Cognitive Load and Education

Abstract

Teachers and academics are becoming increasingly interested in the application of cognitive science to education, as they work to make sure learning is the most effective it can be. Cognitive load theory, a key theory in cognitive science, has long been the source of academic debate, but it is now also widely used in practical education settings. However, many teachers are unsure of the term and how it relates to their teaching methods. This article explains the meanings and practical applications of cognitive load theory and related concepts in cognitive science. It also connects these theories to argument mapping and explains how Endoxa Learning visualises arguments to make them easier to learn than the traditional method of writing arguments as prose.

Defining Cognitive Load Theory

Cognitive load theory has been around for over three decades, but it wasn't until the last few years that it really started to take off in education. Sweller (1988) first introduced this concept that our long-term memory is practically infinite, whereas our working memory is limited. So if we overload our working memory, we are unable to commit information to our long-term memory. To ensure learning is effective we need to avoid adding too much "cognitive load".

Teachers Recognise Cognitive Load, But Don't Know the Theory

Most teachers know a bit about cognitive load theory and many are successfully integrating it into their teaching methods. However, a survey by Teacher Tapp found that while most teachers are aware of cognitive load theory, "only 15 % of teachers" knew the three distinct types of cognitive load (Teacher Tapp, 2019).

Types of Cognitive Load

Imagine telling a student to read a list of European capital cities and to recite it perfectly a while later. This is the information that we are going to expect the student to learn. It will form the **intrinsic cognitive load** of the learning experience, which means that it is the unavoidable load associated with learning this information (Paas et al., 2003).

Now imagine teaching these capital cities by showing a loud, music-filled video clip from each city's tourist agency, while asking the student to sort the cities into alphabetical order. It sounds fun, but this is where we risk cognitive overload. Additional cognitive resources are taken up trying to make sense of this additional information, which we call

extraneous cognitive load. This becomes a problem when there is already a high intrinsic load because the student's working memory is split between these two types of cognitive load. If the student's mind is occupied by extraneous load, they might reach the limit of their working memory and forget the capital of Greece.

To make it easier for the student to deal with the intrinsic load, you might remind them of a lesson that you taught on Greece last term, when they learned that the Parthenon is a popular tourist destination in the capital city of Athens. This encourages the student to use their **germane cognitive load**, which is an important aspect of the learning process. The germane load is the load associated with linking new information with knowledge that already exists in the long-term memory. We can more easily learn new information if we link it to pre-existing knowledge. The germane load is also part of the working memory limit. So, if the extraneous load is too great, the student might struggle to make this link and as a result they might struggle to learn the new information.

Other Important Details

Element interactivity is an important aspect of cognitive load. This refers to the complexity of the information being learned, based on how its different "elements" interact. The greater the element interactivity of the information that needs to be learned, the greater the intrinsic load (Blayney et al., 2010). So, learning that Paris is the capital city of France is easier than learning the timeline of the French Revolution. Element interactivity also affects the extraneous load, such as when a piece of text uses highly descriptive, vocabulary-intensive language to teach a simple concept that could be taught in a few simple words (Sweller, 2010).

To reduce the challenges to cognitive load that are introduced by high element interactivity, we can make use of the **isolated-interactive elements effect** (Blayney et al., 2010). When high element interactivity pushes cognitive load to the limit, we can help students to learn by presenting the information as multiple smaller elements. These "isolated" elements can be processed more easily and once learned, reconnected to learn the entire concept.

Importantly, this effect benefits students with a low level of knowledge, but is no longer helpful once the level of knowledge is very high (Pollock et al., 2002). This is called the **expertise reversal effect**.

The "elements" that make up a piece of information vary by person, depending on the **schemas** that they have acquired. Schemas are mental constructs that a person develops which allow them to process more information without overloading their limited short-term memory (Paas et al., 2003; van Merrienboer and Sweller, 2010). For example, a young child might develop a schema about a dog including the characteristics of having four legs and fur. They can then easily add more information to this, such as that most dogs are friendly. When they walk down the street and come across an animal matching this description, they will now be able to easily recognise that it is a dog – and therefore quickly realise that it is probably friendly. But if they go to the zoo, they might see another four-legged, furry creature. However, this one is orange, has stripes and isn't friendly. The child will need to develop a new schema for the tiger, but the existing schema of the dog will make this process easier. With enough schemas about different animals, the child can more easily develop more complex schemas, such as a schema for mammals or the food web.

Sweller (1994) gives the example of an algebraic problem, which mathematicians will be able to easily solve regardless of the exact numbers that are inserted into the equation. This is because they are able to store the equation as a single schema in their long-term memory. The mathematician will use this equation many times as part of their work and the method will be the same each time. This also means that they can **automate** the process, so that the limited working memory is free to be used for other purposes. The more schemas a student can acquire and the more information they can fit into a single schema, the more easily they can learn complicated concepts and apply them without cognitive overload. This also reduces the number of elements that make up a concept that is being learned.

<u>The Cognitive Load of Reading Arguments as Prose</u>

A geography student might need to learn the scientific argument that humans are causing climate change. This argument would usually be written out as prose (i.e. paragraphs of text), and is a lot of information for the student to take in at once. Prose normally includes additional information apart from the argument, or complicated vocabulary, that add to the **extraneous load**, making it harder for the student to learn the argument. In addition, element interactivity of argumentative prose is high, since the relationships between different statements may not be obvious in text, requiring students to work out how they fit together to create an argument (Dwyer et al., 2011).

It is important to remember that text in the form of prose is linear, while arguments are usually branched. This means that reading an argument that is written in prose can require switching backward and forward between paragraphs to fully understand the argument Dwyer et al. (2012). This "**attention switching**" makes learning slower and less effective since it also increases cognitive load (Tindall-Ford et al., 1997; Dwyer et al., 2012).

So how can we address these problems?

Cognitive Load and Argument Mapping

Argument mapping is a method of presenting arguments as diagrams that aims to make the arguments easier to follow and learn. Cognitive load theory and its related concepts can be applied to this.

Argument mapping was developed as a way of reducing the cognitive load involved in learning arguments (van Gelder and Rizzo, 2001). In an argument map, the extraneous load is reduced by only including simple statements that are essential to the argument. Clark and Paivio (1991) discuss the difference between "concrete" words, which have clear meanings, and "abstract" words, which have unclear definitions and can be interpreted in different ways. In textbook prose, students can stumble over abstract words, which may lead to difficulty understanding or learning the information. By using argument mapping, we can avoid this hurdle by limiting text to "concrete" words and related images.

Furthermore, the relationships between different statements are clearly signified by arrows that connect them, and the diagram is structured non-linearly to make the overall structure of the argument more obvious (Dwyer et al., 2012) and eliminate attention-switching.

Argument mapping further reduces the challenge of **element interactivity** by dividing arguments into individual steps, allowing each step of the argument to be read and learned individually. This follows the isolated-interactive elements effect and helps students to learn complicated arguments without facing **cognitive overload** (Blayney et al., 2010).

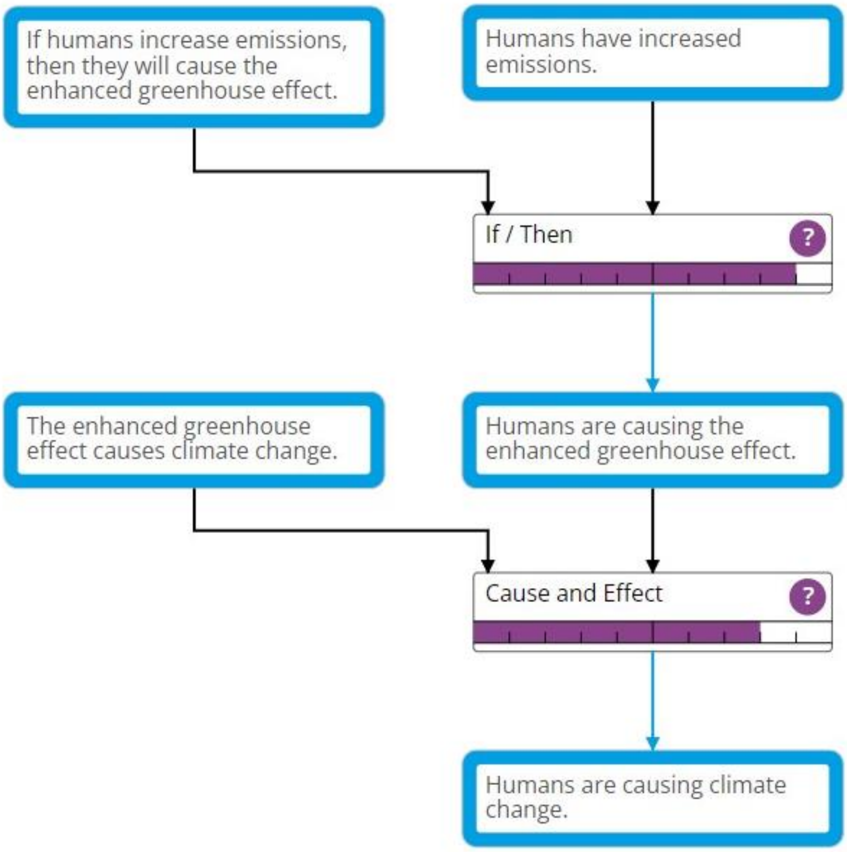

Figure 1: A simple argument graph, mapping two steps of an argument about climate change

At Endoxa Learning, we call these diagrams 'argument graphs'; each lesson in our software is based on an argument graph. Endoxa Learning first introduces students to argument steps individually and in order, before showing the entire argument graph.

Let's look at the example of a student studying the argument that humans are causing climate change. If this argument is completely new to them, trying to immediately get from "humans have increased emissions" to "humans are causing climate change" might not make sense, because they have not developed a schema about the relationship between emissions and climate change. In an argument graph (Figure 1), the student can first focus on the connection between greenhouse gas emissions and the enhanced greenhouse effect. Once they have grasped this connection, they can move onto the relationship between the enhanced greenhouse effect and climate change. This allows the student to learn the argument without experiencing cognitive overload. Written as prose, the connections between these individual concepts would not have been as obvious.

Endoxa Learning uses a limited menu of 'argument types' (known as 'argumentation schemas' in the literature) which connect premises to conclusions and are models of different kinds of reasoning. Students quickly get used to these (automation), which makes understanding an argument much faster. For example, in our software, there is one argument type for 'Analogy', but in prose, there are countless ways in which an analogy can be presented. Argument types also make it much easier to spot bad reasoning. Once a student is comfortable with an argument type, they can see what kind of premises are required to reach a given conclusion and vice-versa. This also makes arguments quicker for teachers to check.

As the length and complexity of argumentative prose increases, so do the cognitive load benefits of using an argument graph. Argument graphs for longer arguments will have multiple sections. Students who have had some experience with reading argument graphs can start to skip over individual argument steps and go straight to reading a whole section of the argument graph at a time. The student will have automated the process of reading an argument graph, following the expertise reversal effect.

Finally, we believe that one of the most beneficial aspects of argument graphs is their ability to save cognitive load on understanding text, so that the student can quickly start to add their own ideas to the argument. By reducing extraneous load, we encourage the student to recall related knowledge using their **germane load**. The student can make links between the argument graph and this existing knowledge by using our unique **edit mode**. Our argument graphs don't just help students to learn arguments. They encourage them to expand on them and to confidently apply their own knowledge to complex academic concepts.

Click here to read more about how our argument graphs work.

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