EDUC6775

Cognitive Load Theory and Explicit Teaching

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Professional Standards for Teachers

Graduate Level

1 Know students and how they learn

1.2 Understand how students learn
Demonstrate knowledge and understanding of research into how students learn and the implications for teaching.

3 Plan for and implement effective teaching and learning

3.3 Use teaching strategies
Include a range of teaching strategies.

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The Limits of Working Memory

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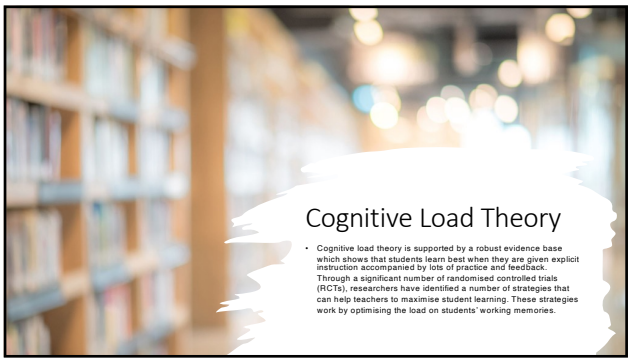
Cognitive Load Theory
Cognitive load theory is supported by a robust evidence base which shows that students learn best when they are given explicit instruction accompanied by lots of practice and feedback. Through a significant number of randomised controlled trials (RCTs), researchers have identified a number of strategies that can help teachers to maximise student learning. These strategies work by optimising the load on students' working memories.

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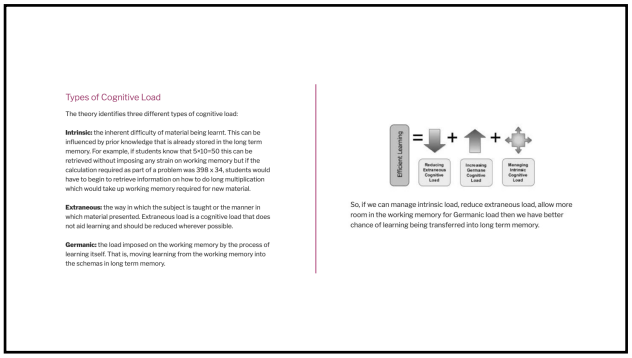
Types of Cognitive Load
The theory identifies three different types of cognitive load:
Intrinsic: the inherent difficulty of material being learnt. This can be influenced by prior knowledge that is already stored in the long term memory. For example, if students know that 5×10=50 this can be retrieved without imposing any strain on working memory but if the calculation required as part of a problem was 398 x 34, students would have to begin to retrieve information on how to do long multiplication which would take up working memory required for new material.
Extraneous: the way in which the subject is taught or the manner in which material presented. Extraneous load is a cognitive load that does not aid learning and should be reduced wherever possible.
Germanic: the load imposed on the working memory by the process of learning itself. That is, moving learning from the working memory into the schemas in long term memory.
Efficient Learning
Reducing Extraneous Cognitive Load
Increasing Intrinsic Cognitive Load
Managing Germanic Cognitive Load
So, if we can manage intrinsic load, reduce extraneous load, allow more room in the working memory for Germanic load then we have better chance of learning being transferred into long term memory.

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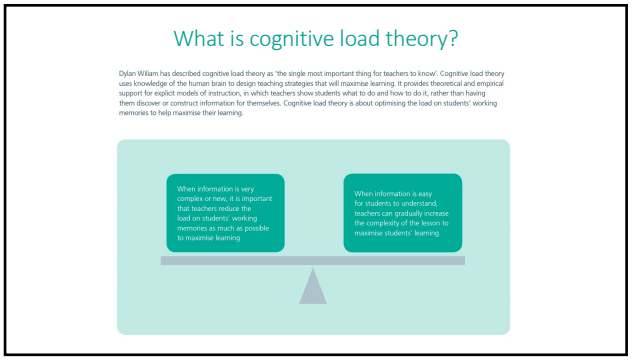
What is cognitive load theory?
Dylan Wiliam has described cognitive load theory as 'the single most important thing for teachers to know'. Cognitive load theory uses knowledge of the human brain to design teaching strategies that will maximise learning. It provides theoretical and empirical support for explicit models of instruction, in which teachers show students what to do and how to do it, rather than having them discover or construct information for themselves. Cognitive load theory is about optimising the load on students' working memories to help maximise their learning.
When information is very complex or new, it is important that teachers reduce the load on students' working memories as much as possible to maximise learning
When information is easy for students to understand, teachers can gradually increase the complexity of the lesson to maximise students' learning

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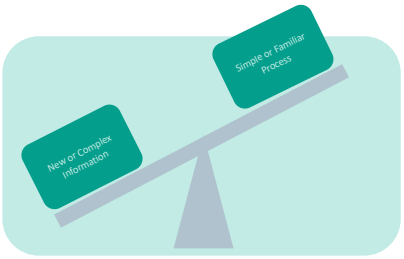
When I need to teach new or complex content?



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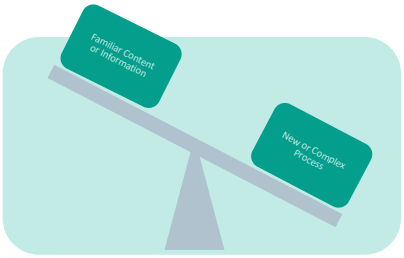
When I need to teach a new or complex process?



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What happens if I teach new or complex content with a new or complex process?

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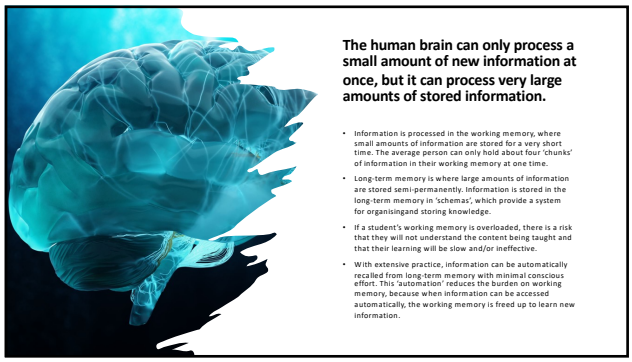

The human brain can only process a small amount of new information at once, but it can process very large amounts of stored information.

- Information is processed in the working memory, where small amounts of information are stored for a very short time. The average person can only hold about four 'chunks' of information in their working memory at one time.
- Long-term memory is where large amounts of information are stored semi-permanently. Information is stored in the long-term memory in 'schemas', which provide a system for organisingand storing knowledge.
- If a student's working memory is overloaded, there is a risk that they will not understand the content being taught and that their learning will be slow and/or ineffective.
- With extensive practice, information can be automatically recalled from long-term memory with minimal conscious effort. This 'automation' reduces the burden on working memory, because when information can be accessed automatically, the working memory is freed up to learn new information.

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Research from cognitive load theory has produced a number of instructional techniques that are directly transferable to the classroom.

- These include the 'worked example effect', which is the widely replicated finding that novice learners who are given worked examples to study perform better on subsequent tests than learners who are required to solve the equivalent problems themselves.
- Another finding is the 'expertise reversal effect', which shows that as students become more proficient at solving a particular type of problem, they should gradually be given more opportunities for independent problem solving.

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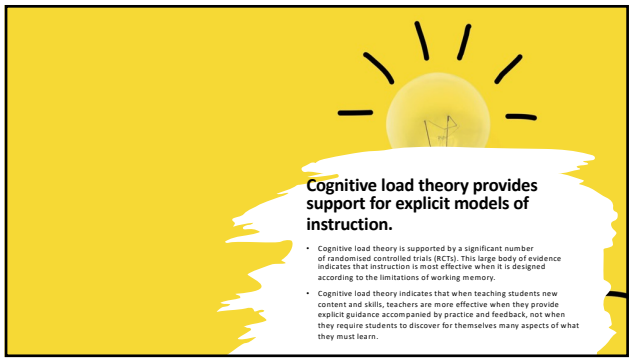

Cognitive load theory provides support for explicit models of instruction.

- Cognitive load theory is supported by a significant number of randomised controlled trials (RCTs). This large body of evidence indicates that instruction is most effective when it is designed according to the limitations of working memory.
- Cognitive load theory indicates that when teaching students new content and skills, teachers are more effective when they provide explicit guidance accompanied by practice and feedback, not when they require students to discover for themselves many aspects of what they must learn.

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Explicit Teaching Strategies

Underpinned by ***Cognitive Load Theory***

STRATEGY 1
Tailor lessons according to students' existing knowledge and skill
'Element interactivity effect'

STRATEGY 2
Use worked examples to teach students new content or skills
'Worked example effect'

STRATEGY 3
Gradually increase independent problem-solving as students become more proficient
'Expertise reversal effect'

STRATEGY 4
Cut out inessential information
'Redundancy effect'

STRATEGY 5
Present all the essential information together
'Split-attention effect'

STRATEGY 6
Simplify complex information by presenting it both orally and visually
'Modality effect'

STRATEGY 7
Encourage students to visualise concepts and procedures that they have learnt
'Imagination effect'

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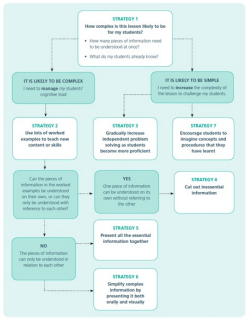
When do I use which strategy?



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STRATEGY 1
Tailor lessons according to students' existing knowledge and skill

Students learn best when teachers tailor lessons to their existing knowledge and skill.

One of the most important implications of cognitive load theory for teaching practice is the need to optimise students' cognitive load, by striking the right balance between too much and too little load. To do this effectively, teachers need to have a strong understanding of where students already sit in their learning. When teaching a lesson that is relatively simple for students to understand, there is room in their working memories to process a little bit more information. In this case, teachers should aim to increase the complexity of the task to challenge their students. But when the task is already complex, there is no room in students' working memories to process any more information. In this case, teachers should focus on reducing the cognitive load.

Why is it effective?

The reason instruction is most effective when it is tailored to students' existing knowledge is because of how human brains learn and use knowledge. Human brains can only process a small amount of new information at once, but can process very large amounts of stored information. For this reason, information that is already stored in students' long-term memory can help reduce cognitive load – and thus result in more effective learning. By drawing on students' existing knowledge, and managing the amount of new information that students have to process at once, teachers can maximise student learning.

How can I use it in the classroom?

Teachers should consider two things when identifying whether a lesson is likely to place a heavy cognitive load on their students:

1. **The number of different pieces of information that need to be understood together to make sense of the material.**

   For example, the knowledge that one added to one equals two is not very complex, because it only has a few pieces of information that need to be understood together. On the other hand, an advanced arithmetic equation is quite complex because it has lots of different pieces that all need to be understood together.

2. **The prior knowledge of the student.**

   Information that is complex for a beginner might be simple for an expert. For example, a student who is just learning to read might find the task of reading the word 'cat' complex, but an expert reader will find this too easy and will benefit from being challenged more.

There are some techniques that teachers can use to make complex information more accessible for students. These include:

The 'part-whole approach'

The teacher breaks the complex task down into a series of sub-tasks, and gradually builds the students' skills at solving each sub-task before eventually bringing the sub-tasks together in the whole task.

The 'whole-part approach'

The teacher introduces the whole task to students from the beginning, but then directs their attention to each sub-task. This context can help students to understand how each of the sub-tasks interact with each other.

When teaching new content to students without much pre-existing knowledge, teachers should provide students with lots of detailed, fully guided instruction.

As the students' knowledge and skill increases, teachers should provide a mix of guided instruction and problem-solving practice.

Finally, as students become very proficient, teachers should provide minimal guidance and allow students to practise their skills with lots of problem-solving tasks. Some students will progress to independent problem-solving faster than others.

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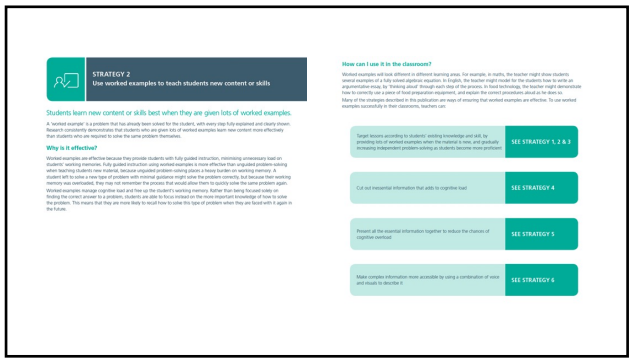
STRATEGY 2
Use worked examples to teach students new content or skills
Students learn new content or skills best when they are given lots of worked examples.
A 'worked example' is a problem that has already been solved for the student, with every step fully explained and clearly shown. Research consistently demonstrates that students who are given lots of worked examples learn new content more effectively than students who are required to solve the same problem themselves.
Why is it effective?
Worked examples are effective because they provide students with fully guided instruction, minimising unnecessary load on students' working memories. Fully guided instruction using worked examples is more effective than unguided problem-solving when teaching students new material, because unguided problem-solving places a heavy burden on working memory. A student left to solve a new type of problem with minimal guidance might solve the problem correctly, but because their working memory was overloaded, they may not remember the process that would allow them to quickly solve the same problem again.
Worked examples manage cognitive load and free up the student's working memory. Rather than being focused solely on finding the correct answer to a problem, students are able to focus instead on the more important knowledge of how to solve the problem. This means that they are more likely to recall how to solve this type of problem when they are faced with it again in the future.
How can I use it in the classroom?
Worked examples will look different in different learning areas. For example, in maths, the teacher might show students several examples of a fully solved algebraic equation. In English, the teacher might model for the students how to write an argumentative essay, by 'thinking aloud' through each step of the process. In food technology, the teacher might demonstrate how to correctly use a piece of food preparation equipment, and explain the correct procedures aloud as he does so.
Many of the strategies described in this publication are ways of ensuring that worked examples are effective. To use worked examples successfully in their classrooms, teachers can:
Target lessons according to students' existing knowledge and skill, by providing lots of worked examples when the material is new, and gradually increasing independent problem-solving as students become more proficient
SEE STRATEGY 1, 2 & 3
Cut out inessential information that adds to cognitive load
SEE STRATEGY 4
Present all the essential information together to reduce the chances of cognitive overload
SEE STRATEGY 5
Make complex information more accessible by using a combination of voice and visuals to describe it
SEE STRATEGY 6

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STRATEGY 3
Gradually increase independent problem-solving as students become more proficient
Students benefit from gradually being given more opportunities for independent problem-solving to practise using the knowledge and skills they have learnt.
While fully guided instruction is very effective for teaching students new material, it becomes less effective as students become more expert at a particular skill. Eventually, fully guided instruction becomes redundant or even counter-productive and students benefit more from independent problem-solving. As students become more skilled at solving a particular type of problem, they should gradually be given more opportunities for independent problem-solving.
Why is it effective?
As students develop expertise in a particular area, the information that was once essential becomes counter-productive. Providing too much guidance can cause more expert students to try and crosscheck the teacher's guidance against what they already know. This crosschecking causes an unnecessary load on students' working memories, but does not add anything to their understanding.
How can I use it in the classroom?
This strategy reinforces the need for teachers to give students more opportunities for independent problem-solving, by:
Omitting some of the steps from a worked example
Gradually giving the students fewer worked examples
Teachers can continuously monitor students' knowledge and skill levels, and adjust their teaching strategies accordingly as students gradually become more proficient at a particular type of skill or area of knowledge.

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STRATEGY 4
Cut out inessential information
Students do not learn effectively when their attention is directed to inessential information.
We sometimes assume that providing students with extra information is helpful, or at the very least harmless. However, presenting students with inessential information can hinder learning. Inessential information can be information that students already know, additional information that is not directly relevant to the lesson, or the same information presented in multiple forms.
Why is it effective?
When students are provided with inessential information, they may not be able to distinguish between the information that they need to understand the lesson, and the inessential information that does not contribute to their learning. The inessential information adds to the load on their working memory, but does not contribute to their learning. If students' working memories are overloaded, it is harder to transfer knowledge into their long-term memories and learning is inhibited.
How can I use it in the classroom?
For lessons that students find very challenging, extra information that is not directly relevant to the lesson should be minimised. For information that is less complex, it is not as important to minimise extra information.
Information that is essential for beginning students might become redundant as they become more advanced. For example, for students who have just begun learning Spanish, it might be very important to provide a reminder of how to conjugate verbs. For students who are proficient Spanish speakers, this extra information is redundant and might distract them from the lesson.

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STRATEGY 5
Present all the essential information together

Students do not learn effectively when their limited attention is split between two or more sources of essential information that have been separated.

Cognitive overload can occur when students have to split their attention between two or more sources of information that have been presented separately, but can only be understood in reference to each other.

Why is it effective?

Presenting information in a split format means that students have to hold two separate pieces of information in their heads at the same time, and mentally integrate them. This can overload the working memory and inhibit learning. Cognitive overload can be avoided by presenting separate sources of information together.

There are two types of split information, which teachers should avoid:

Split by time

✗ A maths teacher explains how to solve an algebraic equation but does not show the students an example of the equation until several minutes later.

Split by space

✗ A biology textbook includes a diagram of the human respiratory system on one page, but does not provide a description of each respiratory organ until the next page.

How can I use it in the classroom?

The table below shows some lesson formats that include multiple sources of information, and gives examples of how they could be changed from a split format to an integrated format.

Lesson format	Example	Split format	Integrated format
A combination of diagrams and written explanations.	A science lesson on the life cycle of a frog.	Students are given a diagram illustrating the life cycle of a frog, but the written explanations of the different stages of the life cycle are provided in a separate text box below.	The written descriptions of each stage of the life cycle are incorporated directly into the diagram, as close as possible to the relevant section.
Two or more sources of written information.	A language lesson in which students have to translate a passage of text with unfamiliar words.	Students are given an extract of text written in French, and a French-English dictionary to look up unfamiliar words.	The vocabulary translations are incorporated into the passage itself, directly above each unfamiliar word.
Students read instructions while learning to operate a piece of software or equipment.	A lesson on how to use an Excel spreadsheet to create mathematical formulas within cells.	Students are given a printed set of instructions to follow while they enter the formulas into the cells.	The instructions are incorporated directly into the spreadsheet, with each instruction positioned in the cell adjacent to where the formula needs to be created.

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STRATEGY 6
Simplify complex information by presenting it both orally and visually

Students can process complex information more easily when it is presented in both oral and visual forms at the same time.

When there are two or more sources of information that can only be understood in reference to each other, cognitive load can be managed by presenting information both orally and visually. This strategy increases the capacity of students' working memories, creating more mental space for learning.

Why is it effective?

Our working memories have two separate 'channels' – one for dealing with visual information, and another for dealing with auditory information. By spreading the delivery of information across both of these channels at once, teachers can manage cognitive load and make it easier for students to learn the information. This can be done by communicating information using both images and sound. For example, the teacher could show students a diagram, and explain it orally at the same time.

How can I use it in the classroom?

Combining oral and visual information is particularly effective for teaching content that is very complicated and difficult to understand. Students' working memories can easily be overloaded by trying to process a lot of new information that is only presented visually, such as a combination of written descriptions and diagrams. Teachers can manage students' cognitive load in situations like this by communicating some of that information verbally – such as by removing the written descriptions from the diagrams, and reading the descriptions out loud instead.

It is important to remember that this strategy only applies to essential information. Information that is not essential to the lesson should be removed.

The strategy of combining oral and visual information is particularly effective for teaching students very well-defined material, such as technical procedures or mathematical processes. The strategy is not known to be as effective in areas that are less well-defined, such as the creative arts.

For this strategy to be effective, teachers should:

1. **Break down spoken explanations into short, simple statements.**

   Using long, complex sentences in spoken language places large demands on working memory because the student has to retain lots of information in order to understand each sentence. This does not leave much capacity for absorbing new information.

2. **Use visual cues to indicate which section of a diagram they refer to.**

   This could be done simply by pointing to the relevant section of the diagram. This is important because, if students have to listen to a verbal description while also searching for the relevant section of the diagram, they are likely to experience cognitive overload.

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STRATEGY 7
Encourage students to visualise concepts and procedures that they have learnt

Students understand and recall information better when they visualise the things they have learnt.

Encouraging students to visualise what they have learnt helps them to better understand and recall the information. Once students have a good grasp of the content, the mental process of visualising helps students to store the information more effectively in their long-term memories. This strategy should only be used once students are familiar with the content, as visualising imposes quite a heavy cognitive load.

Why is it effective?

The process of visualising means mentally reproducing a procedure or concept. For example, a student learning how to solve a geometry problem might visualise each of the steps required to reach the solution. When students have to visualise something they have learnt, they are required to retrieve information held in their long-term memory and process it in their working memory. This mental process helps students to engage with information more deeply, and to begin to recall it automatically without much conscious effort.

How can I use it in the classroom?

Recalling something takes up a lot of mental resources, so these strategies will only be effective if there is enough mental space available in the working memory. For this reason, visualising concepts is a very useful practice once students have a good grasp of the content, but should not be used for students who are new to the material.

Encouraging students to visualise concepts is a way of adapting teaching strategies to suit more proficient learners. In this way, the strategy is similar to the approaches of omitting steps from a worked example or gradually giving students fewer worked examples. This strategy is often more effective than 'fading out' guidance, because it avoids providing redundant information.

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Summary

- Students who experience explicit teaching practices, accompanied by effective feedback, make greater learning gains than students who do not experience these practices, and the evidence for this is long standing.
- Cognitive load theory provides theoretical and empirical support for explicit models of instruction. The research demonstrates that for novice learners, explicit instruction, incorporating direct guidance accompanied by practice and feedback, is more effective than partial guidance.

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