Endoxa Learning White Paper

Contents

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Abstract

Endoxa Learning visualises academic arguments to help students learn key subject knowledge while improving their critical thinking skills. They are guided through subject-relevant arguments step by step, with facts and context exactly where needed. Our lessons are the ideal way to introduce students to the arguments, improve essay-writing and develop the important life skill of critical thinking.

Endoxa Learning content covers KS3, KS4 and KS5 curricula (year 7 to year 13). It is a web app which runs in the computer's browser, so no software has to be installed, and is suitable for desktop, laptop and tablet computers.

Website: https://endoxalearning.com

The Importance of Critical Thinking

What is Critical Thinking?

Critical thinking *is "reasonable, reflective thinking that is focused on deciding what to believe or what to do."*
- Ennis (1989, p. 4)

The definition of critical thinking has been debated by academics, but it always includes the idea of *reflectiveness*. This means we actively think things through for ourselves, raise questions and find information. Fisher (2021) argues that "critical thinking is contrasted with *unreflective* or *passive* thinking, the kind of thinking that occurs when someone jumps to a conclusion, or accepts some evidence, claim or decision at face value, without really thinking about it". So, critical thinking is about really thinking about things, before reaching a conclusion, or taking a decision.
Critical thinking is *reasonable*. We have to give reasons for what we believe and what we decide to do. In other words, we have to make an argument for them, carefully considering our assumptions and evaluating our reasoning. This puts making arguments at the heart of critical thinking.

So how do we think critically and avoid jumping to conclusions? There is wide agreement that critical thinking is a set of skills which can be learned, practiced and improved. The 'Delphi Report' (Facione, 1990) was the result of a process lead by the philosopher, Peter Facione, involving 46 experts in the critical thinking field. The objective was to define critical thinking and make recommendations to educators. Facione (1990) found a consensus among academics as to the skills required for critical thinking. These skills also feature in other academic works, such as Fisher (2021).

At Endoxa Learning, we have used the expert literature on critical thinking to develop the following list of critical thinking skills.

- **Interpretation**: categorising information; decoding conventions; clarifying meaning
- **Analysis**: detecting and analysing arguments to identify their structure, conclusion, premises (and missing premises) and logical relations; sorting out irrelevant material
- **Evaluation**: judging the truth of statements, the credibility of sources and the strength/validity of arguments; anticipating objections and how additional information might affect an argument
- **Argument Creation**: supporting premises; formal and informal reasoning; presenting arguments and drawing conclusions; considering alternatives; justifying methods

The first three skills are for dealing with inputs from other people, while argument creation is how we use those inputs to develop our own argument. The outcome of a critical thinking process is to produce one's own argument for one's own conclusion.

Critical thinking is also a value-laden activity. The expert sources agree that critical thinking demands critical thinkers with the right values. Facione (1990) goes into great detail about the 'dispositions' the ideal critical thinker should possess. We have simplified this list to highlight these four values, which we think capture the spirit of critical thinking.

- **Fair-mindedness**: making, changing or suspending beliefs according to the evidence; evaluating one's own arguments with the same level of scrutiny as others'

- **Inquisitiveness**: being curious and questioning; taking care be generally well-informed; willing to consider alternatives
- **Open-mindedness**: willing to give the other side a fair hearing; being open to divergent world views; being honest and self-critical in facing one's own biases
- **Confidence**: evaluating and challenging received opinions; belief in one's ability to reason

Leaning and practicing critical thinking in education involves internalising these values, which are vital for success in later life.

Why is Critical Thinking Important?

As knowledge becomes ever more easily available via the internet, critical thinking is becoming one of the top skills recruiters look for – and this trend is expected to accelerate. The Future of Jobs Report (WEF, 2018) predicted that the technological advancements of the 4th Industrial Revolution will cause some skills to emerge as the most important for the 21st century. Critical thinking is one of these skills and is listed as an important emerging skill in many countries in the report.
Critical thinking is one of the '3C's' (critical thinking, complex problem solving, creativity) - identified as the three most important 21st-century work skills by the World Economic Forum (WEF). These three skills will be crucial as technological advances reduce the need for many traditional jobs, while opening doors for new jobs that require 'soft' skills like critical thinking. For this reason, it is essential that critical thinking skills are emphasised in education.

Top 10 skills in 2020 and 2015, showing critical thinking as high and rising into 2020 (Soffel, 2016)

There is also a wider context in which society requires its citizens to possess critical thinking skills. If critical thinking is crucial for decision making, it must be crucial to democracy. This skill is important to learn because "it helps the citizen to form intelligent judgements on public issues and thus contribute

democratically to the solution of social problems. Perhaps at no time in our history has wider realization of this educational objective been more urgently needed" (Glaser, 1985, p. 27). This statement is equally true today as when it was made.

Furthermore, Ennis' (1989) definition would suggest that critical thinking is applicable and crucial for decision making in many aspects of life. Indeed, Facione (1990) found that "critical thinking is vitally important in the personal and civic life of all members of society" and that "like reading and writing, critical thinking has applications in all areas of life and learning." This sentiment is repeated by other authors:

Critical thinking is *"an academic competency akin to reading and writing*" – Fisher and Scriven (1997)

Lastly, critical thinking is clearly important for education. The requirements for critical thinking increase as the student advances through secondary school and on to further or higher education. At A level, the reforms introduced from 2015 increased the proportion of marks for assessment objectives related to critical thinking, e.g. in questions using command words such as "analyse" and "evaluate". In higher education, the requirement to master argument is essential, so universities value critical thinking skills very highly. In a survey of over 1000 teachers, 92 % listed critical thinking as "one of the most important skills … needed for success in higher education" (Stewart, 2014).
The literature supports the idea that "critical thinking instruction should not be reserved only for those who plan to attend college. Nor should it be deferred until college, since it is not likely to be effective if it were." (Facione, 1990). Given only half of students will enter higher education, it is important that critical thinking training should start earlier in a student's academic career, at secondary school (if not earlier). If students learn critical thinking skills in school, they will have more success whether they decide to enter higher education or not.

"In middle schools and high schools, instruction on various aspects and applications of critical thinking should be integrated into all subject area instruction." - Facione (1990)

The Problem

Mastering Critical Thinking is Difficult

Critical thinking is difficult for students. The survey mentioned above found that 85 % of teachers thought critical thinking skills were inadequate when students reached post-16 education, while 56 % said the same of students going into higher education (Stewart, 2014). Accordingly, many universities have decided to run critical thinking courses for their students, however Arum and Roska (2011) argue that students struggle to improve their critical thinking skills once at university.

The qualitative research that we undertook in schools revealed some of the typical worries that students have such as: losing track of the argument; not planning the argument before starting the essay; including irrelevant information. Examiners' reports consistently point out the lack of a good argument in exam entries. Moreover, teachers are expressing concern with regards to teaching of and critical thinking skills. Students are often much better at learning facts and case studies than making a good argument to answer the question. The requirements to think critically have increased, but the textbooks and training have not always kept up.

> *"We should be teaching students how to think. Instead, we are teaching them what to think."*
> (Clement, 1979, p. 1)

Some teacher insights on critical thinking in education:

> *"You used to get by with a list of points for and against, now you have to make an argument."*

> *"A Levels are so content-heavy, there is no time to teach technique [such as making an argument]."*

Why is Mastering Critical Thinking Difficult?

In school, students are introduced to critical thinking by reading and writing arguments in prose. The textbooks, articles and original sources they read are in prose, as are the essays they write. But prose is not the optimal way to represent an argument. Why is this?
Firstly, students cannot look at argumentative prose and immediately find the argument. Prose makes no distinction between the sentences which are part of the argument and those which do other things, such as supporting facts and context. So the argument is hidden amongst other information, much of which is distracting or even irrelevant.
Secondly, prose is linear, but arguments are usually branched. Students cannot understand the structure of the argument by looking at the prose. Moreover, the whole structure has to be kept in mind when evaluating the argument. For example, if they find a counter-example to one step of an argument, they need to know the structure to realise whether this defeats the whole argument or just a part of it.

> Argumentative prose "*contains many more sentences than just the propositions that are part of the argument, but also, … proceeding necessarily linearly, the prose obscures the inferential structure of the argument*" (Harrell, 2004)

For these reasons, argumentative prose imposes a heavy cognitive load on the reader. Students are obliged to work hard to discover what an argument is about before they can even begin to critique it. If students cannot recognise a good argument in prose, this can limit their understandings of key critical thinking skills: interpretation, analysis and evaluation. In turn, this can limit the student's ability to create their own arguments. This is especially difficult for those who have reading difficulties such as dyslexia.

School students normally create their own arguments in prose by writing essays. Prose is a very flexible medium; it can be used for arguments, stories, reports, descriptions, and so on. But this flexibility also allows argumentative writing to be unrigorous, ambiguous, or irrelevant. Many students' writing lacks cogency. Even if they are well-informed they write a lot of facts without pulling them together into an argument.

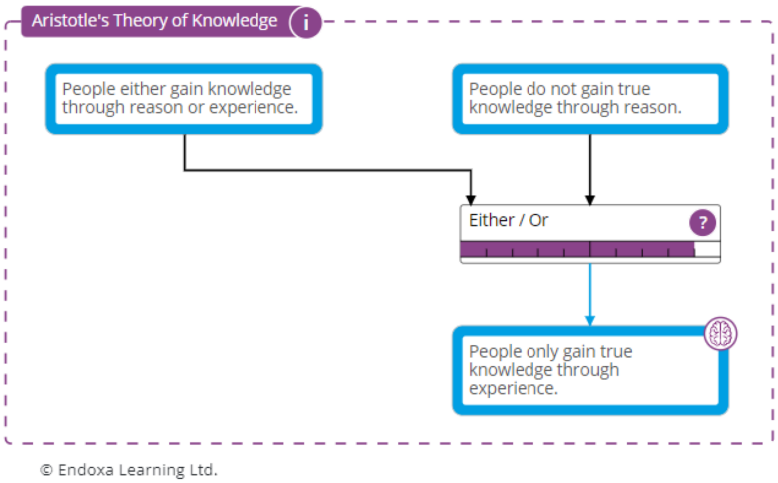
The teacher gives corrective feedback to the students' essays, but it is difficult to point out exactly how an argument is at fault, because prose hides and obscures arguments. School students and their teachers are therefore involved in a very complex loop of writing essays and giving feedback, which lasts for years and, for many students, does not result in robust critical thinking skills being acquired. Lundquist (1999, p. 529) argues that in higher education, students often default to "uncritical thinking", because "a focus on results rather [than] on the process makes uncritical thinking a rational response from students". Students work hard to improve their feedback, without really learning the critical thinking that underpins a good argument.

Lastly, there are practical difficulties with argumentative prose. It is slow to read and very slow to write. It is also slow for teachers to check and mark. And it is very difficult for students to collaborate on a prose work, such as an essay, since prose is not mergeable.

The Solution

The Argument Graph

An argument graph (also called an argument map) is a diagram which represents an argument visually, using a simple set of colours and shapes and a minimum amount of text. Argument graphs make use of dual coding, which involves using a combination of written or verbal information and visual information, thereby "increasing the likelihood that we will remember the concept" (Ofsted, 2019, p. 21). At Endoxa Learning, we use argument graphs to integrate critical thinking into secondary school subject content, using the visualisation of the argument to help the student to remember and understand it. Each argument graph is presented as an interactive lesson, which takes the student through subject knowledge and argument logic simultaneously. In this way, Endoxa Learning introduces students to argument without the complexity of prose. Arguments on any subject and of any complexity can be represented using an argument graph. Even very subtle arguments can be easily explained with this method. As a result, argument graphs have been found to improve critical thinking abilities in students (Harrell, 2012; Cullen et al., 2018; Davies et al., 2021).

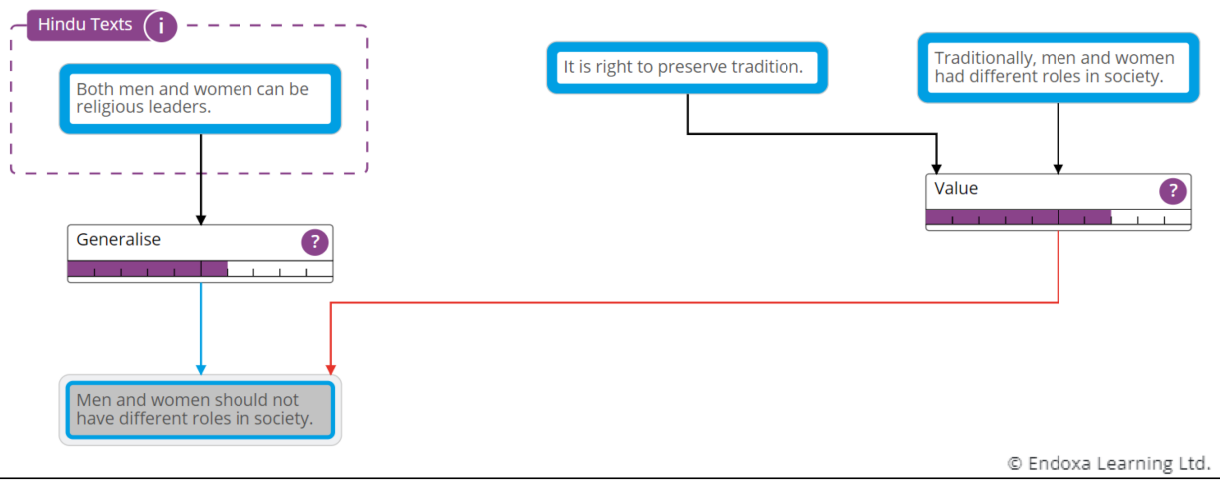


This is a single step of an argument graph in an Endoxa Learning lesson. There are three statement nodes and a connection node called an "argument type". "*Either/Or*" is one of 12 argument types, which classify different kinds of inference. The black arrows show that the two statements above are premises, the blue arrow reaches the conclusion at the bottom.

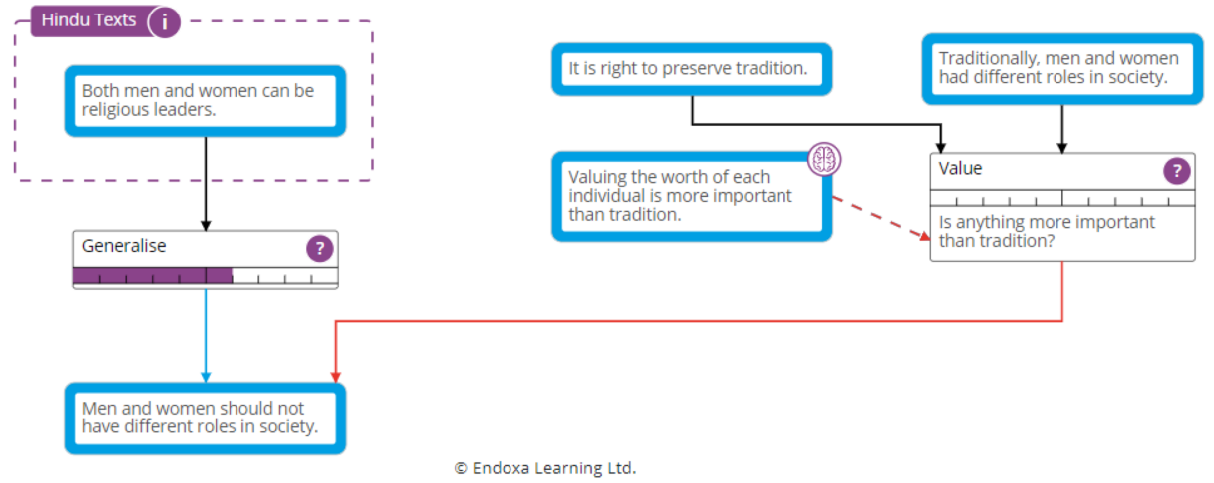
In this example, contextual information can be found by clicking the box "Aristotle's Theory of Knowledge"; factual information can be found by clicking the brain icon on the conclusion statement.

Endoxa Learning provides teachers with argument graphs that take their students through an argument on a particular topic. Contextual and factual information is available to the student, but it does not distract from the argument. Students are incentivised to click on knowledge and scenario boxes to earn virtual "coins", so they can learn the relevant subject content.

Argument graphs say with pictures what can take many words to explain. They also avoid a lot of technical critical thinking jargon.



In this example, the *Generalise* step is connected to the conclusion with a blue "pro" arrow. The *Value* counter-argument step is connected to the same conclusion with a red "con" arrow, so it rebuts the *Generalise* step. Since the two argument steps are in conflict the conclusion is greyed out. The student knows that the conflict has to be resolved to reach a coherent argument.



The conflict is relieved by an evidence statement which addresses a "critical question" and undermines the *Value* argument so the conclusion becomes true. Each argument type has its own critical questions, which help the student to think how it can be supported or undermined.

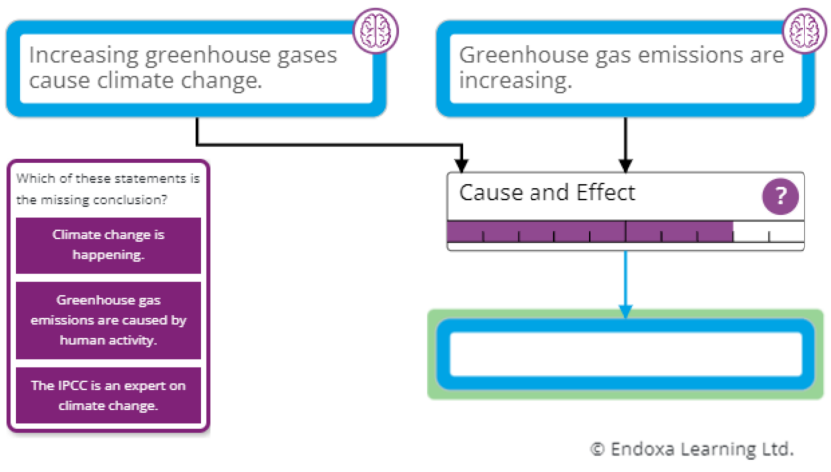
Each lesson is divided into three sections: The core argument, an additional supporting argument and a counter-argument. The latter is an ideal way to introduce the student to differing opinions on a subject. Each counter-argument causes a conflict with the previous arguments, which needs to be solved. To solve the conflict, the counter-argument is then either defeated or shown to cast doubt on the previous arguments. This makes Endoxa Learning stand apart from the lists of pros and cons that have traditionally been used to introduce students to argument. The argument graph discusses different sides of an argument in a way that shows their interrelations and effects on other aspects of the graph.

As a result, the student learns that good argument creation is about more than the number of pros versus cons.
Reasoning is immediately evident in an argument graph, which means that a reader can easily understand an argument and identify its weaknesses. At each step, the student can add their own notes or disagree with the statements in the argument. Therefore, the format of the lesson encourages the student to think ahead and to critique the argument, rather than treat it as a "black box" of undisputable knowledge. This process is challenging when reading an argument in a textbook, since a poor argument can be hidden easily within prose (Davies et al., 2021).

Low-Stakes Testing

Scholars have argued that the benefits of an argument graph for critical thinking can be enhanced by using automated feedback (van Gelder, 2015). Endoxa Learning lessons include automatically-marked questions, so that low-stakes testing can be done without adding additional marking to the teacher's workload. As the student progresses through an Endoxa Learning lesson, automated testing is provided in two ways:

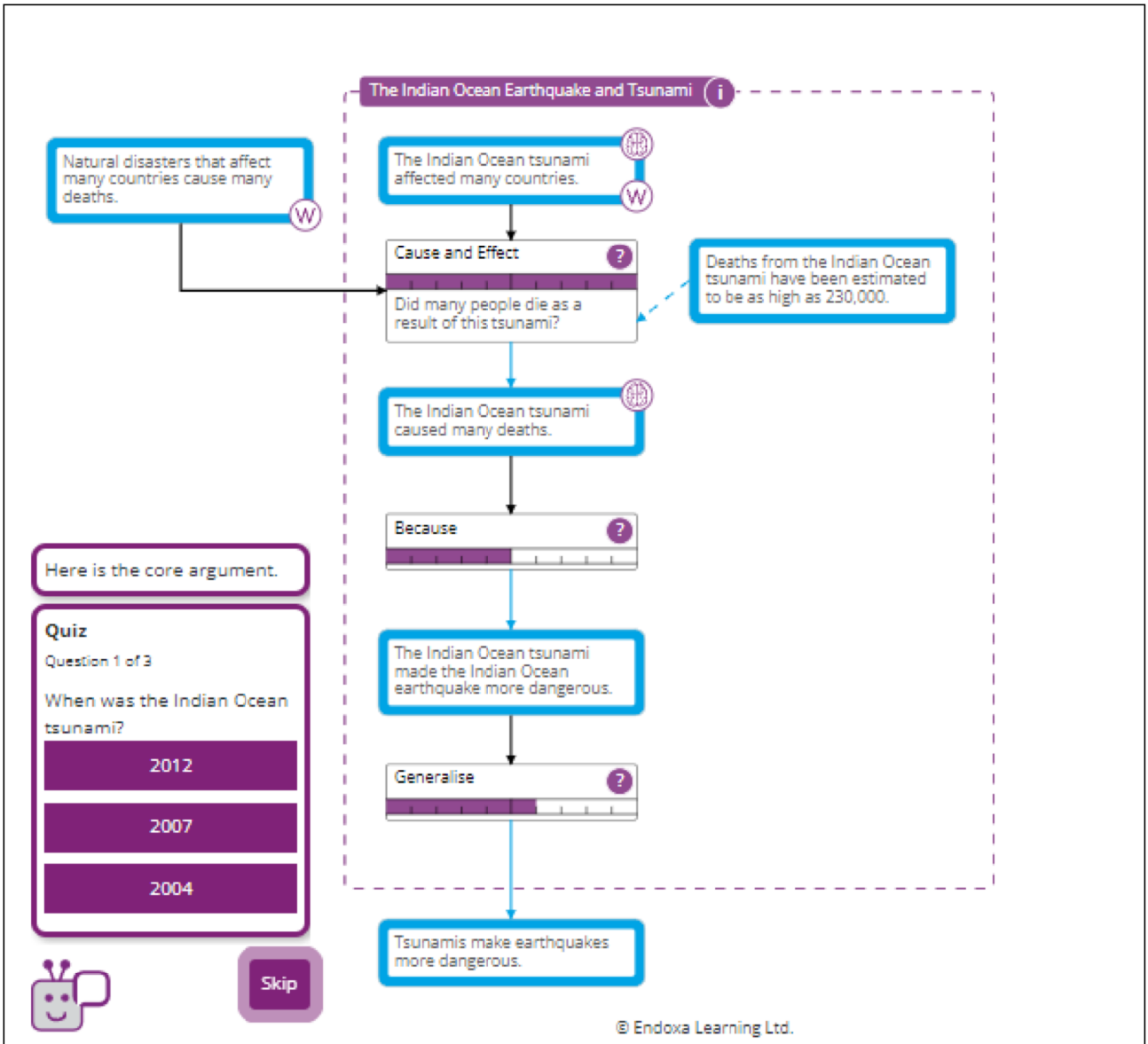
Tasks:



In this task, the student needs to choose the correct conclusion for the argument step. To complete the task, the student should understand that the argument step is discussing a causal relationship between greenhouse gases and climate change. Rather than testing subject knowledge, the task tests the student's understanding of the argument.

Constructing arguments is new to KS3 students and limited in higher year groups, so Endoxa Learning ensures that students are able to understand argument steps. Tasks appear during the lesson, and students choose the correct statement to fill the empty premise, conclusion or evidence statement box, quickly showing whether they have understood the argument that is being made. Each possible answer may be a true statement, but only one can be reached logically from the argument step premises. Coins are earned for correct answers, with the number of coins decreasing with each attempt.

Quizzes:



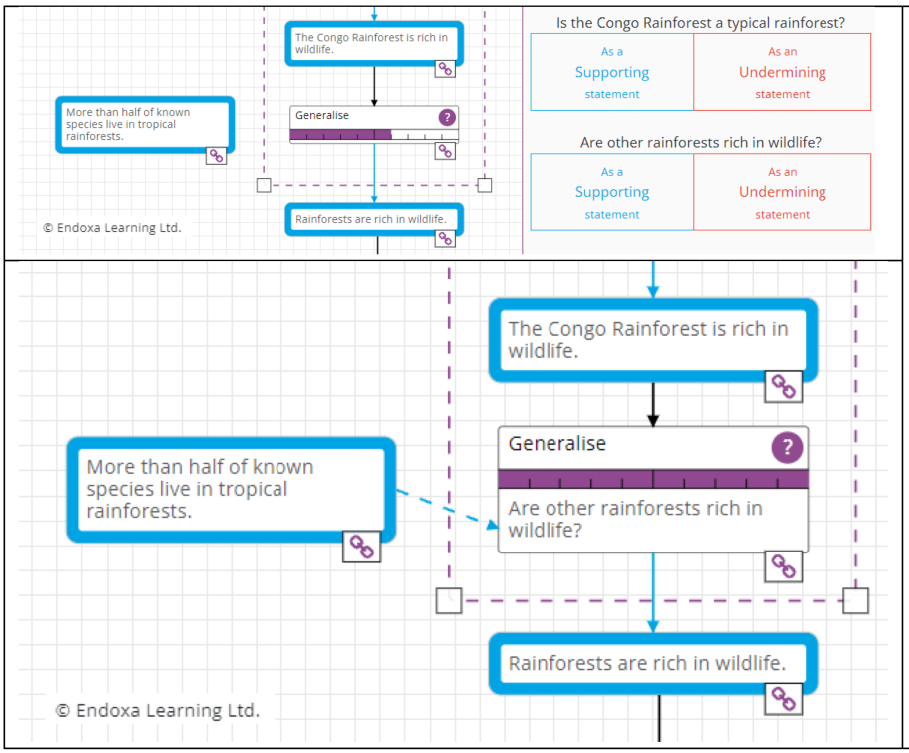
At the end of each section of the lesson, the student can view the whole argument. A quiz is used to test subject knowledge as well as understanding of the argument.

Answering quiz questions also earns coins. Quiz questions test on aspects of the lesson such as definitions, contextual and factual knowledge and the argument itself. Earlier questions focus more on the first two aspects, while the student's understanding of the argument is tested more at later stages. If the student does not remember the answer to a question, the answer is found by clicking on the diagram, or by re-reading the argument steps. In this way, the quiz checks engagement with the argument, rather than acting as a test of memory.

Editing the Graph

Endoxa Learning has worked alongside teachers and test classes to find the perfect balance between student engagement and lesson complexity. The sections above illustrate the benefits of tasks and quizzes, but we also recognise the importance of encouraging students to create their own arguments. Throughout the lesson, students are able to express whether they agree with statements or not, and they can also make notes about why they have chosen that truth value. This information can be

revisited at the end of the lesson when the entire argument graph is visible, in “edit mode”. At this point, students are given the opportunity to alter and add new content to the existing argument graph, using the critical questions and their notes as a guide. The evaluation system ensures that the student’s additions are coherent, so that they can construct strong arguments.



One of the ways that a student can edit an argument graph is by using evidence to support or undermine an argument step. In this example, the student has added some supporting evidence about tropical rainforests in general. By adding evidence from their own knowledge, the student has strengthened this argument step from the original argument graph.

Edit mode provides a great opportunity for low-stakes testing of the student’s argumentative ability. This part of the lesson is particularly useful for students at GCSE and A Level, when constructing an argument becomes increasingly important. Davies et al. (2019, p. 117) argue that giving students the opportunity to experiment with an argument graph helps them to better understand how it is structured and encourages them to “more actively engage with critical thinking tasks than they would do otherwise”.

The student's edited argument graph is also stored, and can be used as a visual essay plan. The graph provides the opportunity for “retrieval practice”, where the lesson and the edited graph are revisited after a length of time. Retrieval practice is known to encourage “effective retention of knowledge in the long-term memory” (Ofsted, 2019, p. 20). The student will also use it for revision for exams. Edit mode is also a great opportunity for students to practice “elaboration”, an activity whereby students explain their argument to others, “making connections among ideas and connecting the material to one’s memory and experiences” (Ofsted, 2019, p. 20).

Research

The Theory of the Argument Graph

An argument graph is part of a class of diagrams used in education called "graphic organisers". These are diagrams combining text, data and graphical symbols to convey information in a way that promotes learning. A simple example would be a bar chart, which can convey the trend of a data series more vividly than a table of numbers. Argument graphs, on the other hand, display an argument in discrete steps, "chunking" it so that it can be understood more easily. This visualisation makes them suitable for improving critical thinking (Davies et al., 2021).

There is a sound theoretical and empirical basis for the visualisation of information. Cognitive load theory hypotheses that our working memory is limited, while our long-term memory is almost unlimited. Information is transferred from the working memory to the long-term memory, but this will be hindered if the working memory is overloaded. The ideal teaching method should therefore maximise the amount of knowledge that is retained in the working memory, and then committed to the long-term memory. "Dual Coding" theory claims that graphics and texts are processed by different cognitive systems, which share the load (Vekiri, 2002). The dual coding of an argument graph means that the student can focus on "the argument itself rather than trying to figure out what the argument is", which encourages deeper critical thinking (van Gelder, 2003; Dwyer et al., 2012). Ofsted (2019) recommends dual coding as a means of "increasing the likelihood that we will remember the concept". So, by taking advantage of dual coding, argument graphing makes the argument easier to retain than one that is written as prose. This means that more information can reach the long-term memory.

> *"A key benefit of an argument map is the way that it displays the argument in a branching structure. Given that argument maps support dual-coding of information in working memory via integration of text into a diagrammatic representation, cognitive resources previously devoted to translating prose-based arguments into a coherent, organised and integrated representation are 'freed up' and can be used to facilitate deeper encoding of arguments in argument maps, which in turn facilitates critical thinking"* Dwyer et al. (2012, p. 223)

Furthermore, the branched structure is ideal for editing. The student can immediately build on the argument graph in the lesson to express their own ideas, which is very difficult with prose. In Endoxa Learning, the student can take control and add their own arguments to the topic of debate.

The success of the argument graph method is illustrated in studies that compare teaching methods with argument graphs to those without. An experiment directed toward higher education students found that the visualisation of arguments improved participants' essay structure and encouraged a stronger understanding of arguments (Cullen et al., 2018). Similarly, van Gelder (2015) confirmed that high-intensity argument graphing improves critical thinking skills significantly more than traditional critical thinking courses. Argument graphs have also been shown to have a particular benefit to higher education students who are at "low and intermediate academic levels" (Harrell, 2011). Of course, secondary school students are at an early stage of critical thinking, so the argument graph is an ideal medium of developing this skill.

Other results support the use of argument graphs as a method of teaching critical thinking:

- Álvarez Ortiz, C. M. (2007) showed that teaching students using argument diagrams is far more effective at developing critical thinking skills than other methods, through a meta-analysis of 55 studies. For example, the effect size of using argument diagrams is about 3 times bigger than taking a philosophy class. Twardy (2004) reported a similarly big result, as did Dwyer et al. (2012).
- Cullen et al. (2018) reported that training students in argument diagramming and giving them exercises in interpreting and creating argument diagrams leads to a big increase in students' analytical and reasoning abilities. This improvement cashes out in improved essays and exam grades.
- Harrell (2012) showed that those who master argument diagrams get better at critical thinking compared to those who do not.

What We Changed

We have made several improvement to the method of argument graphing, compared with the prior art.

Content: The most important difference compared to existing software is that Endoxa Learning is not just a drawing package, but a library of lessons containing subject-relevant arguments and knowledge. Each subject contains 100 – 200 lessons, covering the entire curriculum.

Modelling the argument: Snyder and Snyder (2008, p. 94) argue that teachers should improve students' critical thinking by first "walking students through it" by modelling an answer to a question that involves critical thinking. This, they argue, helps students to bridge the gap between simply learning knowledge to using logical reasoning to apply that knowledge to their own arguments. Endoxa Learning lessons take the student through a good argument, showing each step of the argument graph in turn. In this way, they combine the benefits of the argument graph with the "modelling" of exemplar arguments, thereby helping students to understand the process before they attempt an argument from scratch. The student is then given the opportunity to contribute to the argument in "edit mode".

Argument types: An Endoxa Learning argument graph shows the logical relations between statements, based on Walton's theory of the "argumentation scheme". We have simplified this system from 100+ argumentation schemes down to a list of 12, which we call "argument types". Our argument types are common-sense, ranging from "*Opinion*", based on a claim that someone might make about something and why we should listen to them, to "*Cause and Effect*" which shows a causal relationship between different things. The use of argument types means that the logical relationships between statements are clear to the student and not buried within dense prose, or explained with logical jargon. This greatly simplifies the analysis of an argument. Furthermore, each argument step in an Endoxa Learning argument graph includes its own, unique critical questions. This provokes the student to evaluate each argument step, based on the critical question prompts.

Evaluation: An evaluation system is used to calculate the strength of the argument step, the truth of the statements and conflict (incoherence) within the argument. This is done using conditional probability calculations, which take place in the background, in real time. This helps the student evaluate arguments and guides them to make their own strong and coherent argument.

Using Endoxa Learning

Endoxa Learning in Your Curriculum

Critical thinking is a question for the whole curriculum, but some subjects are more suitable for developing critical thinking skills than others. In STEM subjects, lots of good problem-solving thinking is not critical thinking. But in HASS (Humanities, Arts, Social Sciences) subjects, problem solving is often an exercise in pure critical thinking.

For example, typical exam problems in A level RE are: “To what extent was Jesus merely a political liberator?” and “‘Good’ is meaningful. Discuss.” They require analysis and evaluation of competing arguments, some interpretation of sources, and the creation of an argument for the student’s point of view. These are all critical thinking skills. Typical exam problems in A level chemistry are: “Calculate a value for the enthalpy of lattice formation of MgO.” and “Explain the bonding in and the shape of a benzene molecule.” These problems require understanding of chemistry, mathematical skill and some creativity, but not critical thinking skills.

Put simply, critical thinking is needed when the answer to the question could go 'either way' and the student has to make an argument for their point of view. In STEM subjects up to A Level, the correct answer is never in doubt, but in HASS subjects, it is. This is not to say that STEM subjects never require critical thinking skills. All subjects require critical thinking at a high enough level, where there are problems on which even the academics disagree. But in secondary school, the HASS subjects deal with open-ended problems from year 7 onwards. Therefore these are the most suitable subjects for developing critical thinking skills at school.

At Endoxa Learning, we have developed courses on secondary school subjects that involve critical thinking. These range from Religious Education and Geography at KS3 to Politics and English Literature at A Level. Essentially, The software is designed to follow students’ academic journeys throughout secondary school, by gently introducing critical thinking at KS3 and evolving into complex arguments as students move through school. While the level of critical thinking develops over time, the software does not change, so teachers can confidently deliver lesson content through Endoxa Learning at any level. We have complete courses available for a number of subjects at KS3 and A Level and are building and testing GCSE content.

Content is based on the curriculum for each subject, and the main exam boards, so that the teacher can integrate Endoxa Learning graphs into their lesson plans and use them instead of or alongside traditional textbook resources. For example, the KS3 Geography course includes topics based on key geographical regions that are recommended for the Geography curriculum, such as Russia and the Middle East. Within each lesson, key subject concepts are drawn from other areas of the course. This makes Endoxa Learning lessons ideal for interleaving and spaced learning, pedagogical techniques which are recommended by Ofsted (2019).

Integrating Critical Thinking Into Your Subject

It has been recognised for a long time that argument diagrams could be a good way of helping students with argumentative skills. But most of the educational research we have seen has been in the context of separate critical thinking courses. Curriculum narrowing is already putting established subjects at risk, so reintroducing critical thinking courses is unlikely (Ofsted, 2019). Furthermore,

experts who contributed to Facione (1990, p. 4) argued that critical thinking should not be thought of "as a body of knowledge to be delivered to students as one more school subject along with others".
We believe that critical thinking should be integrated within school subjects, rather than competing for space on the timetable. This benefits teachers, too. The Department of Education (2019) stresses the importance of reducing teacher workload as a goal of technology in education. The primary purpose of Endoxa Learning is to integrate critical thinking skills within core lesson content, so that the teacher can teach argument while continuing to deliver subject knowledge. It has also been argued that humanities subjects can improve critical thinking skills, so integrating critical thinking into these subjects is more beneficial than standalone critical thinking courses (Dumitru, 2019).

To make our lessons more flexible to the needs of a teacher, we have adapted them to be suitable for both the infusion approach and the immersion approach to teaching critical thinking. The infusion approach involves teaching critical thinking within a subject and making it clear that the student is learning this skill. This is where our argument types are important. Conversely, the immersion approach integrates critical thinking into the subject in such a way that the student is not aware that they are being taught it. The latter can be useful when the teacher wishes to focus on the subject content or believes that critical thinking terms would confuse a lower-level learner. To this end, teachers can choose to hide argument types in Endoxa Learning lessons. However, the structure of an argument graph means that the student will still be able to appreciate that an argument is being developed and understand the logical progression of that argument. This means that when argument types are turned back on in future lessons or school years, they should not negatively affect the student's confidence.

"Endoxa [Learning] is a path through the forest" – A Level teacher, on using Endoxa Learning.

An Endoxa Learning lesson takes the student through the argument graph in a structured and non-overwhelming way. Ofsted (2019) argues that "effective teaching" uses cues such as "signalling transitions" and section reviews to break up large quantities of new information. This is especially important for complex arguments, so Endoxa Learning uses chunking to tackle a small part of the argument graph during each lesson stage and includes signposting comments from our "avatar". The teacher can take advantage of each lesson stage transition to structure their teaching, checking the students' understanding of each stage. This is aided by the intermittent tests. The quiz stage brings together every argument step, allowing the student to review the entire argument. The separation of the argument graph into three sections also means that it is flexible to learning capacities and level of study. For example, the core argument might be taught to a Year 7 class, while all three sections of the same lesson could be used to teach a balanced argument to a Year 9 class or above. The complete argument graph can also be understood as an essay plan, preparing the student for essay-based argument at A Level.

An Endoxa Learning graph is suitable for individual work and can also be used to present material to the whole class. Testing of the software among KS3 students has already suggested the benefits of increasing engagement and encouraging collaboration, with students discussing each argument step and debating its argument. This supports academic literature, which suggests that collaboration on argument graphs is beneficial for critical thinking (Scheuer et al., 2011).

"It engaged them in analysis and evaluation of arguments to a much deeper level than is possible with a textbook …Their arguments were more sophisticated." – A Level teacher, on using Endoxa Learning.

Endoxa Learning *"extended their ability to learn independently outside the classroom. It is the latest active learning at its best"* – A Level teacher, on using Endoxa Learning.

Teacher Dashboard

The teacher can set work and view their class's progress on the dashboard, in real time, checking that each student understands and has engaged with the lesson. This includes viewing the coins earned for tasks and quizzes, as well as the students' notes and their edits to the argument graph. The teacher can then make their own comments on the students' edits, which are stored on the lesson. This makes each lesson versatile for formative assessment.

Accessibility

Endoxa Learning colours have been chosen to avoid problems with colour blindness.

Endoxa Learning cuts the number of words which have to be read to grasp an argument by over 90%. This has great potential to improve learning for people with dyslexia and other reading difficulties. We intend to research this thoroughly and optimise further, e.g. with background colours.

Endoxa Learning does not work with existing screen readers for visually-impaired students. Fixing this is on our product roadmap.

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