Innovating Pedagogy 2016

Exploring new forms of teaching, learning and assessment, to guide educators and policy makers

Mike Sharples, Roberto de Roock, Rebecca Ferguson, Mark Gaved, Christothea Herodotou, Elizabeth Koh, Agnes Kukulska-Hulme, Chee-Kit Looi, Patrick McAndrew, Bart Rienties, Martin Weller, Lung Hsiang Wong

Open University Innovation Report 5

A full-text PDF version of this report is available to download from **www.open.ac.uk/innovating**

Illustrations:
Front cover. Trainees at MAKLab fabricating chairs designed by Open University students, in the RE:FORM project for distributed design and manufacturing. Photograph by MAKLab. Reproduced with permission.
Page 9. Elements of a new science of learning. In Meltzoff, A.N., Kuhl, P.K., Movellan, J., Sejnowski, T.J. (2009). Foundations for a new science of learning. Science, 325(5938), 284-288. Image © Andrew Meltzoff. Reproduced with permission. [Photo credits: R. Goebel (neuroscience), iStockphoto.com/J. Bryson (education), Y. Tsuno/AFP/Getty Images (machine learning)].
Page 13. Propaganda poster from World War II reproduced in Twitter feed @RealTimeWWII.
Page 17. Combinatorix interactive tabletop system to explore the mathematics of combinations. Image © Bertrand Schneider, Stanford University Graduate School of Education. Reproduced with permission.
Page 20. The teachback process in healthcare. Image adapted from **culturallyconnected.ca/skills/supporting-health-literacy/** . Reproduced with permission.
Page 23. Representation of the educational project 'Moscow Through the Engineer's Eyes', an 'Innovations in Education' competition finalist (http://www.kivo.hse.ru). Image © Diana Koroleva, Institute of Education, National Research University, Russia.
Page 26. Citizen inquiry on the nQuire-it website. Screen image captured from **http://www.nquire-it.org/** .
Page 29. Children designing games in Quest to Learn school. Image © Institute of Play.
Page 33. Formative analytics in OU Analyse. Screen capture from OU Analyse software. Image © The Open University. Available for reproduction under Creative Commons CC-BY 3.0 licence.
Page 36. Elements of future-ready learning. Image © Innovating Pedagogy 2016 report available for reproduction under Creative Commons CC-BY 3.0 licence.
Page 39. Students discuss a topic in pairs using their home language, in TESS India. Image © TESS India. Available under Creative Commons CC-BY-SA 3.0 licence.
Page 42: A pictorial illustration of blockchain for learning. Image © The Open University. Available for reproduction under Creative Commons CC-BY 3.0 licence.

Suggested citation:
Sharples, M., de Roock , R., Ferguson, R., Gaved, M., Herodotou, C., Koh, E., Kukulska-Hulme, A., Looi, C-K, McAndrew, P., Rienties, B., Weller, M., Wong, L. H. (2016). *Innovating Pedagogy 2016: Open University Innovation Report 5*. Milton Keynes: The Open University.

Institute of Educational Technology, The Open University,
Walton Hall, Milton Keynes, MK7 6AA, United Kingdom

Learning Sciences Lab, National Institute of Education,
Nanyang Technological University, 1 Nanyang Walk, Singapore 637616

ISBN 9781473022812

Contents

Executive summary

This series of reports explores new forms of teaching, learning and assessment for an interactive world, to guide teachers and policy makers in productive innovation. This fifth report proposes ten innovations that are already in currency but have not yet had a profound influence on education. To produce it, a group of academics at the Institute of Educational Technology in The Open University collaborated with researchers from the Learning Sciences Lab in the National Institute of Education, Singapore. We proposed a long list of new educational terms, theories, and practices. We then pared these down to ten that have the potential to provoke major shifts in educational practice, particularly in post-school education. Lastly, we drew on published and unpublished writings to compile the ten sketches of new pedagogies that might transform education. These are summarised below in an approximate order of immediacy and timescale to widespread implementation.

1 **Learning through social media:** Outside schools and colleges, people learn less formally. Some use social media such as Twitter and Facebook to share ideas and engage in conversations. These sites can offer a range of learning opportunities, to access expert advice, encounter challenges, defend opinions and amend ideas in the face of criticism. Unfortunately, the same sites may present learners with inaccurate information, biased comments and hostile responses. Some organisations have set up social media specifically to offer learning opportunities. Learners are helped to share experiences, make connections, and link these with teaching resources. Other educational sites are based on projects, such as 'RealTimeWorldWarII', 'The Diary of Samuel Pepys' and NASA's 'MarsCuriosity' Twitter account. Educators on these sites have multiple roles that differ from those of a classroom teacher. These projects require expertise, as well as the time and ability to take on different roles. Anyone can engage and leave at any time, but a skilled facilitator who takes on the tasks of filtering resources and engaging people can keep a social media project running for many years.

2 **Productive failure:** Productive failure is a method of teaching that gives students complex problems to solve and attempt to form their own solutions before receiving direct instruction. The aim is for students, working together, to use their prior knowledge to consider possible solutions, then evaluate and explain the best answer. By struggling and sometimes failing to find a solution, the students gain a deeper understanding of the structure of the problem and its elements. After this process, their teacher explains the essential concepts and methods of the solution, helping students to consolidate their knowledge by comparing good and bad answers. Productive failure has been

investigated in 26 Singapore schools, and has been replicated by studies in the USA, Canada, Germany, and Australia. The pedagogy requires students to embrace challenge and uncertainty. They may feel unconfident at first, but this experience can help them become more creative and resilient. In order to implement learning with productive failure, teachers will need a deep understanding of the topic and may need to make fundamental changes to how they teach.

3 **Teachback:** As well as learning from teachers, we can learn by explaining to other people what we think we know. This is the basis of Teachback. One person (who may be a teacher, an expert, or another student) explains their knowledge of a topic to a learner. Then that learner attempts to explain, or teach back, what they have understood. This offers two benefits. It helps learners to understand a topic or problem by reframing it in their own terms. They also need to explain what they have learned in a way that is understandable. If the listener cannot make sense of the learner's explanation, then they discuss the topic until they understand each other. Teachback has been used in healthcare. Doctors and nurses can check that they have explained a treatment clearly by asking their patients to explain or demonstrate what they have been told. The method could be adopted more widely, for any topic where it is important to reach a shared understanding. However, if neither person is knowledgeable, the outcome could be shared misunderstanding.

4 **Design thinking:** Design thinking solves problems using the methods and thinking processes used by designers. These include creative processes such as experimenting, creating and prototyping models, soliciting feedback, and redesigning. Design thinking places learners in contexts that make them think like designers, creating innovative solutions that address people's needs. Learners need to solve technical problems but they also need to understand how users will feel when employing the solutions. Design thinking is a social as well as a mental process. It involves thinking and working across different perspectives and often involves conflict and negotiation. For example, students designing an educational computer game need to think from the perspective of a good teacher as well as from the perspective of a game player. As a pedagogy, design thinking may involve civic literacy, cultural awareness, critical and creative thinking, and technical skills. When implementing this approach in the classroom, the teacher and students need to take risks and try new methods.

5 **Learning from the crowd:** Appealing to the crowd gives access to valuable sources of knowledge and opinion. Amateurs and experts exchange ideas, generate and discuss content, solve problems, vote for the best solutions, and raise funds. A classic example of the crowd in action is Wikipedia, the online encyclopaedia co-created and continually updated by the public. Other examples include citizen science activities such as identifying birds and classifying galaxies. However, we are not yet using the wisdom of the crowd to its full potential as a resource in education and for learning. Possible applications of crowdsourcing in education include collecting and curating teaching resources, letting students share and discuss their work online, and providing opinions and data for use in projects and research studies. Crowdsourcing can lead to research that is initiated by the general public, rather than by scientists, and the opportunity to seek solutions to real-life problems. Designing and supporting such activities offers a way to scale them up. It also teaches the public to think scientifically, to appreciate sciences, and to support the work of scientists. Approaches need to consider the quality and validity of the contributions that are made by the public; the crowd may be wrong!

6 **Learning through video games:** Video games are powerful market and social forces. They can make learning fun, interactive, and stimulating. 'Lemonade Stand' was a 1970s computer game that engaged children in pricing, advertising, buying, and selling lemonade. From this promising beginning an industry has grown that includes serious games, gamification and game-infused learning. The focus can be on games designed for education, the use of game elements in workplace training, simulations such as flight trainers, or on social benefit. Players can try out unfamiliar roles and contexts and make consequential decisions, for example in simulated financial trading. However, it is difficult to balance learning with fun. A solution may lie in collaboration between professional game designers, software engineers, and learning experts. Together, these groups could develop game engines based on effective pedagogy, employing learning analytics to adapt game experiences to players' educational goals and actions.

7 **Formative analytics:** Most current applications of learning analytics aim to measure and predict the learning processes of students by tracing their behaviour and inferring their thinking processes. Analytics track, for example, time spent on online learning, or performance on an assessment. By identifying who may be at risk of failing a test, summative learning analytics provide teachers with a digest of performance and insight into who needs support. In contrast, formative analytics support learners to reflect on what they have learned, what can be improved, which goals can be achieved, and how they should move forward. By providing analytics for learning rather than analytics of learning, formative analytics have the potential to empower each learner through timely, personalised, and automated feedback, including visualisations of potential learning paths.

8 **Learning for the future:** Learners need to be educated not just for today but for the future. They should acquire skills and dispositions that will enable them to cope with an uncertain life and a complex work environment. Learning for the future builds human capacity to learn. The emphasis is not just on mastering content, but also on acquiring skills to learn, unlearn and relearn. These include the ability to change perspectives in the light of new information and understanding. This approach can help students to acquire critical thinking skills, gain social competencies related to learning and working together, and develop resourcefulness in learning. Future-ready learners have agency and autonomy in planning what and how to learn. They have the skills to be responsible citizens, contributors and innovators in an uncertain future. They also have mature cultural and interpersonal understanding.

9 **Translanguaging:** In a globalised world, many learners are studying in and speaking a language that is not their mother tongue. Translanguaging refers to moving flexibly and fluidly between languages. Pedagogical strategies engage the language abilities of bilingual students in teaching and learning, for example by using bilingual partners, organising international collaboration, searching the internet in multiple languages and accessing a wide range of online communities and resources. Translanguaging can expand and deepen students' understanding and help them to gain broader perspectives. It can also enrich the cultural experience and world views of other learners. But a bilingual classroom may exclude monolingual learners or take for granted the ability of bilinguals to use their languages for effective learning. Translanguaging might also encourage fusion of languages and threaten the survival of 'standard' languages (such as International English) that can facilitate access to education and build mutual comprehension between people from different cultural backgrounds.

10 Blockchain for learning: A blockchain stores digital events securely on every user's computer rather than in a central database. This is the technology behind digital currencies like Bitcoin. Blockchain learning explores how this approach could be applied to education, shifting from central records of student performance held by schools and universities to a more democratic model in which achievements are recorded by a wider range of participants. Blockchain technology allows any participant to add a new record such as an exam score to a single digital chain of events. This chain is stored across many computers, yet cannot be altered or undone. A blockchain could be used as a permanent shared record of intellectual achievement. It enables anybody to store academic certificates, creative works such as poems or artworks, even original ideas. There is no need for individuals to claim their inventions – the record is there for all to see. Just as bitcoin is a financial currency, so an educational blockchain could be linked to a currency of intellectual reputation. People can gain credit for carrying out an intellectual task such as reviewing another person's creative work, or can donate small amounts of reputational credit to boost another person's artefact or idea – all recorded and visible on the shared educational blockchain. While blockchain technology opens new possibilities for trading educational reputation as a currency, it also raises significant concerns about treating learning as a commodity to be bought and sold.

Introduction

This is the fifth in a series of annual reports on innovations in teaching, learning and assessment. The Innovating Pedagogy reports are intended for teachers, policy makers, academics and anyone interested in how education may change over the next ten years.

This report is the result of collaboration between researchers at the Institute of Educational Technology in The Open University, UK, and the Learning Sciences Lab at the National Institute of Education, Singapore. We have shared ideas, proposed innovations, read research papers and blogs, and commented on each other's draft contributions. We worked together to compile this report by listing new educational terms, theories, and practices, then reducing these to ones that have the potential to provoke major shifts in educational practice. This 2016 report introduces ten pedagogies that either already influence educational practice or offer opportunities for the future. By 'innovative pedagogies', we mean novel or changing theories and practices of teaching, learning and assessment for the modern, technology-enabled world.

> "The method of design-based research has been widely adopted for educational innovation."

Together, the five reports have described 41 innovative pedagogies. Some of these have already had a major impact on education worldwide. Over 30 million people have engaged with massive open online courses (MOOCs), which we introduced in our 2012 report. MOOCs are now evolving into new types of pedagogy, including massive-scale social learning that applies techniques from social networks (such as Facebook and Twitter) to help people comment on topics, share and 'like' ideas, and review contributions from other learners.

With so many new and emerging pedagogies, the obvious question for teachers and education policy makers is "which ones should we adopt?" Where is the evidence that helps us decide whether to explore adaptive teaching systems (described in our 2015 report), to teach science through threshold concepts (2014), or to embrace dynamic assessment (2014)? Fortunately, alongside these innovative pedagogies has come a new science of learning, where findings from neuroscience, cognitive sciences, educational and social sciences are combined to produce a deep understanding of how we learn. Recent studies have compared different methods of teaching in classrooms and online to reveal which methods increase knowledge, improve exam scores, and keep learners engaged.

There has been a deep, and often justified, resistance from many educational researchers to the 'medical model' of evidence, which treats pedagogies as pills administered to students, tested in the same ways as a new medicine. Learning a topic is not the same as swallowing a pill – it involves a series of mental processes and often-complex social interactions with a teacher and other students. There is no educational equivalent of a 'placebo' (a similar-looking pill with no medical effect). It may take many months or years for the effects of good teaching to become apparent, as skills learned at school or in college are applied in the workplace.

Rather than relying solely on controlled experiments to evaluate new pedagogies, research is now piecing together evidence from multiple sources, rather like pieces of a jigsaw puzzle, to build up a picture

of effective methods of teaching, learning and assessment. The method of design-based research has been widely adopted for educational innovation. Researchers using this approach carry out a series of trials of a new method of teaching, with each trial (or 'design experiment') leading to improvements in the method and insights into learning theory and practice.

Cooperative learning

The most obvious success has been in cooperative learning. Until the 1970s, most research in educational innovation was directed towards individualised instruction – how to match teaching content to the needs and activities of individual students. Then, findings from social psychology began to show the value of working together. When students cooperate in small groups of between four and eight people, this can result in greater creativity and better outcomes than working alone. Over the past 40 years, hundreds of studies in labs, classrooms and online, have uncovered conditions for successful cooperative learning. For groups to work well, they need to have shared goals, each person should know how and when to contribute, and everyone should make an appropriate contribution. They should share rewards such as group marks in a fair way, and members of a group should all have opportunities to reflect on progress and to discuss contributions. For many students, learning in groups is not a natural process, and they need to learn how to cooperate by arguing constructively and resolving conflicts. The key phrase is 'positive interdependence' – everyone sees the benefits of learning together and works to achieve the group's goals. All over the world, schools and colleges now make time for group learning activities, founded on these principles of positive interdependence.

Collaborative and social learning online

More recently, learning through positive interdependence has been extended to collaborative and social learning online. Here, the groups may be looser and less coherent, without shared goals. For example, the learners may be people from around the world who have signed up to study a six-week MOOC. The learning benefits come from sharing ideas and perspectives through discussions and constructive argument.

The effects of such online computer-supported collaboration are much harder to measure than for group work in a classroom. A recent study has made an ingenious comparison of the learning benefits of 157 distance learning courses offered by The Open University. Each course had been carefully designed according to a set of pedagogic principles, with differing mixtures of individual and collaborative learning. The university collects the exam scores for all students taking the courses, as well as results from surveys of student satisfaction with the teaching, and data on how many students drop out from each course. From these data the researchers calculated which types of course produced the most successful outcomes.

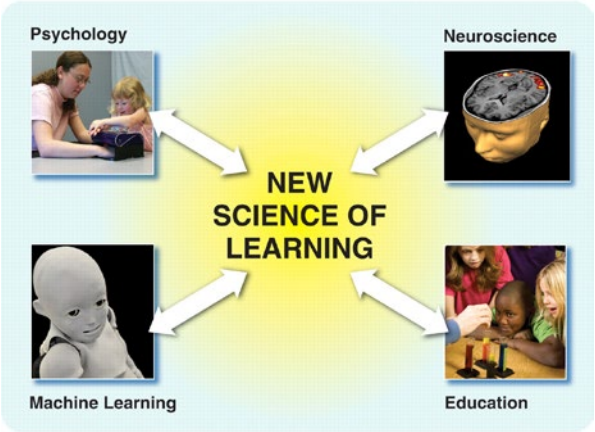
The researchers found that the design of the course had a significant effect on student satisfaction and performance. Students were more satisfied with courses that had a large element of individual reading and watching of instructional videos, but students were more likely to complete courses that had more collaborative learning. Furthermore, exam scores were lower on average for the courses that were based more on individual learning by reading and watching. These findings match other studies showing that although students may be reluctant to take part in group activities, they can benefit from the experience of pooling knowledge and sharing diverse views.

Feedback for learning

Another robust finding from studies of human psychology applied to education is the value of feedback to learning. Feedback can come from a teacher, another more knowledgeable person, another learner, or a computer. It is most successful when the feedback helps a learner to improve, by finding out how to correct a misunderstanding, or to build new knowledge in reaching a goal. I learn something and think

I understand it, I am tested on that learning and find some missing or faulty knowledge, then I am helped to correct it.

It is easier to study the effects of feedback than many other educational methods, so many experiments have been run on whether feedback should be immediate or delayed, positive or negative, and combined with praise or punishment. In brief, giving immediate feedback works best for easy learning tasks and when the student is building knowledge.



Elements of a new science of learning

Both positive and negative feedback can help learning. Negative feedback points out shortcomings and how to correct them; positive feedback can encourage students to continue. There is good evidence that praise alone does not produce learning. Feedback must be relevant to the task and lead to specific action.

Active and constructive learning

Active and constructive learning involves students carrying out an activity that can support learning – such as commenting, critiquing, constructing – while thinking about the purpose and aim of the activity. This contrasts with instructivist learning that mainly involves listening and watching, a lecture for example. A series of studies have compared the sequencing of constructivist and instructivist approaches. They found that students who actively explored a topic (for example, by trying out a science simulation) and then received instruction performed better on tests of knowledge than students who listened to the lecture before active exploration. The method is described later in this report, in the section on Productive Failure. The results are clear, but the explanations of why this happens are still speculative. A plausible explanation is that students who are instructed first and then explore become fixed on the specific items delivered by the lecture, whereas those who explore first gain a broader understanding of the possibilities and dimensions of the topic, which provide a framework for understanding the lecture.

Human memory and learning

The success of active, constructive and collaborative learning raises a question as to how young children learn. Around the age of 8, a typical child is learning to speak about five to eight new words a day, without the mental effort of exploring, discussing, and critiquing. How do they do it, and could that same accelerated learning be adopted or re-discovered in adulthood?

Making associations, such as “hello – bonjour”, is the basic process of learning. Studies of associative learning began over 100 years ago. They show that trying to cram lots of facts and associations into memory does not work. Instead, we need to space the practice over time, so that the learning is repeated just as the association is fading from memory, for example at 5 seconds, 25 seconds, 2 minutes, 10 minutes, 1 hour, 1 day, 5 days, 25 days, 4 months and 2 years. Rather than just viewing the association at these intervals, it is better to try to recall it. For example, learners might be asked, “What is the French for ‘hello’?” while using ‘flash cards’ with the English word or phrase on one side and the French on the other. Many language-teaching methods are based on this method of spaced repetition. It is at the core of successful learning platforms such as Memrise and Duolingo.

Spaced repetition on flash cards is successful for making memory associations, such as learning vocabulary or multiplication tables. A similar method has been shown to work for more complex topics. A method called ‘spaced learning’ builds on findings from neuroscience that explain how humans form long-term memories. Things we remember in

short-term memory fade rapidly, but if they are transferred to long-term memory they can last a lifetime. The neuroscience studies show that permanent neural connections are more likely to be made when a brain cell is stimulated at intervals than when it is constantly stimulated. This is good evidence for learning by spaced repetition and it is already being applied to the teaching of curriculum subjects.

In a spaced learning session, students are given intensive teaching by lecture for 20 minutes or less. They then take a short break from mental effort by doing a sports activity or physical exercise. After this, the same or similar content is repeated for 20 minutes, followed by more physical activity, with a final teaching session to focus on applying the knowledge or skills the students have just acquired. A controlled study that compared one hour of spaced learning for school biology with a four-month course of classroom teaching found similar learning benefits. This is the nearest that education gets to a 'learning pill', so it has attracted media attention. It is still research in progress, though it is based on a century of research into human memory and learning. The studies are being repeated, with some variations, in 15 schools over an academic year.

A new science of learning

The cognitive and social processes involved in learning fundamentals of Biology may be very different to those required for discussion on MOOCs. Research is combining observations of learning in classrooms and online, controlled psychology experiments, investigations of human brain functioning, and computational models of machine learning. Together, this work is establishing a new science of learning. Researchers piece together the evidence to form a composite picture of how people learn, individually and together, with and without the support of a teacher, at different ages and in differing cultures. This new science of learning can already help in predicting which innovative pedagogies might work in which contexts.

New pedagogies based on principles of cooperative learning are likely to be successful when the students have shared goals, similar motivations to learn, and time and ability to reflect. These conditions may apply, for example, to professional development in the workplace. Findings about collaborative and social learning can inform the design of pedagogies for learning at massive scale, where the diversity of views create a 'social network effect' of vibrant discussion but with a need to manage and contain the discussions.

Research into feedback for learning is already leading to new forms of assessment (see Dynamic Assessment in the *Innovating Pedagogy 2014* report) and to computer-based systems for adaptive teaching (described in *Innovating Pedagogy 2015*). The value of active and constructive learning underpins many recent innovations described in our previous reports, such as Citizen Inquiry (2013), Flipped Classroom (2014), and Computational Thinking (2015). The neuroscience of human memory may provide a basis for new pedagogies of accelerated and optimized learning.

Amongst all this innovation in teaching, learning and assessment, some principles endure. The teacher still performs a central function, but that is changing from delivery of educational content to facilitating discussion and reflection. Structure is still important, perhaps even more than it was before, as we discover effective ways to initiate, embed and extend learning. Learners still need appropriate goals and support. Most important, learning is a collegiate process. It works best when people want to learn, enjoy the process and support each other. The next decade of innovating pedagogy may focus less on the individual elements of instruction and more on how to merge the new pedagogies into an effective process of lifelong learning.

Resources

Introduction to design-based research
Wang, F. & Hannafin, M.J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development*, 53(4), 5-23.
bit.ly/2eLQsrF

Cooperative learning
Survey of successful methods and procedures of cooperative learning:
Johnson, D.W. & Johnson, R.T. (2009). An educational psychology success story: social interdependence theory and cooperative learning. *Educational Researcher*, 38(5), 365-379.

Collaborative and social learning online
Comparison of group activity in online courses showing that assessing group activity does not improve participation, but that well-structured and appropriate tasks can make groups more effective:
Brindley, J.E., Walti, C. & Blaschke, L.M. (2009). Creating effective collaborative learning groups in an online environment. *The International Review of Research in Open and Distributed Learning*, 10(3).
http://www.irrodl.org/index.php/irrodl/article/viewArticle/675

Comparison of courses with individual and collaborative learning:
Rienties, B. & Toetenel, L. (2016). The impact of learning design on student behaviour, satisfaction and performance: a cross-institutional comparison across 151 modules. *Computers in Human Behavior*, 60, 333-341.
oro.open.ac.uk/45383/

Toetenel, L. & Rienties, B. (2016). Analysing 157 learning designs using learning analytic approaches as a means to evaluate the impact of pedagogical decision-making. *British Journal of Educational Technology*, 47(5), 981-992.
oro.open.ac.uk/45016/

Social learning at massive scale
Ferguson, R. & Sharples, M. (2014). Innovative pedagogy at massive scale: teaching and learning in MOOCs. In C. Rensing, S. de Freitas, T. Ley & P.J. Muñoz-Merino (Eds.) Open Learning and Teaching in Educational Communities*, proceedings of 9th European Conference on Technology Enhanced Learning (EC-TEL 2014)*, Graz, Austria, September 16-19. Heidelberg: Springer, pp. 98-111.
r3beccaf.files.wordpress.com/2014/06/mass-pedagogy-preprint.pdf

Constructive feedback
Review of research on feedback, with advice on how to design effective feedback:
Shute, V.J. (2008). Focus on formative feedback. *Review of Educational Research*, 78(1), 153-189.
myweb.fsu.edu/vshute/pdf/shute%202008_b.pdf

Active and constructive learning
Research on transfer of knowledge from one task to another:
Bransford, J.D. & Schwartz, D.L. (1999). Rethinking transfer: a simple proposal with multiple implications. *Review of Research in Education*, 24, 61-100.
http://artstart2011.pbworks.com/f/Bransford%2B%2526%2BSchwartz-transfer.pdf

Chi, M.T.H. & Wylie, R. (2014). The ICAP framework: linking cognitive engagement to active learning outcomes, *Educational Psychologist.* 49(4), 219-243

Overview of learning through productive failure:
www.manukapur.com/research/productive-failure/

Human memory and learning
Early paper on 'graduated interval recall' for foreign language learning:
Pimsleur, P. (February 1967). A memory schedule. *The Modern Language Journal*. Blackwell Publishing. 51(2), 73–75.
files.eric.ed.gov/fulltext/ED012150.pdf

Spaced learning
Kelley, P. & Whatson, T. (2013). Making long-term memories in minutes: a spaced learning pattern from memory research in education. *Frontiers in Human Neuroscience*, *7*, 589.
journal.frontiersin.org/article/10.3389/fnhum.2013.00589/full

Duolingo:
www.duolingo.com

Memrise:
www.memrise.com

A new science of learning
Koedinger, K., Booth, J.L. & Klahr, D. (2013). Instructional complexity and the science to constrain it. Science, 342(6161), 935-937. doi: 10.1126/science.1238056
Meltzoff, A.N., Kuhl, P.K., Movellan, J. & Sejnowski, T.J. (2009). Foundations for a new science of learning. *Science*, 325(5938), 284-288.
www.ncbi.nlm.nih.gov/pmc/articles/PMC2776823/