), suitable instruction and support should be given to novice learners, while unnecessary guidance and instruction should be removed or remembered as pupils acquire higher levels of competence in a specific domain.

Learning environment mismatch

LEARNING ENVIRONMENT MISMATCH The same classroom can have very different outcomes

Learning strategy substitution only partly explains the mathemathantic effects of certain forms of instruction. A second source lies in motivational variables affecting learners. For example, a learning environment can be very structured and guiding, limiting learner choice, or more open and less structured, giving more choice. Research shows that learners have different goals in learning, for example some learners do their best to be successful while others do their best because they fear failing (i.e. failure avoidance). Learners who fear failure are better served by structured and guiding environments where they feel safe and do their best. Learners focused on success work better in less structured environments where they can show what they're worth and later thank their success to themselves. For both groups, if they have to perform in an environment that does not fit well with their, say, motivational style, they won't perform well. The learning environment can then be counterproductive for learning.

Does this mean that we should differentiate by giving in to learner preferences for a learning environment so that each learner can choose something that suits her or him? No! Students do not make good choices. Those with little prior knowledge or who experience *performance anxiety* often opt for an unstructured environment where they can make many choices with little support. In such an environment, they can discreetly fail. Also, learners with little prior knowledge also tend to overestimate themselves. We see this when students are asked to evaluate their own learning (judgements of learning). This is close to the Dunning–Kruger effect – a psychological phenomenon where people who are less competent in a certain area assess themselves too positively. On the other hand, better learners who would like to experience success often opt for the structured environment, because they expect to score better there. In addition, they sometimes have the tendency to underestimate themselves (also part of the Dunning–Kruger effect) in order to secure success. These choices are the exact opposite of what both groups need. It is therefore up to the teacher to properly align both the instruction and the learning environment with each learner.

THE DUNNING–KRUGER EFFECT Mistakenly predicting your ability as better than it is

Conclusions/implications of the work for educational practice

Teachers should take into account the different levels of knowledge and skills of individual students when teaching. This also includes attending to their levels of strategy use, such that experienced (i.e. more expert) learners are allowed to use their existing strategies when carrying out a task while beginners (i.e. novices) are given step-by-step support and guidance. In addition, teachers must motivate their students in a "prescriptive" way so that learners who are afraid of failure aren't put under too much pressure

Mathemathantic effects occur if learners…	
learning strategies	
… have little prior knowledge	but are given strategies which assume the availability of (partially) automated strategies, knowledge, and skills
… have much prior knowledge	but are given strategies which interfere with already available and automated strategies, knowledge, and skills
motivational goals	
… are afraid of failing	but are placed/allowed to learn in minimally structured and guided environments
… want to achieve success	but are placed/allowed to learn in highly structured environments with much support and guidance
learning environments	
… need a lot of support and guidance	but are made to work in an open environment that asks a lot of them
… need little support and guidance	but are made to work in a highly structured and controlled environment

TABLE 32.1 WHEN MATHEMATHANTIC EFFECTS OCCUR

while learners who go for high grades are challenged. Finally, learners need to be guided in the choice of assignments. Good pupils who don't want to fail need to be inhibited in their tendency to opt for easier assignments. Table 32.1 shows the most common mathemathantic effects. In these cases instruction fails or is even harmful.

How to use the work in your teaching

This chapter makes clear what you intuitively already knew: what works for one student can be counterproductive to the other. Clark gives some rules of thumb that provide guidance in tailoring your instruction and teaching activities to the needs of individual students. Students with little prior knowledge benefit from small concrete steps, while pupils with a lot of prior knowledge actually thrive in a setting in which they can use this knowledge. They must be given the opportunity to use their strategies and automated knowledge. In addition, help learners with a fear of failure by providing structure and support. Learners who want to and can perform on their own thrive better in an open learning environment. Remember that you often know better what a student needs than him/herself. Students often underestimate or overestimate themselves.

Students with greater knowledge benefit from more independence

Knowing what doesn't work (i.e. approaches that are mathemathantic) is just as important as knowing what works (i.e. approaches that are mathemagenic). That's why we conclude this chapter with an overview of the most common mathemathantic effects – that is where instruction fails or is counterproductive.

Takeaways

- What works for one learner doesn't work for the other, or even worse it can be counterproductive and hurt learning.
- Beginners benefit from a great deal of structure and guidance, while more experienced learners benefit from more space and independence.
- You know best what your students need – they often over- or underestimate themselves; catering to their preferences – often seen as learning styles – is not the way to go because they usually do not know what's best for them.
- There are ways to avoid the expertise reversal effect such as gradually reducing support (so-called fading of scaffolding) as learners progress.
- When designing your instruction, make sure what you do adheres to the medical-ethical maxim "to do no harm".[5] This means that it's sometimes better not to do something, or even to do nothing, than to do more harm than good.

5 THIS PHRASE IS OFTEN ATTRIBUTED TO THE HIPPOCRATIC OATH, BUT IT ACTUALLY DOESN'T APPEAR IN THE OATH ITSELF.

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THE DUNNING–KRUGER EFFECT: A POISONOUS PARADOX.

AVAILABLE FROM HTTPS://3STARLEARNINGEXPERIENCES.WORDPRESS.COM/2016/09/06/DE-DUNNING-KRUGER-EFFECT-A-POISONOUS-PARADOX/#:~:TEXT=THE%20DUNNING%2DKRUGER%20EFFECT%20MEANS,CONCLUSIONS%20ARE%20JUST%20PLAIN%20WRONG

Psychologists Justin Kruger and David Dunning published an article in 1999: *Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments*. The Dunning–Kruger effect means that incompetent people (in this case, people with little to no knowledge on the topic at hand) are not capable – because of their incompetency – to see that their reasoning, choices, and/or conclusions are just plain wrong.

LEARNING ORIENTATION RESEARCH: INDIVIDUAL DIFFERENCES IN LEARNING.

LEE CRONBACH'S AND RICHARD SNOW'S IMPORTANT LESSONS FROM THE PAST: HISTORICAL PERSPECTIVE.

AVAILABLE FROM WWW.TRAININGPLACE.COM/SOURCE/RESEARCH/CRONBACH.HTM.

A SHORT VIDEO ILLUSTRATING THE COBRA EFFECT.

AVAILABLE FROM HTTPS://YOUTU.BE/KRK_DL4ENQU?SI=
5HHVM_RWXENR8CHB

33 THE MEDIUM IS NOT THE MESSAGE

MEDIUM NOT THE MESSAGE

DOI: 10.4324/9781003395713-40

33 THE MEDIUM IS NOT THE MESSAGE

PAPER "Reconsidering research on learning from media"[1]

QUOTE *"The best current evidence is that media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition".*[2]

Why you should read this article

Every new medium that has been "invented" seems to also have been touted as being a revolutionary educational change-maker. Each invention, followed by its general availability, has seen this hype, be it the phonograph, radio, film strip, movies, television, computer, or internet. Thomas Alva Edison (1878, 1888) claimed, for example, that the phonograph would allow for preserving the explanations given by teachers so that pupils would be able to refer to them at any moment. He also said that lessons could be placed on the phonograph for convenience in committing them to memory and would also become the primary teacher for children. In 1913 he stated "Books will soon be obsolete in the public schools. Scholars will be instructed through the eye. Our school system will be completely changed inside of ten years" (cited in Smith, 1913, p. 24). And in 1922 he said:

> I believe that the motion picture is destined to revolutionize our educational system and that in a few years it will supplant largely, if not entirely, the use of textbooks. I should say that on average we get about two percent efficiency out of school books as they are written today. The education of the future, as I see it, will be conducted

1 CLARK, R. E. (1983). RECONSIDERING RESEARCH ON LEARNING FROM MEDIA. *REVIEW OF EDUCATIONAL RESEARCH*, *53*, 445–459.
2 IBID., P. 445.

> through the medium of the motion picture … where it should be possible to obtain one hundred percent efficiency.
>
> (quoted in Wise, 1939, p. 1)

EDISON Phonograph and movies will revolutionise education

With the introduction of each new medium, people in and around education (e.g. parents, teachers, researchers, administrators, politicians, and of course commercial companies) expected that each would revolutionise education, lead to amazing improvements in learning performance, and unalterably change the world of the teacher. But is any one medium really better than any other medium? And is that even the right question to ask? Richard Clark (1983) answered this question in a ground-breaking article and it still stands: it's not the medium that determines if teaching/learning is effective or efficient but, rather, the method.

How you teach is more important than the medium used

Abstract of the article

Recent meta-analyses and other studies of media's influence on learning are reviewed. Consistent evidence is found for the generalization that there are no learning benefits to be gained from employing any specific medium to deliver instruction. Research showing performance or time-saving gains from one or another medium are shown to be vulnerable to compelling rival hypotheses concerning the uncontrolled effects of instructional method and novelty. Problems with current media attribute and symbol system theories are described and suggestions made for more promising research directions.

The articles

This chapter is actually about two articles. The first is "Reconsidering research on learning from media" in which Clark looks back on earlier research into the effect of different types of media (i.e. "mechanical instruments, such as television and computers" (p. 445) used as delivery devices for instruction) on learning. In the article's introduction, he presents the spoiler when he says that:

> most current summaries and meta-analyses of media comparison studies clearly suggest that media do not influence learning under any conditions. Even in the few cases where dramatic changes in achievement or ability have followed the introduction of a medium … it was not the medium that caused the change but rather a curricular reform that accompanied the change.
>
> (p. 445)

Technology is not a form of pedagogy

AS OLD AS …

In 1924, Révész and Hazewinkel working at the Psychological and Paedagogical [*sic*] Laboratory in Amsterdam, published "The didactic value of lantern slides and films" in the *British Journal of Psychology*.[1] In that article, they studied the value of films versus slides for educational purposes. They wrote,

> No reasonable objection can be raised against the cinematograph as a means of spreading knowledge, or as an auxiliary in scientific research and instruction. About its usefulness in these fields all are agreed, but there is no consensus of opinion, when the merits of the film are weighed against those of the camera, and when the question is put whether the film is in every way to be preferred to the lantern-slide and can entirely replace it. This question can not [*sic*] be answered off-hand, but only after a thorough experimental investigation.
>
> (p. 184)

They conclude, "Our investigations have shown that the energetic propaganda made for the film on the strength of its alleged didactic importance is not well-founded. On the other hand, its educational importance has not been disproved" (p. 197).

1 THIS WAS A SHORTENED VERSION OF THEIR ORIGINAL 1923 ARTICLE, PUBLISHED IN DUTCH IN *PAEDIGOGISCHE STUDIËN*.

What did Clark actually do? His article is an overview study (today we might call it a meta-analysis) in which he took a close look at research – both empirical studies and previous review studies – on media use in the classroom and their effects on learning. Most studies sought to answer the question of what the best medium was for offering learning material. Clark called such research *media comparison studies*: researchers compared one group that was taught with the new medium to another group that was offered the same material in a "regular" way. In general, these studies found no differences and he concluded that offering lessons via different types of media has no influence on learning. In that article he also noted that comparative studies suffered from three problems.

META-ANALYSIS
Analysis of many studies in a particular area

The research was contaminated

Clark noted that in the studies that did show a positive effect of the new medium there were more differences between the two groups than just the medium used. The method of teaching also differed. We all know, or at least should know, that to draw valid conclusions from a piece of research it's imperative that all aspects of the intervention and the control groups are exactly the same except for the one being studied. This means that if one were to compare the effects of television to the effects of a live lecture, then everything in the two conditions must be the same except for the media involved (live versus televised lecture). If the television lecture also includes illustrations of a concept using moving pictures or animations while the teacher in the classroom only uses a chalkboard and/or static images (i.e. the method used to teach the concept), then it's not possible to determine if any difference found is due to the medium or the method. In this example, the teacher should also have used animations or moving images to illustrate the concept in class or the TV lecture should have shown her/him in front of the chalkboard or using the static images. Clark noted that the differences in effects between the experimental and the control groups become smaller as researchers put more effort into keeping the groups as equal as possible. His conclusion: *There's no specific effect of any medium on learning, but that the (small) effects found can easily be explained differently.*

Education research is messy

New is interesting and sexy

The second problem with research on the effect of media on learning is the *novelty effect*; the increased effort and attention that participants in such studies tend to give to media that are novel to them. After all, it's often about new (and sexy) media, and introducing new things in the classroom often ensures enthusiastic students, which can cause them to work harder. While this novelty of the medium leads to a learning effect, it's short-lived. As soon as the medium becomes "normal", the effect decreases and dies away. When the iPad was first used in education, students became very enthusiastic about it; now the novelty is gone. Clark also found evidence for the novelty effect in the overview studies; the longer the interventions lasted, the smaller the effects became.

NOVELTY EFFECT
When participants in a study respond 'differently' to something new

Publication bias

The third problem is that studies with significant effects are more likely to be published than studies with no difference between experimental and control groups. That is what's known as *publication bias*. Clark explains that scientific journals want the most notable studies which makes the scientific evidence for media effects appear larger than it actually is. Research showing no differences or even the reverse are often shunned by journals.

PUBLICATION BIAS
Tendency to only publish positive results

Conclusion

Clark comes to this conclusion: it may seem that (new) media have positive effects on student learning, but these effects can largely be explained by things other than the characteristics of that medium. He cites Glaser and Cooley (1973) who recommended using any acceptable medium as "a vehicle for making available to schools what psychologists have learned about learning" (p. 855). And that is the crux of the matter. It's the instruction (i.e. the method) and not the carrier of that instruction (i.e. the medium) that leads to a learning effect. According to Clark, researchers can therefore focus better on effective instruction.

The second publication is a chapter by Richard Clark and Dave Feldon in the second revised edition of the *Cambridge handbook of multimedia learning* (2014). There, they raise questions with respect to ten commonly espoused reasons that people give for implementing multimedia in education. They discussed five reasons in a chapter in the first edition of the book (2005) on the basis of strong empirical research. In the second edition they did the same for five new positively perceived learning benefits of multimedia (in addition to the original five that were in the first edition of the book). The first five were that people felt that multimedia instruction should be used because it:

1. *Leads to more learning*. Clark and Feldon show that there's no convincing or plausible proof that one medium or a combination of various media, including multimedia, lead to better learning. If there is proof of better learning then this can be explained by "non-media" factors such as instructional theory (e.g. the method/pedagogy), intelligence, social economic status, ability level of the learner, teacher quality, etc.
2. *Is more motivating*. It's possible that multimedia instruction seems more attractive for learners and that they'll prefer this type of learning approach if available, however this interest doesn't equal motivation for learning nor does it lead to better achievement.

Motivation doesn't lead to achievement

3. *Uses pedagogical agents that support learning*. The idea is that agents make learning more personal, though what they actually do is provide just-in-time scaffolding (e.g. hints, procedures, feedback, instruction). Designing, developing, and implementing such agents requires more time and is more expensive. They're often also, according to the authors, quite silly and learners get bored with them fairly quickly (remember "Clippy", Microsoft's paperclip agent?).
4. *Adapts to various learning styles and thus optimises learning for more learners*. First, learning styles don't exist (Kirschner, 2017). Clark and Feldon explain that multimedia make it possible to map the differences between learners with regard to *what* they learn and perhaps also to offer various versions of instructional material. However, there's no

such thing as interaction between multimedia and non-existing learning styles, except for mathemathantic interactions (activities that kill learning – see Chapter 32, When teaching kills learning).

5. *Facilitates learner-directed, constructivistic, and discovery learning approaches*. The question shouldn't be if multimedia learning facilitates these types of learning, it should be if constructivistic and discovery learning facilitate learning in the first place (see Chapter 22, Why discovery learning is a bad way to discover things). Interestingly, PISA 2015 (OECD, 2016) makes clear that on the one hand teacher-directed instruction has a strong positive effect on achievement while on the other hand enquiry learning has a medium to strong negative effect on achievement.

What methods of instruction are effective in the first place?

Clark and Feldon show that guided instruction is more effective and that the only types of learners who are good at discovery or inquiry-based learning are experts (also see the next principle).

The next (new) five focus on the *expectation* that multimedia instruction is *good for learning* because it provides:

1. *Autonomy and control over the sequence of instruction*. Although many multimedia environments allow for this, there are two challenges associated with learner control. First, learners typically don't have the required cognitive or metacognitive knowledge to effectively and efficiently determine their own learning sequence (see Chapter 31, Did you hear the one about the kinaesthetic learner ...?). When allowed this type of control, they usually achieve less. Second, experts would be really good at controlling their own learning sequence but experts usually don't require instruction.

AUTONOMY
Most learners aren't equipped to direct their own learning

2. *Higher order thinking skills*. There's limited evidence that multimedia instruction supports these skills, but even if it does, we encounter the same challenges as with the previous principle. It's more likely that the instructional approach is supporting the increase in higher order thinking skills and not the multimedia.
3. *Incidental learning of enriching information*. Incidental learning takes place when you learn more than planned for in the instruction. Multimedia research shows that if you emphasise something in instruction, this will be learned (i.e. intentional learning) and all remaining points (i.e. incidental learning) are at a disadvantage. This goes for all types of instruction and not just for multimedia instruction. Think here of learning prompts, adjunct questions, stated learning goals, etc.).

INCIDENTAL LEARNING
Not all learning is useful

4. *Interactivity*. This refers to, for example, accessing content through hyperlinks. This, unfortunately, doesn't actually add to learning but rather distracts from it. Gavriel Solomon called this the butterfly defect (learners fluttering like a butterfly from one piece of seemingly interesting information to another without actually learning). Linda Stone

BUTTERFLY DEFECT
Flittering from hyperlink to hyperlink

(2014) referred to this as *continuous partial attention* where a person pays simultaneous attention to a number of different sources of incoming information, but at a superficial level. Furthermore, proponents of multimedia instruction seem to forget that the instructor is actually the most interactive medium and an intelligent one as well.

5. *Authentic learning environments and activities*. The idea here is that the advantage of multimedia lies in increasing motivation (see principle 2) and/or facilitating transfer. However, according to Clark and Feldon, there's hardly any evidence that this is actually the case.

Just to make it clear: Clark and Feldon are not against using multimedia in education! They're only saying that (1) multimedia aren't a panacea, (2) multimedia itself achieve nothing, (3) using multimedia wrongly does more harm than good (i.e. is mathemathantic; see Chapter 32, When teaching kills learning), and (4) the instructional method used is the most critical factor for learning. And this last one is and remains the learning professional's – the teacher's – expertise!

Conclusions/implications of the work for educational practice

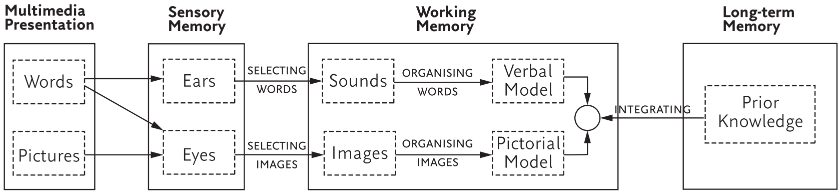
As stated, Clark doesn't say that media can't contribute to learning. Remember, it's not the vehicle, but the instructional method used that influences achievement. In other words, it doesn't matter whether the vegetables that you eat come to the store via plane, train, or truck, you become healthier because of the vegetables you eat (and the way you prepare them) and not because of the means of transporting them. That's why, according to Clark, we shouldn't carry out simple media comparison studies, but rather view media as tools that we can use properly and improperly. We also need to see how the tools can be improved.

This perspective has led to fruitful research into general principles for designing, developing, and implementing multimedia learning material. Richard Mayer is an important name here. His cognitive theory of multimedia learning – based on a combination of information processing theory, cognitive load theory, and dual coding theory (see Chapter 7, Take a load off me, and Chapter 10, One picture and one thousand words) – is a useful guide for using multimedia in class (see Figure 33.1).

Cognitive theory *of* multimedia learning

Mayer formulated 12 design principles based on these three constituent theories (an overview can be found via the link at the end of this chapter). The most famous is probably the *multimedia principle*, which states that people learn better from words and pictures than from words alone (again, see Chapter 10, One picture and one thousand words). Many teachers and makers of instructional materials try to do this, but according to a second principle – the *redundancy principle* – using

FIGURE 33.1 COGNITIVE THEORY OF MULTIMEDIA LEARNING (MAYER, 2021)



MULTIMEDIA PRINCIPLE
See dual coding theory
COHERENCE PRINCIPLE
Keep it simple

visual material plus audio is better than the use of visual material plus audio with written text (think about the teacher that reads her/his PowerPoint® slides to the class); care is needed. The latter is too much of a good thing and can lead to cognitive overload and poorer learning. A third important principle is the *coherence principle*, namely that people learn better when extraneous words, pictures, and sounds are excluded rather than included. These extraneous, often eye-catching or sexy, artefacts distract learners. With Mayer's design principles in hand, we can effectively choose or design multimedia teaching materials.

How to use the work in your teaching

The first rule here is to choose media carefully. The media that you choose should make your teaching more efficient, more effective, and more enjoyable, both for you and your students. To do this, you need to know the characteristics of the different media and what the best educational uses of them are.

What media can and cannot do

Thanks to Clark and Feldon, we know the ten things that media doesn't do. For example, media doesn't motivate, doesn't increase learning, doesn't facilitate construction of new knowledge, and so forth. Thanks to Mayer we know that you shouldn't include seductive or superficial elements that merely "engage" students as they are often counterproductive and can distract students. Also you need to take care that you don't overload students when using (multi)media and thus that you should use the media's possibilities to help them focus their attention on what's important. From this chapter, but also from Chapters 7 and 10, you now know that if you want to explain something with written text and images, you must make sure you integrate them properly. Either present a figure showing the steps in a process with their description in the figure (i.e. create spatial contiguity) or verbally describe the steps without the accompanying written text (i.e. avoid redundancy).

Takeaways

- No one medium is better than any other medium.
- It's not the medium, but the instructional method that makes the difference.

- Don't fall prey to the hypes around using media in the classroom.
- For meaningful use of (multi)media in your teaching you need knowledge of characteristics of the media and their educational uses.
- More media is not always better.
- If you use PowerPoint® or another presentation programme, make sure that what you say and what you project complement each other; *do not* read your slides.
- Just because students are "engaged", it doesn't mean they are learning anything. The call for new forms of media in education goes back over 150 years despite a distinct lack of evidence to back its use.
- The content and learning goals should determine the choice of media, not the other way around. Technology for the sake of technology is bad practice.

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34 THE TEN DEADLY SINS IN EDUCATION

TEN DEADLY SINS

DOI: 10.4324/9781003395713-41

34 THE TEN DEADLY SINS IN EDUCATION

QUOTE *"This isn't right. This isn't even wrong".*[1]

This book is about a particular tradition, a tradition which focuses on how to cultivate the best conditions which foster learning. By "learning" we mean a change in long-term memory (Kirschner, Sweller, & Clarke, 2006). Any attempt to do this which ignores the cognitive architecture of the brain is unlikely to be successful and may even hinder long-term learning. For many teachers on the frontline, the advice they have been given has been based on folk wisdom, vague abstract theory, and approaches that conform to Wolfgang Pauli's famous quip: "This isn't right. This isn't even wrong". One aim of this book is to empower teachers to be able to not only evaluate what they are advised to do but to provide a strong evidence base from which they can refine and reflect on their own practice and create the best conditions under which their students can flourish.

The Christian teaching, attributed to the Desert Fathers, speaks of seven cardinal or deadly sins that we need to overcome to live a virtuous life: pride, greed, lust, envy, gluttony, wrath, and sloth. In this chapter we very briefly describe what we feel are the ten deadly sins of education. Giving in to those sins is often tempting, but if you do you'll be guilty of implementing evidence-*un*informed education and flying in the face of evidence.

1. The learning pyramid

The learning pyramid (see Figure 34.1) is a seemingly useful model that reflects the effectiveness of different forms of teaching. According to the pyramid, pupils only remember 5% of a classroom lesson (what the teacher says), 10% of what they read, 20% of an audio-visual

1 WOLFGANG PAULI WAS AN AUSTRIAN BORN PHYSICIST. HE IS REPORTED TO HAVE SAID THIS AFTER READING A COLLEAGUE'S PAPER. IT IS QUOTED IN *THE SUCCESSFUL TOASTMASTER: A TREASURE CHEST OF INTRODUCTIONS, EPIGRAMS, HUMOR, AND QUOTATIONS* (1966, P. 350) BY PROCHNOW AND IN *MATHEMATICAL APOCRYPHA REDUX: MORE STORIES AND ANECDOTES OF MATHEMATICIANS AND THE MATHEMATICAL* (2005, P. 194) BY KRANTZ.

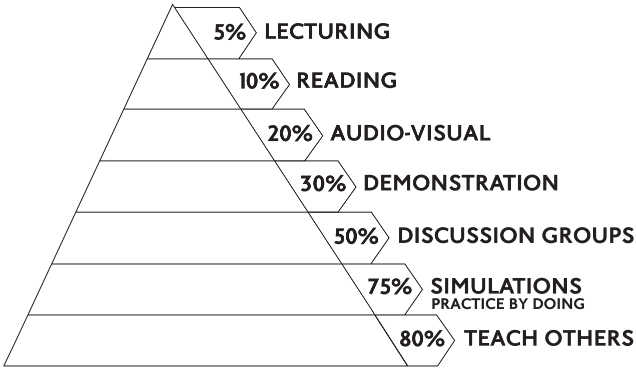

FIGURE 34.1
THE LEARNING PYRAMID

presentation, 30% of a demonstration, 50% of a discussion, 75% of what they do themselves, and 80–90% of what they explain to others. The percentages vary in different sources, but that's not important. What is important is that it's nonsense that you shouldn't fall for.

First, there is no basis for such percentages. Even the institution that everyone quotes (National Training Laboratories in Bethel, Maine, USA) says they don't have data to support them. Furthermore, the pyramid is simply a corruption of Edgar Dale's cone of experience (1954), in which he indicated how different media differ along a continuum from abstract (language, letters) to concrete (direct experience). Finally, even if the percentages were correct, you can't do anything with it. A teacher standing in front of the class and teaching about electricity (5%) can write the main points and principles on the whiteboard or show them in a PowerPoint® presentation (+10%), show a video clip about circuits (+20%), give a small demonstration of a battery or lamps in series and in parallel (+30%) and then discuss the results of the demonstration with the students (+50%), etc. No lesson is purely one or the other and just adding these percentages up teaches us that you could learn more than 100%!

2. Learning styles

People are all different and just as they may prefer different foods, they also may prefer different ways of learning. One prefers pictures while the other prefers words. While it sounds and even feels logical that there are children who are visual learners (learn best when information is presented as pictures, diagrams, and charts), while others are auditory (learn best in a lecture or group discussion) readers/writers (learn best through reading and writing) or kinesthetic (hands-on learners who learn best through physical experience), there's no evidence whatsoever for this. And this is just one of the 72 different learning styles (the so-called VARK) that Coffield, Moseley, Hall, and Ecclestone (2004) found when they went through the literature.

Unfortunately, all that glitters is not gold. This way of looking at how children learn, and therefore how the teacher should teach, has at least three problems, as we have already described in Chapter 31, Did you hear the one about the kinaesthetic learner ...?. First, in most studies learning styles are determined based on what people say they prefer. It's therefore about learning *preferences* and not learning *styles*. Second, there's a big difference between these and what leads to better learning. I think we all can agree that if we ask people what they prefer to eat, many if not most will say fatty things and/or salty things and/or sugary things. I think that we can also all agree that these preferences are not the constituents of a healthy diet. That you prefer it doesn't make it good for you, both in food and learning. Finally, most so-called learning styles are based on specific types: people are classified into different groups. However, there's no evidence for the existence of these groups. And this discounts the fact that even if they all did exist, if the 72 types of learning styles were simply dichotomous (e.g. concrete versus abstract thinkers), which they aren't as we saw with VARK, there would be 2^{72} different combinations of learning styles, or 4,722,366,482,869,669,245,213,696 different combinations – more than the number of people who have ever lived on earth – so good luck tailoring your teaching to them!

But possibly the most important problem is that if we put learners in different boxes and teach accordingly (i.e. pigeonhole them), we create situations that instead of promoting learning, hinder it (see Chapter 32, When teaching kills learning).

3. Children are digital natives and think differently from previous generations

We have to radically change education! We're teaching a new type of learner with specific competencies that enable them to use ICT effectively and efficiently. This new learner is the *digital native*. Marc Prensky introduced this term in 2001: the idea of a generation that has never lived without digital technologies and therefore has exceptional and unique characteristics that distinguish it from all previous generations with respect to thinking and learning (Prensky, 2001). He concluded that we must design and introduce new forms of education that focus on the special gifts of these digital natives. Unfortunately, he based all of this on simple personal observations of young people and not on any research.

Wim Veen and Ben Vrakking (2006) followed suit, introducing the term *homo zappiëns* to describe a new generation of students who learned significantly differently from their predecessors. They claim that *homos zappiëns* independently and without instruction develop the metacognitive skills needed for discovery learning, networked learning, experimentation, collaborative learning, active learning, self-directed learning, and problem-based learning. Based on these claims (again acquired through personal observation and not research) a growing group of people, including politicians and administrators, believe that education should respond to this. We hear things like "Let's Googlify education", "Knowledge acquisition isn't necessary", and "We need to harness the cognitive and metacognitive skills of this technology-savvy generation!"

Don't! There's no evidence that young people today have any special skills (other than very fast-moving thumbs) that would allow them to learn differently. The proponents of these ideas based this purely on their own experiences and anecdotal evidence.

4. Children can multitask

One of the competencies that people attribute to the non-existent digital native is that of multitasking. There's much confusion about this concept. Multitasking is the ability to simultaneously perform two or more tasks that require thinking (or information processing) without a loss of speed or accuracy. To really multitask you need two or more separate processing units (think of a multicore computer with two, four, eight, or even more Central Processing Units [CPUs]). The problem is that people only have one CPU, namely their brains. When it comes to automated tasks that don't require thinking, we can easily do two or more things at the same time.

What we actually do is switch between tasks (i.e. task switching). But when we switch between tasks, we lose time and we make mistakes. If we switch tasks, we (unconsciously) make a "decision" to shift our attention from one task to another. Our brain then activates a rule to end the processing of one task whereby you leave the cognitive schema that you were using, and initiates another rule to enable the processing of the other task with its concomitant schema. Switching between tasks takes time and distributing attention between these two tasks requires space in our working memory. The two tasks therefore interfere with each other. In short, we simply can't multitask. If we try to do two or more things at the same time that require thought, we do things worse and it takes more time in total than if we had done them one after the other (i.e. serially monotask).

5. With Google, knowledge is no longer important

We hear that just about all the "knowledge" we need can be found on the internet via Google or other search engines and, thus, we no longer need to know as much as we used to, as long as we can look it up. But there are problems here. First, there's no knowledge on the internet; only information, of which a great deal is non-information or outright nonsense from questionable sources. Without a solid knowledge base we can do little with what we find on the internet. In an interview with a Dutch quality newspaper, two women who run a nutrition website propagating a healthy lifestyle stated in 2016 that eggs are the menstruation of chickens and are, therefore, bad for you. The two are registered dietitians and therefore you might conclude that this is true.[2] But mammals menstruate and chickens aren't mammals! In other words, nonsense. But how could you know that without basic knowledge of biology?

So what we read, see, and understand is determined by what we already know and not the other way around (see Chapter 11, What you know determines what you learn). Our prior knowledge and experiences determine how we see, understand, and interpret the world around us. It also determines how well we can look up, find, select, and process (or evaluate) the information available on the internet. Unfortunately, in the best case, students only have minimal prior knowledge of a subject (after all, they are students; if they already had the knowledge, they would be experts).

Related to this is the myth that knowledge has a limited expiration date (as perishable as fresh fish is sometimes said). This is nonsense too. The vast majority of what we have learned is still correct. There is a huge increase in information. But as said, without knowledge we can do little with it.

6. You learn to solve problems by solving problems

Problem-based learning is quite popular. One of its premises is that the best way to learn to solve problems is to solve them. Unfortunately this isn't the case (see Chapter 7, Take a load off me). To solve problems, we must first have knowledge of and skills in the domain in which we must solve that problem. We can't solve a chess problem without being able to play chess (knowing how the pieces move, what the rules are, what the common strategies and tactics are, etc.), just as we cannot solve a maths problem without maths knowledge. In other words, skills are domain specific.

Also, it helps enormously if we have a set of possible solution strategies plus knowledge of when we can best use each one. This is called procedural knowledge (knowing what the steps are) and is very similar to the so-called twenty-first century computational thinking skill,

2 THE DUTCH NUTRITION CENTRE WARNS THAT FOLLOWING THE ADVICE OF THESE TWO WOMEN CAN LEAD TO A WEAKENED IMMUNE SYSTEM, BONE LOSS, AND WEAKENED MUSCLES.

which means that you can analyse a problem in smaller steps so that you can solve it. But again, without knowledge you can't carry out the procedure and so you cannot acquire this domain-general twenty-first century skill.

Finally, without domain-specific and procedural knowledge, problem-solving becomes an exercise in trial and error. This is neither effective nor efficient, especially since we're constantly hitting walls because we're doing it wrong (which can be quite frustrating). And then, should we happen to solve the problem, we usually don't know why we've succeeded and it's therefore difficult to repeat and apply in other situations. And finally there's a good chance that we'll teach ourselves a wrong approach that we'll have to unlearn in the future.

7. Discovery learning is the best way to learn

Jerome Bruner introduced discovery learning as a research-based instructional form in 1967 (Bruner, 1967). He assumed that it would be better for students to discover facts and the connections between them than to provide them as a teacher. But if we use such an approach with starting students, we do not take into account the limitations of their working memory (see Chapter 6, A novice is not a little expert). During discovery learning, we must always look for links between things and the principles that apply in the domain. Beginners, however, hardly have any domain knowledge and also have no systematic approach to finding it. This therefore requires a great deal of their working memory, all the more because inexperienced students are capable of connecting any and all elements in the domain through ignorance. They're faced with an explosion of combinations without knowledge to keep them under control. Moreover, this load on working memory doesn't result in more knowledge in long-term memory as it was used to discover and not to learn.

In addition, this approach is based on the idea that a child is a kind of miniature scientist. But children not only have less knowledge than a scientist (who can use discovery as a way to move forward; it's their epistemology), they also see and interpret the world differently (much more naively), think differently (concretely and not abstract), and therefore experience the world differently. That is why we shouldn't use the working method of the scientist as an educational approach for the inexperienced student!

8. Motivation leads to learning

A frequently heard statement from parents, teachers, politicians, and even scientists is that the problem with contemporary education is that pupils find it boring and unattractive and therefore don't learn well.

People often use concepts such as motivation and engagement as keys to better education and as proxies for learning; as if being hyped about or engaged with something means that you've also learned something. The idea is that the more we motivate learners, the better they'll learn. Unfortunately this isn't the case. Don't get us wrong. Of course motivation is great and motivated students will start on something sooner than if they aren't motivated, but this is no guarantee for learning. In fact, if a student starts out motivated but doesn't succeed, that motivation fades away very quickly and we're worse off than if the learner was only lukewarm to begin with.

What we know from research is this: there's neither a causal relationship (motivation does not lead to better learning and performance) nor a reciprocal relationship (in the sense that motivation leads to learning and learning leads to motivation) between motivation and learning. It's learning that leads to motivation. When we experience success, no matter how small that success is, it feeds our motivation to continue (as we saw in Chapter 13, Beliefs about intelligence can affect intelligence). For example, good maths performance has a significant positive effect on the intrinsic motivation of students for maths, but motivation for maths doesn't lead to better maths performance (Garon-Carrier et al., 2016; McConney et al., 2014). And that applies to both boys and girls.

9. Non-existent grit

It's weird. On the one hand, we hear that learning is boring and hard and should be fun, but on the other hand, everyone is talking about grit. Grit is putting your shoulders to the wheel and noses to the grindstone. According to the creator of the term, Angela Lee Duckworth, grit is the passion and perseverance to achieve long-term goals combined with interest, practice, purpose, and hope. For her, grit is being so driven to reach your goal that you never ever give up – even in the face of adversity – and do everything you can to achieve it. In short, perseverance, dedication, efficacy, and resilience.

Marcus Credé and his colleagues (2016) have shown that grit is just old wine in new bottles and is actually nothing more than perseverance. In addition, they looked at, among other things, the relationship between grit and both learning performance and remembering what was learned, and that was also disappointing. Researchers found poor correlations between grit and learning performance and grit and remembering, while there are strong correlations between, for example, learning and cognitive ability (IQ), study habits, and skills. Even perseverance alone, without all the extra trimmings from Duckworth, was more strongly correlated with learning than grit!

10. School kills creativity

Ever heard of a straw man? According to Wikipedia, a straw man is a type of fallacy – reasoning that is wrong, but seems plausible – whereby the actual position of an opponent isn't refuted, but a caricature thereof. The man who claimed that schools kill creativity – Sir Ken Robinson – was guilty of this. He presented the school as a place where teachers do nothing but preach from the pulpit and where students do nothing but listen obediently and do their homework. We don't know of any such teachers or schools, do you?

Strange here is that Sir Ken defines creativity as "the process of having/coming up with original ideas that have value – usually the result of the interaction of different disciplinary ways of seeing things".[3] In other words, it is based on domain-specific knowledge! Without knowledge and skills which we acquire at school it's impossible – except in the case of luck – to come up with something of value. The most creative painters, even surrealists, first learned how to paint. Therefore, we suggest that you quote Keith Sawyer rather than Ken Robinson. Sawyer (2012) says that "creativity is largely domain specific – that the ability to be creative in any given domain, whether physics, painting, or musical performance, is based on long years of study and mastery of a domain-specific set of cognitive structures" (pp. 11–12).

This idea that everything has to be "relevant" to children is a debased view of the profession. The notion that children can only learn things through the prism of their own interests and that to ask them to consider things outside of that is somehow beating a love of learning out of them is demeaning, not just to teachers but to students themselves. Possibly the greatest thing a teacher can do is to introduce students to wondrous worlds beyond the limited borders of their own experience, to allow them to see the previously unseen, and to make new and enriching connections that were hitherto unavailable to them.

Takeaway

- If you want to teach well, avoid these ten deadly sins!

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Further reading and links

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BLOG MOTIVATION: CLOSE THE STABLE DOORS: EFFECTS OF MOTIVATION AND ENGAGEMENT ON LEARNER ACHIEVEMENT?

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SOME EXCELLENT PIECES ON WHY SIR KEN ROBINSON'S ARGUMENTS ARE PROBLEMATIC ARE

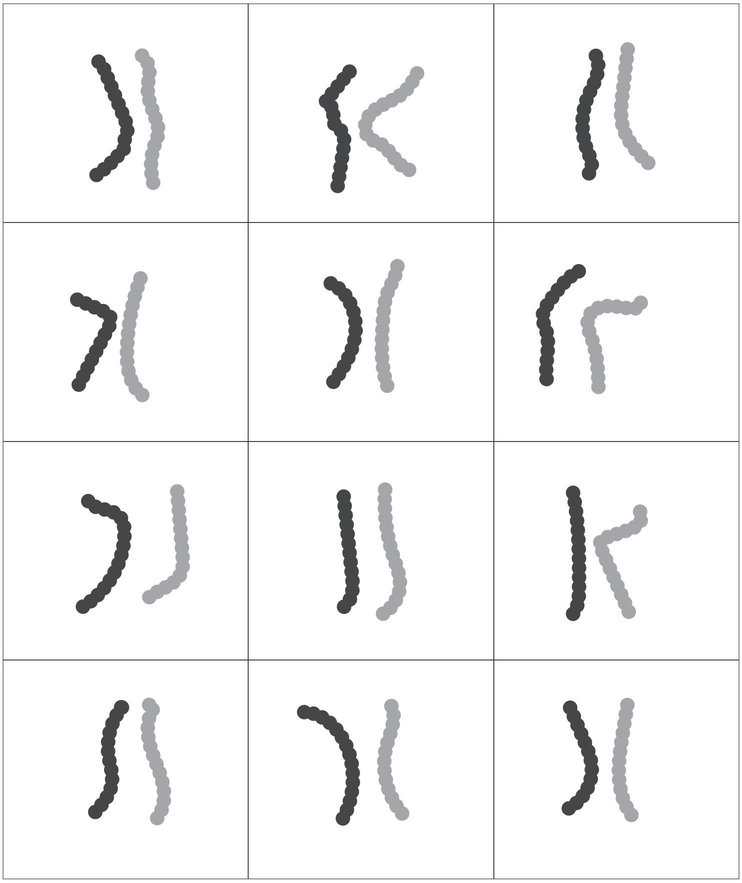
AVAILABLE FROM CRISPIN WESTON: HTTPS://EDTECHNOW.NET/GUEST-POSTS/KEN-ROBINSON-REBUTTAL.

JOE KIRBY: HTTPS://PRAGMATICREFORM.WORDPRESS.COM/2013/10/12/WHAT-SIR-KEN-GOT-WRONG.

CARL HENDRICK: WWW.TES.COM/NEWS/KEN-ROBINSON-TEACHER-BASHER-SCHOOLS-MUST-STOP-LISTENING-HIS-PANGLOSSIAN-IDEAS.

35 LETHAL MUTATIONS

THE DIRTY DOZEN



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35 LETHAL MUTATIONS

QUOTE *"I think it's important that cognitive science is understood more broadly than just a checklist of strategies to implement. This helps to reduce the chance of so-called lethal mutations."*[1]

When a Good Idea Goes Bad

Biologically and evolutionarily speaking, a mutation is a change that occurs in an organism's DNA structure or sequencing (i.e. in their genes) which leads to changes in that organism. This change can be beneficial, neutral, or even harmful to the organism. When the mutation is beneficial, the organism thrives. Think of the peppered moth which blends in with tree bark so that predators can't see it. But a mutation can also be extremely harmful (i.e. lethal) such that it's so detrimental to an organism's survival that it results in the death of the organism, often before that organism can reproduce and pass its genes on to the next generation.[2] Cystic fibrosis, sickle cell anaemia, and achondroplasia are examples of human illnesses caused by recessive lethal genes.

Genetically, lethal mutations can be *embryonic* or *conditional*. Embryonic lethality, as the term suggests, occurs in the embryo and causes the embryo to die off. Conditionally lethal mutations are lethal mutations where the correct or incorrect function of the gene depends on environmental variables such as temperature or diet. Favism, for example, is a sex-linked genetic condition that causes a form of anaemia upon eating fava beans.

In the context of education, the term lethal mutation is used metaphorically to refer to misinterpretations or misapplications of

1 PERRY, T., LEA, R., JØRGENSEN, C. R., CORDINGLEY, P., SHAPIRO, K., & YOUDELL, D. (2021). *COGNITIVE SCIENCE IN THE CLASSROOM: EVIDENCE AND PRACTICE REVIEW.* EDUCATION ENDOWMENT FOUNDATION (EEF). THE REPORT IS AVAILABLE FROM: HTTPS://D2TIC4WVO1IUSB.CLOUDFRONT.NET/DOCUMENTS/GUIDANCE/COGNITIVE_SCIENCE_IN_THE_CLASSROOM_-_EVIDENCE_AND_PRACTICE_REVIEW.PDF?V=1681841871

2 TO CHARLES DARWIN, FITNESS WAS THE QUANTITATIVE REPRESENTATION OF INDIVIDUAL REPRODUCTIVE SUCCESS OF AN ORGANISM.

educational theories, practices, or policies that can negatively impact students' learning, motivation, and overall well-being. These changes could be related to the curriculum, teaching methods, assessment practices, or other factors that affect the educational experience of students. In other words, they're conditional mutations.

The term lethal mutations as it pertains to education and teaching was coined by Edward Haertel, an expert in the area of educational testing and assessment at Stanford University, and was first used in a chapter by Ann Brown and Joseph Campione (1996). According to the Educational Endowment Foundation in TES (n.d.), "a lethal mutation occurs when evidence-informed practice is modified beyond recognition from the original practice. This can happen when teachers adapt evidence-informed practices and techniques to fit within their own contexts, leading them to unwittingly develop counterproductive strategies".

What follows is our *Dirty Dozen* of possible and actual lethal mutations in education and teaching. Of course there are many more but we had to make choices.

Rosenshine's principles aren't a checklist

1. Barak Rosenshine's Ten Principles of Instruction can become a checklist of "must dos"

Barak Rosenshine combined what was known from 40 years of research in *cognitive science* about how we acquire, make sense of, and use information about *teacher behaviours* related to observed student learning gains (i.e. teacher effectiveness studies), and *intervention studies* about what can be changed in the instruction and how they affect learning outcomes (see Chapter 12 in *HTH*). In an original study for UNESCO (2010), Rosenshine distilled 17 research-based principles of instruction but most well-known are his Ten Principles of Instruction published in the *American Educator* (2012).

Unfortunately, Rosenshine's principles can devolve/lethally mutate into a checklist teachers, teacher trainers, and even inspectorates think must be used in order to teach well. A lesson that doesn't begin with a short review of previous learning, provide models for problem-solving and worked examples and so forth, and end with a review of what was learnt yesterday, last week, last month isn't a good lesson. As Mark Enser writes:

> Rosenshine…was like a gateway drug luring [teachers] into the exciting and heady world of research and pedagogical discussions …[but] for some it risks becoming either a stick to beat them with, a performance to put on or a checklist of a rigid idea of teaching.
>
> (Enser, 2019)

2. Desirable difficulties can become making it difficult/letting them fail

We've all heard the saying "No pain, no gain"; to get better (e.g. in a sport) you must endure/suffer (with hard and often painful training). In 1994, Robert Bjork launched the idea of *desirable difficulties* (see Chapter 14 in *HTH*). In his own words, desirable difficulties make [learning] hard, but in a good way. The five desirable difficulties were: interleaving, contextual interference, spaced practice, diminishing feedback, and tests for learning (i.e. retrieval practice). All five of these require extra but desirable cognitive effort, as opposed to rereading, underlining, or highlighting for example, thereby improving long-term performance and transfer.

Desirable difficulties isn't making it difficult

Unfortunately, teachers who may not really understand his message can concentrate more on the difficulty of a task than its desirability. Desirable difficulties can and sometimes have morphed into: making the task harder and more difficult to solve; giving learners problems or tasks that are beyond their reach (often basing this on Vygotsky's Zone of Proximal Development – see later in this chapter); and productive failure where the teacher deliberately gives learners problems that they can't solve, thereby inducing failure which is thought to stimulate future learning and motivation (actually, failure tends to demotivate except possibly in learners with a mastery approach goal orientation; see Chapter 16, Where are we going and how do we get there?). This is not to say that introducing some of these difficulties might not work – though they usually don't – but they definitely aren't desirable!

3. Retrieval practice doesn't have to start every lesson

Retrieval practice isn't mandatory quizzes

The testing effect is possibly the most well-evidenced aspect of what is now commonly referred to as the "Science of Learning" (Roediger & Butler, 2011). In more recent years the term "retrieval practice" has become commonplace and the central idea is that learning is not so much an event as a *process* in which getting learners to generate an answer through trying to retrieve knowledge from their memory is more effective than rereading and highlighting. This approach to studying and learning has been shown time and again to work in multiple empirical studies (for a review, see Dunlosky et al., 2013) and is one of Bjork's five desirable difficulties as well as Logan Fiorella and Richard Mayer's generative learning strategies (see Chapters 13 and 14 in *HTH*).

If the evidence is so strong, how has it become a lethal mutation? There are two reasons. First, teachers have learnt, and even understand to a certain extent, that retrieval practice is effective, but they don't completely understand the concept. As a result, they overuse it. It's kind of like they've learnt that an enzyme laundry powder works at 40°, so they use it at 60° to have it work even better. Unfortunately the enzymes, necessary to remove certain stains, break down at 60° and won't work. A little bit of knowledge can be dangerous.

Second, as so often happens, good ideas become adopted by senior leaders with little to no understanding of the science behind them and become systematised into something far removed from the original research. So for example, we often see retrieval practice now being mandated at the start of every lesson, regardless of the subject, stage of learning, or the students' level of understanding of that specific topic. For the struggling students in a class who often haven't understood the content, a quiz is probably not going to be effective as they're not consolidating previous learning but rather being quizzed on what Tom Sherrington (2022) poetically calls the "thin air of vaguely-encountered wisps of disconnected factoids from a dim past". If the students haven't properly learned the content they're being quizzed on, then they're merely guessing and the effect is at best to highlight what they don't know and at worst, most probably to demotivate them.

4. Constructivism as a philosophy of knowing has become a pedagogy

Constructivism is a philosophy, not a pedagogy

Epistemology is the study of knowledge and what it means to know something (Shaffer, 2007) that addresses questions such as: What is knowledge? How is knowledge acquired? What do people know? In other words, it's a learning or meaning-making theory that offers an explanation of the nature of knowledge (Kirschner, 2009). As a *philosophy of knowing*, it's really hard to deny; we all see the world differently and thus interpret it differently. In Paul's PhD thesis (1991) he wrote that *what you know determines what you see*, and what you know is based upon your personal experiences in life, school, interactions with others, and so forth. Constructivism should tell teachers that they need to take into account their students' prior knowledge, skills, misconceptions, and attitudes when teaching.

What you know determines what you see

Unfortunately, constructivism has morphed into a pedagogy. While, in essence, it's about how someone practising a profession understands their profession and gains new knowledge in that profession, it has become a standard of educational progressivism going back to the early 1960s when the US was shocked by the launch of the Sputnik 1 marking the start of the space race. The idea was: we need more scientists and engineers and we need them fast. Since scientists and engineers gain new knowledge through experimentation, inquiry, and discovery, we should educate our children through experimentation, inquiry, and discovery. The problem with doing this is that (1) learners aren't little experts; they see and interpret things differently exactly because of what constructivism tells us (see Chapter 6, A novice is not a little expert), (2) students are *learning science* as novices while scientists are *doing science* as experts (Hodson, 1985, 1988), and (3) the *expertise reversal effect* (Kalyuga, 2007) teaches us that the relative effectiveness of different learning conditions reverses with changes in the level of learner expertise (i.e. what's good for a novice, and in the school most (if not all) students are novices in the subject being taught, isn't good for an expert and vice versa). This has led to decades of inquiry and discovery learning dominating the pedagogy used in schools and negatively affecting student learning (Kirschner, Sweller, & Clark, 2006).

5. Biologically primary learning for biologically secondary knowledge and skills

In instruction, David Geary's distinction between biologically primary and secondary knowledge occupies an important place. The idea is that there is a kind of knowledge that we learn (or rather pick-up) fairly naturally such as walking, talking, and recognising faces. This is called biologically primary (hard wired and need for our survival as a species) but another kind of knowledge is much more hard-won, such as learning to read, write, or do maths, which is biologically secondary (cultural artefacts that have recently evolved). The conflation between these two has been the source of a good deal of poor instruction as we have seen in reading instruction where the approach which has a good deal of evidence to support it (explicit systematic phonics) was not used in place of approaches which have a poor evidence base (whole word, balanced literacy, or three-cueing approaches).

How we acquire a primary skill isn't how we acquire a secondary skill

This confusion is totally understandable. After all, if you have seen a 2-year-old pick up new vocabulary and speech simply through being immersed in language then why would you not use the same strategy to learn a similar skill such as learning to read? You don't need to tell a child to put their tongue in this position or use air from their lungs to make a particular sound so why would you need to explicitly tell a kid how to read the word "dog"? This is where science can help to subvert such cognitive biases because the way in which children best learn to read exists whether we think it is true or not and whether we like it or not. Now of course there are many children who are autodidacts and can learn a great many things simply through their own innate intellectual curiosity, but these cases are rare and certainly not a good basis for education policy. For the vast majority of children, learning to read and write does not come naturally to them, and allowing them to "discover" it in the same way they learned to talk would be disastrous.

You don't need to communicate (primary) to survive long enough to procreate, but you can reproduce even if you're illiterate (secondary)

6. Dual coding can become "use lots of illustrations"

Dual coding
Complementary text and pictures

Dual coding, as discussed in Chapter 10 (One picture and one thousand words), holds that by optimally integrating written or oral texts with images during instruction (i.e. that the texts and images supplement or complement each other), the learner makes use of both the phonological loop and the visuo-spatial sketchpad which comprise working memory. By doing this, working memory is increased, connections between the items in those memory stores are made, and learning is improved. The premise and research behind this is that two different memory stores in working memory are activated when text and pictures are combined, namely the phonological loop for text (we read things aloud to ourselves) and the visuo-spatial sketchpad for picture. For this to occur, the pictures and words have to be either complementary or supplementary in that it allows students multiple ways of making sense of the material being presented.

The mutation occurs when teachers just add picture (e.g. photos, drawings, diagrams, …) that don't add anything to each other. In a recent research review of cognitive science approaches in the classroom, the Educational Endowment Foundation (EEF, 2021) noted that "teachers have reported that dual coding sometimes means that irrelevant illustrations are added to presentations, which may be a distraction rather than a way of developing schemas and optimising cognitive load" (p. 8). While adding images and illustrations to learning materials, be they textbooks or slides, may increase learner engagement, it also makes learning more difficult by distracting students from what they need to be focusing on (i.e. seductive details). A second problem is that if the text and the illustration convey the exact same information, this may increase the complexity of the task for the student, leading to less learning. This is what's known as the redundancy effect in cognitive load theory.

Seductive details
Redundancy effect

7. Interleaving can become rotating subjects and more

Interleaving of related topics

Interleaving (see Chapter 14, … thinking makes it so) is an instructional and a study strategy where related topics (e.g. styles of modernist painting, areas/volumes of shapes/objects, conjugation of different types of verbs) and/or types of questions (e.g. application, inference, recall) are alternated in a random order, so that the learner continuously must think about what they're doing. They can't just plug in a formula or procedure, but must discern similarities in tasks that look similar and similarities in tasks that look different. This is different from what we normally see in lessons and textbooks (i.e. blocked practice), which involves studying or practising one topic very thoroughly before moving to another; carrying out the tasks without really thinking.

Unfortunately, there are a few lethal mutations that can occur when interleaving isn't really understood. The first is when subjects instead of topics are interleaved, for example 20 minutes of maths followed by 20 minutes of Spanish followed by 20 minutes of art history. The second is that while staying within a subject, disconnected topics are interleaved; for example, in a biology lesson a teacher interleaves 20 minutes about the respiratory system, 20 minutes about the skeletal system, and 20 minutes about cells and cell metabolism. A third is that it's not necessary to have mastered the subject of or type of task before going on to a second and a third. Interleaving should be used only after students have developed the fundamentals. Finally, you can make the mistake of interleaving too many things or leaving too much time between topics. With the former, the student can get really mixed up and frustrated. With the latter, too much forgetting happens as the task really hasn't been mastered.

8. Cognitive load theory can become "we must minimise cognitive load"

Cognitive load theory (see Chapter 8, Dancing in the dark) holds that we have a limited amount of space in our working memory and that when we exceed this limit we impede or even kill learning. There are basically two types of load: intrinsic and extraneous. *Intrinsic load* is effort that's inherent to the task: the number of new information elements in the task and the interaction between those elements. Learning to speak in Dutch as a second language not only requires learning new words (i.e. new elements) but also their noun gender, number, how this relates to the adjectives and articles used, and so forth, as these interact if you want to speak flawless Dutch. The intrinsic load is only moderated by the learner's expertise. For instance, in Dutch, this is knowing that words that you make diminutive (i.e. adding the suffix -je and -tje) make every word gender neutral, independent of whether it was masculine, feminine, or neutral. This means that you also know which article to use (Dutch has two: de and het) and the form of the adjective you might use. That makes the task of speaking the language less intrinsically loaded. Extraneous load is the effort added by how something is taught. Different approaches add different amounts of extra load. The goal is to optimise the two sources of load such that the effort that the learner needs to expend plus the inherent load doesn't exceed the learner's available resources.

The goal of CLT is load optimisation and not load minimalisation

Unfortunately there are a few mutations that occur. The first is that people confuse how difficult a task is with how much load a task incurs. This confusion is between simple and complex (based on task complexity) on the one hand, and easy and difficult (based on prior knowledge/expertise) on the other. A simple task in quantum mechanics (e.g. few information elements and little interaction between them) is difficult for someone in Physics 101, but easy for a master student in physics. The second is that teachers often think that the goal is to minimise cognitive load. All learning costs effort and deep and long lasting learning too. Minimising effort often means that learners enjoy learning (i.e. they find it easy) but don't learn much or only learn at a superficial level. No pain, no gain is the key, but too much pain leads to injuries!

Zone of proximal development

9. Zone of proximal development: all children must learn in groups

Ask any teacher what they remember from their teacher training course and you are likely to hear the term "zone of proximal development" (ZPD) by Russian Lev Vygotsky. His main idea here is that first, learning is mediated through language and the aforementioned "zone" represents the gap between where the child is at in terms of their learning and what they are capable of being with the right level of interaction from a peer or adult. Now there is very little to disagree with here, however it's also arguable that there is not much to use as the basis for teacher instruction. Indeed, as Donald Clark (2006) points out, it's not so much a theory as a "trite observation". Since the 1980s, the zone of proximal development has been hugely influential and often been invoked as a justification for collaborative learning in the form of group work, although as Yvon, Chaiguerova, and Newnham (2013) argue: "his works have been used as the basis for certain socio-constructivist school reforms that he would surely have completely disapproved of" (p. 32). Why might this be the case?

The first issue here is that this is a theory about development not learning, and the word "development" places ZPD in a problematic area with Piaget, whose developmental theory is now widely discredited and largely at odds with modern cognitive psychology. Second, in Vygotsky's own words, the gap between where a child is at and what they're capable of can be closed "under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). Teachers are often told to get students into groups in order to get them into this "zone"; however, how many of them are working with "more capable peers" and, furthermore, why is it the job of those peers to teach other kids when we have very strong models of fully guided instruction with decades of evidence? So there are very good reasons for students to work in groups in terms of socialisation and subject-specific tasks (especially in science and the arts) but invoking Vygotsky as a justification for group work in every lesson and every subject just doesn't stand up to scrutiny.

10. Self-determination theory often becomes "give children autonomy in school"

Self-determination isn't "let them do what they want"

Self-determination theory (SDT) is a psychological framework developed by Richard Ryan and Edward Deci that focuses on individuals' intrinsic motivation and autonomy in various life domains, including education. It posits that individuals have three basic psychological needs: autonomy, competence, and relatedness. When these needs are met, people are more likely to be motivated, engaged, and satisfied. However, the authors don't speak of true autonomy, but rather perceived or experienced autonomy. Perceived autonomy (also called feelings of autonomy) refers to an individual's *belief* or *perception* that they have control over their actions and decisions, which may not always align with true autonomy, as people can feel autonomous in situations where their choices are actually limited or externally controlled. Ryan and Deci (2000) write: "self-direction were found to enhance intrinsic motivation because they allow people a greater feeling of autonomy" (p.70), "extrinsic motivation entails personal endorsement and a feeling of choice" (p. 71), and "internalization is more likely to be in evidence when there are ambient supports for feelings of relatedness" (p. 73). If an individual perceives themselves as being more competent and/or that there is more relatedness, and/or autonomous, they are more likely to be motivated and satisfied with their actions and decisions, even if their true autonomy is limited.

Belief or perception of control

However, if the principles of SDT are misinterpreted or poorly implemented in teaching, it can lead to negative consequences. One of the major problems is the idea that Ryan and Deci were speaking of true autonomy. While promoting autonomy is important, too much emphasis on it may lead to a lack of structure and guidance. This can result in students feeling overwhelmed and directionless, potentially hindering their learning and development.

Motivation is important, but it doesn't lead to learning

11. Motivation doesn't always lead to achievement, but achievement often leads to motivation

Motivation in education is important. Every teacher should do their best to motivate their students to learn. Motivation is important to get students started on a learning task. If you don't start on the task, you can't complete it and learn through it. Sometimes this motivation is intrinsic, that is that it comes from within the student. We see this in students who have a mastery approach or orientation to learning (see Chapter 16, Where are we going and how do we get there?). This could be that they're interested in the subject or that they do it because of an inner drive to do it well. Other times it's extrinsic, relying on external rewards ranging from money or presents to gold stars to good grades. We see this

Mastery orientation
Performance approach

in learners who have a performance approach or orientation to learning (again, see Chapter 16). This could be to get the reward, or to be better than everyone else; learning is less important than getting a better grade.

The mutation occurs when people assume that simply being motivated will lead to learning. Concepts such as motivation and engagement are often perceived as keys to improving education. The assumption is that if we're able to increase learners' motivation, then they'll perform better and achieve more. Unfortunately this isn't the case. First, motivation isn't enough. Being motivated is great to begin with, but if you keep hitting walls in what you're trying to achieve, you'll quickly become demotivated, begin to believe that you can't do it, and will never be able to do it, and/or that you're just dumb. Second, research has shown (e.g. Garon-Carrier and colleagues, 2016) that motivation doesn't lead to learning (i.e. that there's a one-way causal relationship: motivation→learning) and the relationship isn't even reciprocal (i.e. there's a two-way causal relationship: motivation↔learning). In their research on maths learning and motivation, Garon-Carrier et al. thought that the relationship would be reciprocal; that intrinsic motivation for maths would influence achievement in maths and vice versa. However, contrary to their hypothesis, they found that maths achievement had a significant positive effect on intrinsic motivation but NOT the other way around! Intrinsic motivation didn't have any effect on maths achievements whatsoever. This was true for both boys and girls. Thus achievement increased intrinsic motivation but not vice versa; motivation didn't affect achievement. If a student experiences success then their motivation to continue to learn will increase; the more success, the more motivation.

Achievement leads to motivation

Kolb is a learning cycle and not a learning style

12. The Kolb cycle has become Kolb's learning styles

In 1984, David Kolb proposed Experiential Learning Theory, a four-stage cyclical model featuring (1) *Concrete Experience*, where the learner experiences a new problem or situation; (2) *Reflective Observation*, where learners observe and consider new situations or problems in relation to their existing knowledge; (3) *Abstract Conceptualisation*, where the learner begins to move from observation to thinking about the problem in a more systematic fashion; and (4) *Active Experimentation*, where the learner attempts to apply their observed evaluation of the problem in an applied way. This learning cycle isn't linear, as individuals can enter the cycle at any stage and move through the cycle in different directions. The process is often iterative, with each stage informing and influencing the others. According to Kolb, effective learning occurs when individuals engage in *all four stages* of the cycle, allowing for a continuous and integrated learning experience.

Effective learning occurs when a learner goes through all four stages

The mutation here is that Kolb's learning cycle has mutated into Kolb's learning styles. This is, at least in part, Kolb's fault. To determine where it would be best for a learner to enter the cycle, he developed what he called a learning style inventory (1976), though he considered them and spoke of them as preferences. In the inventory he proposed four different types of learner: the *accommodator* who learns in a practical, hands-on way; the *converger* who thrives in abstract conceptualisation; the *diverger* who's imaginative and artistic in nature; and the *assimilator* who's interested in planning, research, and creating theoretical research. This has mutated into the idea that we have four types of learners (each with a specific learning style) who should only be taught in a manner which is consonant with their learning style. For example, accommodators should only be taught in a hands-on manner.

The dirty dozen is now complete. But there's also a strange case of when three approaches to learning and instruction that harm learning

Mathemathantic

(i.e. are potentially mathemathantic (see Chapter 32, When teaching kills learning) can actually produce something of worth.

The flipped classroom is lethality turned positive

The flipped classroom: when three wrongs made a right

There's some uncertainty as to the origin of the flipped classroom. Some people point to Eric Mazur who came up with "peer instruction". Others attribute the idea to Jonathan Bergman and Aaron Sams who worked in a rural US school. Our search led to a 2000 article by Maureen Lage, Glenn Platt, and Michael Treglia, who came up with a technique they called "inverting the classroom".

In a hodgepodge of pseudoscience, they first drew on the Grasha-Reichmann learning styles which allegedly determine students as dependent, collaborative, or independent learners. The next application of pseudoscience was based on personality types as measured by the Myers-Briggs Type Indicator (MBTI), which has been shown to be neither accurate nor reliable, lacking evidence showing a positive relation between MBTI types and success. And as if the cocktail wasn't poisonous enough, they added Kolb's (1981) learning styles to focus on how students take in and process information. According to the Kolb inventory, you are either an assimilator, a converger, a diverger, or an accommodator.

Based upon these three premises, the authors came up with a way to teach their beginning economics students in a way that "can appeal to all types of learners" (Lage et al., 2000, p. 32). They gave their students a diversity of instructional materials that they could access before the class, which could be used to complete small assignments. Having done this prior to coming to the class, in the class they discussed the materials and their assignments in small groups, applied the principles that they learned, discussed each other's questions, and presented to each other in mini-lectures. Lege and Platt noted that both learners and instructors found this method very motivating and more effective in achieving the course learning outcomes. There's a lot to criticise in their research (see Paul's blog, Kirschner, 2021) but suffice it to say, when implemented properly, this is a poisonous cocktail. It includes: a very thorough and strict pedagogy/instructional strategy, careful choice of materials, prepared follow-up, and strict control of whether students carried out their assignments to ensure that the necessary prerequisite work was carried out.

Takeaways and concluding remarks

- A lethal mutation is an idea or a practice that is prompted by sound scientific evidence, but is implemented in a way that reduces, or even completely negates, its effectiveness. Lethal mutations can be reversed over time with reflection, effort, and change, but prevention truly is better than a cure.
- "Cognitive science needs to be understood more broadly than just a checklist of strategies to implement in order to reduce the chance of so-called lethal mutations" (Perry et al., 2021, p. 241).
- To avoid creating lethal mutations of evidence-informed practice, schools need to think carefully about the key psychological bases and pedagogical strategies at the core of an intervention.
- Just because a strategy works in one context or even one subject area, doesn't mean it will work in all.
- Using a good strategy wrong is often worse than not using it at all.

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ALANA OLENDORF E-PORT DISCUSSES THE PEPPERED MOTH?

AVAILABLE AT HTTPS://AOLENDORFEPORT.WORDPRESS.COM/2018/04/17/THE-PEPPERED-MOTH/.

KATE JONES DISCUSSES LETHAL MUTATIONS IN EDUCATION AND HOW TO PREVENT THEM

AVAILABLE AT HTTPS://EVIDENCEBASED.EDUCATION/LETHAL-MUTATIONS-IN-EDUCATION-AND-HOW-TO-PREVENT-THEM.

NICK ROSE DISCUSSES SOME LETHAL MUTATIONS OF GOOD PRACTICE SUCH AS SPACED PRACTICE AND THE REDUNDANCY EFFECT.

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AVAILABLE AT HTTPS://3STARLEARNINGEXPERIENCES.WORDPRESS.COM/2023/02/28/DEMYSTIFYING-DESIRABLE-DIFFICULTIES-2-WHAT-THEYRE-NOT/.

BRADLEY BUSCH ON HOW INTERLEAVING SHOULD AND SHOULDN'T BE IMPLEMENTED, INCLUDING A REAL GOOD INFOGRAPHIC

AVAILABLE AT HTTPS://BLOG.INNERDRIVE.CO.UK/INTERLEAVING-DOS-AND-DONTS.

BRADLEY BUSCH DISCUSSES FOUR COMMON MYTHS ABOUT INTERLEAVING INCLUDING A VIDEO ON INTERLEAVING.

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