Endoxa White Paper

Abstract

Endoxa is an innovative system that consists of a customisable network of argument links, allowing rapid learning and improvement of reasoning skills. Initially designed for education, the software is aimed at students and teachers of humanities, social sciences, business studies and all disciplines that require rigorous understanding of arguments.

This white paper concentrates on the application of Endoxa to A-level subjects. Endoxa visualises the arguments that students need to learn for their A-level courses and helps them create their own arguments via a graphical interface.

Website: https://endoxalearning.com
App: https://app.endoxalearning.com

The Problem – Mastering Argument at A-Level

A-levels are a big step up from GCSE exams. In education up to age 16, the focus is largely on skills and knowledge. But at A-level, the most important new skill is to be able to answer a question using a coherent and persuasive argument. A-level questions include command words which signal that an argument is required, such as evaluate, analyse, discuss, assess, or "how far do you agree with...". A-level study requires students to make a step change in their critical thinking[1, 2] skills. Argumentation[3] - being able to understand and create arguments - is at the heart of critical thinking.

This is certainly the case for all subjects that require essay-writing or long written answers: arts & humanities, social sciences, business studies & economics, media & communication studies, and so on.[4] This is illustrated by the percentage of marks for the assessment objectives AO2 (analysis and evaluation) and AO3 (communicate and conclude) across EDEXCEL's A-level subjects. Other exam boards have similar requirements.

EDEXCEL A-Levels	% of Marks for AO2, AO3
Politics	65
History	45
Geography	66
Business Studies	54
RS	60

Following the recent reform of A-levels[5], assessment for each subject is now mainly by exam after two years of study, and the requirements for argument creation and analysis have increased across all subjects. This is reflected in the percent of marks for AO2/AO3 - and also in how argumentation skills are explicitly mentioned in the definitions of the assessment objectives. For example, for AO3, EDEXCEL A-level Politics requires students to: "construct arguments, make substantiated judgements and draw conclusions". Further, mark schemes show that there is more emphasis on argument in the specifications of high-level answers (level 5) than for low level.

Teachers are expressing concern with regards to teaching of argumentation and critical thinking skills. The requirements have increased, but the textbooks and training have not always kept up.

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

This concern is supported by the examiners reports from the 2018 exams, which demonstrated that many students are struggling with the ability to form a coherent, strong argument.

"*Stronger responses sustained a clear argument throughout the essay and usually evaluated as they went along, rather than only in the conclusion*"

Most importantly, A-level students know they have to master argumentation, but often feel that they are ill-equipped to do so. 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; not sticking to relevant information - waffling.

So how can students improve their argumentation skills? It is surprisingly hard. Even defining "argument" is quite difficult.[6] The standard advice is that making an argument means defending a point of view by giving reasons in a logical order for your conclusions. This is true, but vague. Arguments have a structure created by logical relations and students need to learn and practice how to structure their arguments to make them strong and persuasive.

Textbooks do a good job with knowledge – facts, case studies, summaries and so on, but they do not typically analyse arguments or model how to create an argument. The nearest the textbooks usually come to laying out an argument are lists of pros and cons for the issues at stake, but this is not enough. The student can only rely on writing essay assignments and getting feedback from the teacher. But this is an uncertain process if the student does not know what they are aiming for. And teachers need support to be able to rise to the challenge of improving their students' argumentation skills. Some students also have lessons with specialist tutors, but this can also be hit-and-miss, and very expensive.

It is essential for students to learn how to analyse and create arguments, not only for their A-level grades, but also for their careers. In higher education, the requirement to master argumentation is even more important than at school. Universities value critical thinking skills very highly. Employers are also looking for people with strong critical thinking skills. As knowledge becomes ever more easily available, critical thinking is becoming one of the top skills recruiters look for – and this trend is expected to accelerate.[7]

To summarise, students who want to get top grades need to have excellent argumentation skills, because a large proportion of the marks are given for having a good argument. Many students are weak in this area and traditional learning resources do not address this problem.

The Solution - Endoxa's Argument Graph

Argument is normally represented as prose. Students learn arguments by reading books and articles - but this is a slow and difficult process. It is a complex task to analyse an argumentative piece of writing because the structure of the argument is not explicit in the text and the text normally contains all sorts of other information apart from argument. Prose is linear, but arguments are not.
Textbooks do not normally model argument and it is also difficult for teachers to explain how an argument works in speech without confusing the matter with a lot of argumentation jargon.

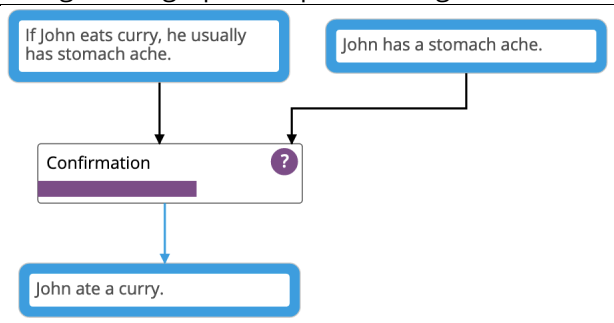
"*...argumentative prose contains many more sentences than just the propositions that are part of the argument, but also ... proceeding necessarily linearly, the prose obscures the inferential structure of the argument*"[8]

Students learn to create arguments by writing essays. The essay format is very flexible, but that makes it very easy to produce unargumentative waffle-filled writing. Many students find it easy to write something about the subject, but very hard to produce a coherent and persuasive argument.

The solution is to change the way an argument is represented – we call this an *Argument Graph*. An argument graph[9] is a diagram which represents the argument using graphical symbols and a minimum amount of text. This is much easier to understand than the normal prose form of an argument because the structure of the argument is the structure of the flowsheet – you grasp it simply by looking at it. The roles and relationships of each part of the argument are communicated graphically with a simple set of colours, shapes, etc. An argument graph breaks the argument into steps which are expressed in a standardised way and which are presented and understood one by one. There is also an evaluation system to calculate the strength and coherence of the argument.

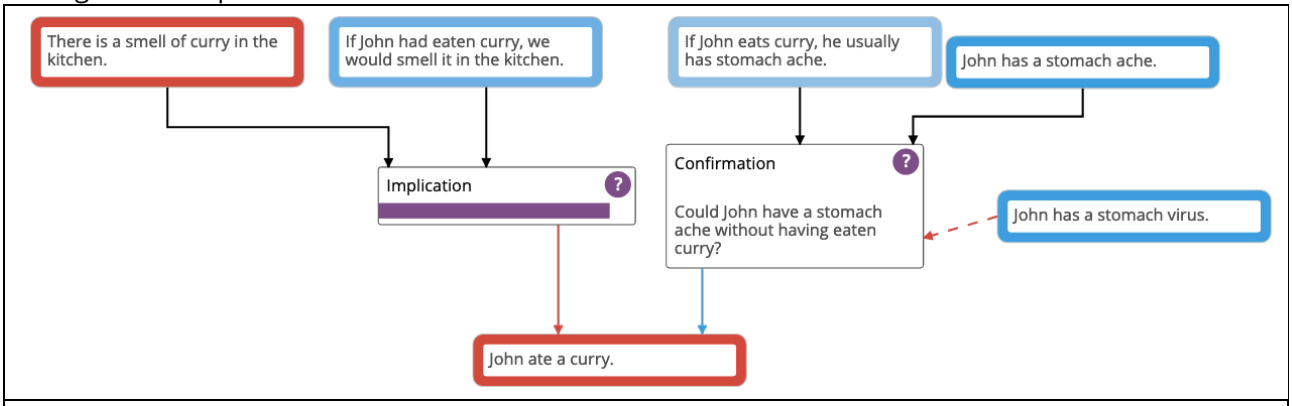
It is much easier to explain how the argument graph works using pictures rather than words! The following diagrams are not meant to be an exhaustive training in Endoxa, but give most of the central ideas.

An argument graph is depicted using boxes and arrows.



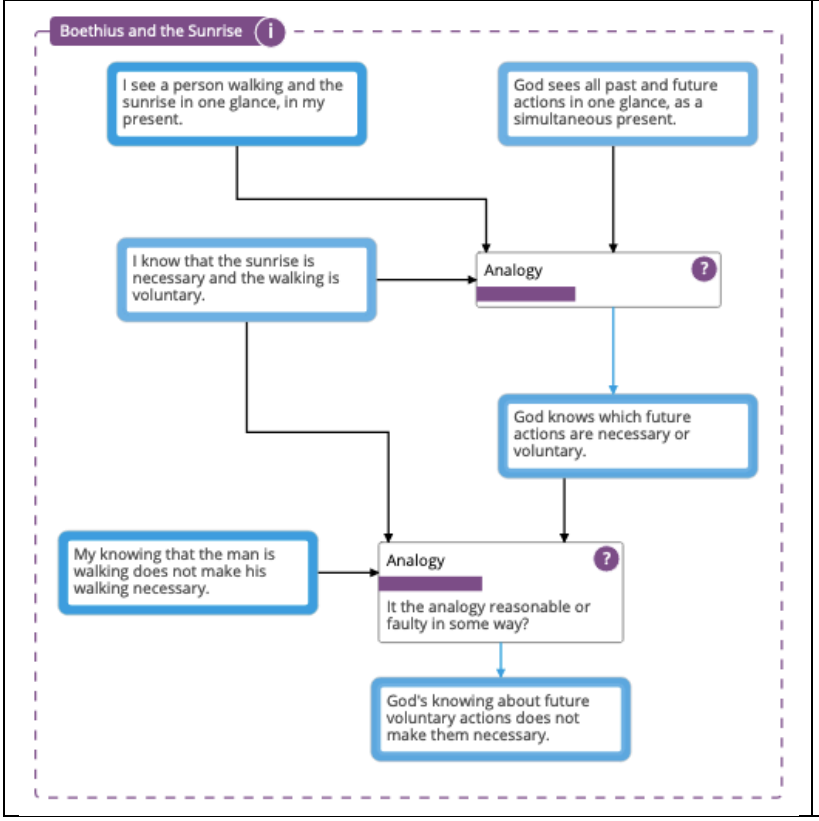
This is a single step of an argument graph. There are three statement nodes and a connection node called an "argument type". Argument types are a classification of different kinds of inference - "Confirmation" is one of a menu of 15 types. The length of the purple bar represents the strength of the argument step.
The black arrows show that the two statements above are premises. The blue arrow shows that the statement below is the conclusion and that the argument step is "pro" the conclusion (a red arrow means "con".)

The graphical features of the argumentation graph allow reasoning to be represented visually without adding textual explanations.



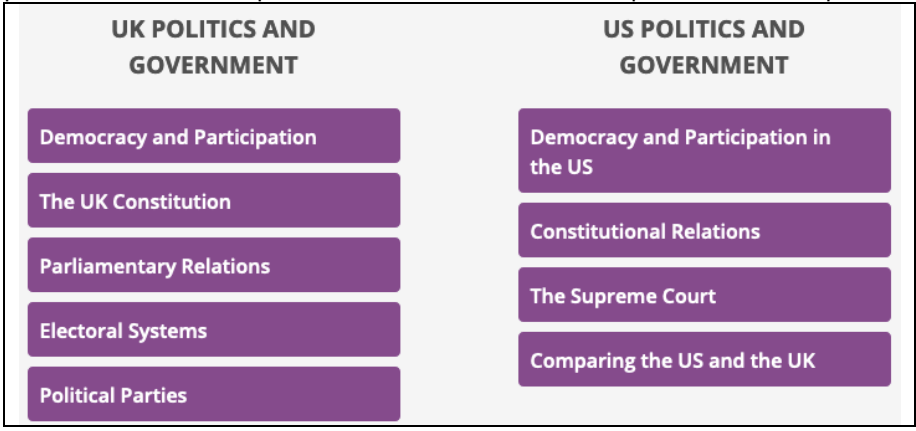
This diagram shows a rebuttal - two argument steps in conflict. The Implication step is connected to the conclusion with a "con" arrow, so it rebuts the Confirmation step.
Each argumentation scheme has a set of "critical questions" which suggest to the student how it can be supported or undermined. The dashed red arrow shows that the statement undermines the confirmation argument and the purple bar disappears, because the argument is defeated.
The conclusion statement is made false by the falsification step and its colour changes from blue (true) to red (false). The truth value calculations are made in the background using conditional probability tables.

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.



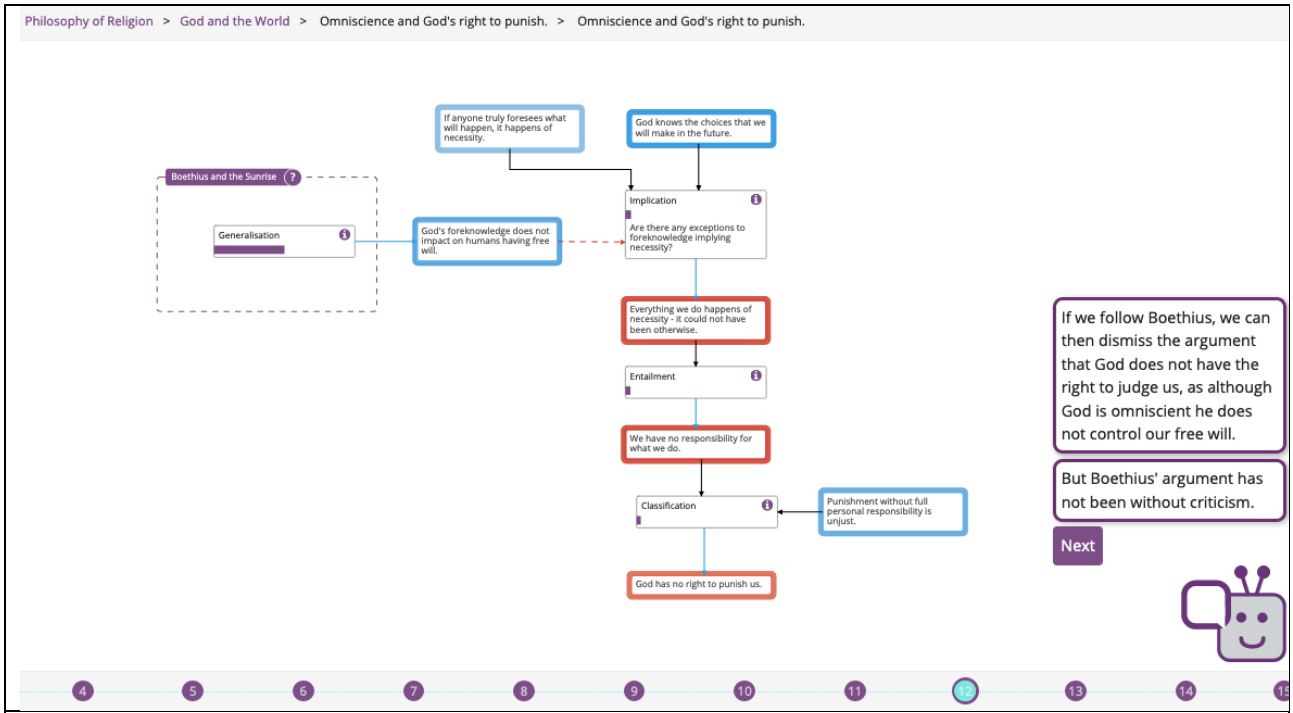
This graph shows a part of the 6th century philosopher Boethius' argument that God's foreknowledge does not compromise our free will, represented as a 2-part analogy. This is a classic theological argument and is relevant to A-level RS and philosophy students.
The dashed purple box represents a *scenario* - in this case Boethius' thought experiment. A scenario box can be used to represent a case study, a fiction, historical context, a possible future, and so on.
The "i" and "?" symbols can be clicked to give more information about the scenario and to give a text equivalent of each inference.

In Endoxa, argument graphs are used to deliver lessons centred on a topic of debate. These cover all parts of the A-level specification and coincide with possible exam question topics.



Part of the Endoxa menu structure for A-level Government & Politics.

A lesson consists of several short, interactive presentations of argument graphs relevant to the lesson topic. Through this, students learn the arguments relevant to the topic and practice their reasoning skills by going through the lesson stage by stage. The student then constructs their own argument using the argument graphs they have seen. Their final graph represents their thinking on the debate topic and can be used as an essay plan or for revision.



This is stage 12 of a 15-stage lesson on philosophy of religion. The argument graph is on the left and Doxa the instructor's comments are on the right. The graph is *lessonised* - as the student goes from stage to stage, the graph grows one step at a time.
The instructor may ask the student to perform tasks such as connecting a new statement to the graph or choosing a new statement from a multiple choice. This makes the student think carefully about the argument and helps keep the student engaged.

Argument First

Students' results do not magically improve just because instruction is delivered by a computer. Educational software has to be designed according to best practices. We have worked hard to design Endoxa to deliver the best results for students.

- *Relevance*: lessons in Endoxa follow the A-level specifications.
- *Visualisation of information*: text is kept to a minimum to simplify the task of understanding. Argumentation-related information such as the role played by each statement, truth/falsity, pro/con, etc. are conveyed by graphical means. Once the student has learned how the software works, it is easy to understand any argument.
- *Interactivity*: interactive instruction is good both for student engagement and for learning. Lessons in Endoxa contain tasks that make the student think about the argument as they go through it step by step.
- *Chunking*[10]: the argument graph is an analysis of argument that breaks it into "chunks" – the argument steps - which the student can work through at their own pace. This is an effective strategy to improve memorisation and understanding.
- *Simple logical model*: the argument graph is based on argumentation theory (see below), adapted so it is easy to use, but powerful enough to express any argument – without requiring advanced training in logic.
- *Rigour*: an argument graph only represents argument. Other facts and information are added as knowledge annotation, but the form of the graph forces the student to think and express themselves argumentatively. No more waffle.
- *Branching*: linear learning does not allow the student to express their own ideas, which is vital in all the essay-writing subjects. In Endoxa, the student can take control and add their own arguments to the debate topic.
- *Balance*: all teachers know that there is a balance to be kept between spoon-feeding students and self-directed learning. Endoxa keeps this balance by scaffolding[11] the lesson arguments for the students, but making them complete learning tasks and create their own final argument graph for each topic.

Endoxa represents a new type of pedagogy, which we call *Argument First*. Traditionally, students will learn the facts first and then start to think about arguments. A-level textbooks for subjects like Geography, Politics and English Literature are full of case studies and examples and students spend a huge amount of time learning them. But these facts are of secondary importance compared with the arguments. Geography A-level questions do not ask things like "how much migration is there between low income countries?", they ask things like "does migration between low income countries cause inequality?". What a question like this requires is an argument in which facts are deployed to support the points being made. There is no point learning facts which are not connected to an argument.
Endoxa makes the student think about the argument first, and then embeds the facts into it using scenarios, knowledge annotation and instructional comments. We think this is the most effective way to learn and the right way to do essay planning and revision notes.

By changing the way that arguments are represented, Endoxa makes it much easier for students to learn argument, to practice their argumentation skills and to create their own arguments. The content covers the entire A-level specification and is deployable for essay planning and exam revision.

The Benefits - The Case for an *Argument First* Approach

There is a lot of good educational software out there, but the right tool has to be used for the right job. Flash cards can be great for memorising facts, but are of less use for learning arguments. Arguments require a tool that allows analysis and evaluation.

An argument graph is part of a class of diagrams used in education called "graphic organisers"[12]. 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.

Graphs using boxes and arrows are a sub-class of graphic organisers that convey relationships between a set of objects. For example, an organisation chart shows the supervisor-subordinate relationship between employees of an organisation - and a family tree does a similar job for kinship relations. Examples of graphs which are sometimes used in education are: mind maps (objects related by association), concept maps (relations between concepts) and knowledge maps (relations between items of knowledge). In a similar way, graphs can be drawn of arguments and Endoxa is an example of this.

Many different types of argument diagram have been tested by researchers. A simple argument diagram would show statements connected by links to show which are the reasons to support a conclusion and which are the objections against it. But it does not explain how the argument works.

An Endoxa argument graph shows the logical relations between statements, based on a model taken from argumentation theory. The early work on argumentation theory was done by the philosopher Stephen Toulmin[13] in the 1950s with subsequent work by Prof. Doug Walton[14], who elaborated the theory of the "argumentation scheme"[15] - a way of classifying informal reasoning into types. We have simplified this system from 100+ argumentation schemes down to a list of 15, which we call "argument types". The argument graph uses these to classify the argument steps into types, each with their associated critical questions. This helps the student think about how the argument works, so they can critique the logic rather than treat it as a "black box". This amounts to a detailed analysis of the argument.

In a normal argument diagram, the evaluation is left up to the student. The student simply has to weigh the reasons for and against a conclusion and decide which is stronger. For Endoxa, we have devised an evaluation system which calculates a truth/falsity value for each statement and compares this to the student's judgement. If they differ, this indicates that the student's evaluation of the argument is incoherent. In this way, the student is guided to produce a strong and coherent argument. Thus, the argument graph helps the student with both analysis and evaluation of the argument.

Some of the best educational software has been written for mathematics and for learning computer coding. At Endoxa, we are fans of Kahn Academy, Hegarty Maths and other similar online learning tools. What these products do very well is to follow the design rules listed above, in particular:

- Relevance: the lesson content covers 100% of their course specification
- Visual learning: lots of instruction videos, diagrams, etc.
- Interactivity: the student shuttles between instructions and doing a task, learning all the time and the software automatically detects if the answers are correct and gives feedback.
- Chunking: the lesson is broken into discrete steps, which cover a concrete learning goal

For the essay-writing subjects, there is nothing like this, not for A-level, nor for university level learning. Typically, what we can find are online textbooks and collections of lectures on video. As discussed above, it is difficult to analyse arguments in text (or speech) format. Books and lectures are neither visual nor chunked nor interactive. For A-level there are some good websites offering flashcard + quiz-based lessons, which may be good for learning facts. But there is nothing that is going to help students with argumentation skills.

It has been recognised for a long time that argument diagrams could be a good way of helping students with argumentation skills. But all the educational research we have seen has been in the context of critical thinking courses.[16] In contrast, the primary purpose of Endoxa is to learn and practice the argumentative content the A-level course requires. When the "analyse and evaluate" questions come up, we want students to know how to answer them.

We think it makes sense to teach argumentative content in an argumentative way[17] - not in a discursive way - and argument graphs are best for this purpose. This is at the heart of our "argument first" approach.

Students using Endoxa will improve their argumentation skills - and this way of thinking will be transferrable to other subjects and endeavours. But this will simply happen as part of the process of learning what they need to know for their A-level exams. Endoxa is not just another critical thinking course.

There is a lot of research literature on the visualisation of information, on graphic organisers and on argument diagrams in particular. The appendix below contains short summaries and quotes from a variety of published sources - this is meant to be indicative and not an exhaustive list. What follows is a brief review of these findings.

We often hear about "learning styles" - e.g. claims such as "65% of people are visual learners, but 20% learn best by listening". But the research on this is vexed - it is not clear that such learning styles really exist, and we all learn via multiple channels. However, there is a sound theoretical and empirical basis for the visualisation of information. But the point is not the distinction between seeing vs. hearing, it is one of processing graphics vs. text.

Cognitive load theory[18] hypotheses that our working memory[19] is limited, while our long-term memory is (almost) unlimited. Complex learning activities can create a great strain on the working memory and lead to reduced learning performance. Given the cognitive load of learning, there are two theoretical perspectives that can explain why visualisation of information works. The "Visual Argument" hypothesis claims that graphical information is easier to process than textual information. "Dual Coding" theory claims that graphics and texts are processed by different cognitive systems, which share the load. Both theories have considerable empirical evidence behind them. Vekiri, I. (2002)

Empirical studies looking at the use of graphical organisers in education have found that the theory works in practice. Studies have shown:

- Mochizuki, et al (2019) students that had constructed knowledge maps produced better, more argumentative essays than those who had not.
- Nesbit, J.C, and Adesope, O.O (2006). Concept maps have a positive effect on learning and out-perform other summary devices such as lists and outlines, consistent with the theory of reducing conceptual load. This was particularly the case for:
    - students constructing maps (vs. merely studying them) - i.e. interactive learning;
    - those with low ability or studying in a non-native language;
    - humanities & social sciences subjects (vs. science).

Studies of argument diagrams have generally concentrated on their effect on critical thinking, as measured by a standardised test such as the CCTST[20]. It is not possible to get a single result for how much argument diagrams help, since the researchers have used different types of diagrams and different protocols. But the results are impressive.

- Álvarez Ortiz, C. M. (2007) This meta-analysis of 55 studies shows that teaching students using argument diagrams is far more effective at developing critical thinking skills than other methods. For example, the effect size of using argument diagrams is about 3 times bigger than taking a philosophy class. Twardy, C.R. (2004) reported a similarly big result, as did Dwyer, C.P. 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, M. (2012) showed that those who master argument diagrams get better at critical thinking compared to those who do not.

Our own research has also shed light on the benefit that argument graph-based learning can bring. In five small studies with A-level students, students rated the argument graphs as 8.3 out of 10 for "helps me understand complex arguments". (Total Base - 35).

We also collected a lot of qualitative findings and used them to guide the development of the product. We know by experience that using a computer for education is not a magical solution to the students' problems. If you make the lesson boring, so the students are not engaged, then it is not going to work. And every teacher and academic we talked to told us that passive learning is not effective - the students

have to have things to do. This is why the lesson components were re-designed to be short (under 10 minutes) and include interactive tasks.
We also asked for feedback on the various features of the product. For example, teachers like the critical questions, because they can see it makes the students think. We are continuing to learn and to improve the product using student and teacher feedback and analytics.

Endoxa is a completely new way to construct and learn the arguments needed for an A-level exam. The argument first approach is based on sound theoretical principles and empirical testing.

Endoxa for Students and for Teachers

We are launching Endoxa with content for one A-level course - Government & Politics. We will expand to more A-levels during the remainder of 2020.

Endoxa is aimed at students who want to improve their argumentation skills, to learn and practice the arguments they need to access higher marks in A-level exams. Endoxa is offered on a subscription basis at a low monthly cost, similar to familiar services such as Netflix or Spotify. This represents an enormous cost saving compared to hiring a private tutor.

The way students use Endoxa is straightforward. The lessons are organised according to the curriculum of the A-level, so the student can easily choose where to start or what to revise. A lesson normally has 3 or 4 components which last around 10 minutes. Each stage of the lesson is pre-programmed with interactive tasks which the student completes. The student can then optionally spend more time editing their own version of the component's argument graph, modifying or adding to the argument. This is saved as their visual essay plan - and as a tool for revision.

We would recommend the student go through one or two lessons per week, ideally choosing lessons to complement what they are learning at school. But the student can work at their own pace, save their progress and take breaks as they wish. Feedback on their work is provided by a user forum, or by expert tutor* - and help is available through instructional videos, help menus, FAQs and live chat. We are also planning to introduce tracking tools and incentives for engagement* as the launch progresses.

We are also aiming Endoxa at A-level teachers who wish to use the app with their class. While the options for how to use the software for a lone student are limited to how we program the interface, there are a lot more possibilities in a classroom setting. Endoxa is a new tool for teachers and it's use creates new opportunities while raising some important questions.

Does this work best as blended learning in-class, or would a flipped classroom approach be better? Endoxa is built as a student-centred learning approach, and the students' ability to pace themselves should make it ideal for differentiated learning: e.g. all students learn what is in the lesson, and the more able students can go beyond the lesson, adding to their own argument graph. For the student, Endoxa is an advance organiser - a framework of argumentative knowledge. Can it be used to encourage students to read more of the source materials for their course? It will be a lot less intimidating to read Hobbes or Hume if they have an idea of what the argument is first.

The way the software is built also creates opportunities to assess students in novel ways. The interactive tasks we have built into the lessons are just a beginning. Once an argument is chunked into steps, it is possible to devise problems that probe the student's understanding in detail. This normally requires a written answer that takes a long time to write - and to mark. But problems within Endoxa could be checked by the software automatically. The software will also be able to track students and provide analytics on what they have attempted, what they had trouble with - leading to a system for documenting their work and their improvement. We can also involve the teacher in customising the delivery of the content. A teacher could modify the assessment tasks, decide whether to hide or display hints, and so on - based on their knowledge of the class's capability.

It is also important to realise what Endoxa is not. It is not an essay-writing machine. We believe that the task of getting the argument right is separable from the writing skills necessary to render that argument as an exam answer or an essay. Such writing skills will be learned by the students in the usual way at school. An Endoxa argument graph is the equivalent of a detailed essay plan, just in a highly visual form. Given sufficient writing skills, a student can easily write the essay from the graph.

This makes argument graphs a highly efficient way to grapple with the arguments of a certain topic, or for an exam question. Once a student has learned the system, they can graph the arguments much quicker than they can write a whole essay on the subject - and the teacher can check it faster, too. In the same way, argument graphs can be an efficient revision tool for exams.

We cannot optimise the use of Endoxa in a classroom setting without the help of teachers. We are looking to engage with teachers who would like to help us understand how to get the most out of this novel approach to learning by participating in classroom testing. We will offer discounted rates to schools & colleges and special offers for those helping with testing.

Personal observations

I am convinced that a visual approach in which arguments are broken into clear steps will help many students grasp academic arguments and produce their own arguments. Many students (myself included) are intimidated by the complexity of the written page and I hope this product can act as a bridge for them to the world of rational discourse.

Julian Plumley
Founder & CEO, Endoxa Learning Ltd.

Website: https://endoxalearning.com
App: https://app.endoxalearning.com

Notes

1 "Critical thinking focuses on 'argument'.**"**
Palgrave Study Skills "Critical Thinking" (Stella Cottrell, 3rd Ed. 2017)

2 "According to the American Philosophical Association's famous Delphi Report (American Philosophical Association, 1990), critical thinking is "purposeful, self-regulatory judgment" requiring "interpretation, analysis, evaluation, and inference" and the ability to defend that judgment with reason and valid evidence." (Harlin, T. 2013)

3 "In a broad sense, **argumentation** refers to 'discussions in which disagreements and reasoning are presented' (ibid.) and, more narrowly, to 'discourse of persuasion, logical proof, and evidence-based belief ' (ibid.). It involves the process of considering an issue or problem to arrive at a considered or reasoned position and involves drawing on: relevant information or data; an individual's or group's understanding of the issue/problem ('conceptual knowledge'); and personal and/or societal values. Thus, the term can be applied variously to refer to:
• A process of **persuasion:** an individual or group attempts to persuade or convince another party of the rationality or reasonableness of their 'argument' – the supported position or perspective they are presenting;
• A process of **knowledge construction** or **co- construction:** an individual or group attempts to develop an ever 'more-adequate' conceptual understanding (or 'schematic structure') relevant to the issue under consideration;
• A process of **metacognition:** an individual or group attempts to gain insight into the structure and logic of their own and others' thinking."
Morgan, A. (2006)

4 In the physical and biological sciences, and in technology subjects, there is less emphasis on essay-writing, so we expect Endoxa to be relevant but less so than for humanities, social sciences, etc. Endoxa is not relevant for mathematics, which has its own approach to logic.

5 "Get the facts: AS and A level reform"
https://www.gov.uk/government/publications/get-the-facts-gcse-and-a-level-reform/get-the-facts-as-and-a-level-reform

6 "Argument [means] using reasons to support a point of view, so that know or unknown audiences may be persuaded to agree."
"An argument includes:

- a position or point-of-view
- reasons given to support the point-of-view
- reasons presented in a logical order (a line-of-reasoning), aiming at a conclusion
- an attempt to persuade others to accept that point-of-view"

Palgrave Study Skills "Critical Thinking" (Stella Cottrell, 3rd Ed. 2017)

7 The 2016 *Future Of Jobs* report, published by the World Economic Forum, predicted that by 2020, critical thinking and complex problem-solving will be the most in-demand sets of skills in the global jobs market.
http://reports.weforum.org/future-of-jobs-2016/shareable-infographics/ … top 10 skills

"Demand for higher cognitive skills such as creativity, critical thinking and decision making, and complex information processing, will grow through 2030 at cumulative double-digit rates."
https://www.weforum.org/agenda/2018/06/the-3-skill-sets-workers-need-to-develop-between-now-and-2030/

Demand for critical thinking skills has risen 158% in early-job career job adverts in the last 3 years alone (https://www.weforum.org/agenda/2017/03/in-the-workplace-of-the-future-these-are-the-skills-employers-want)

8 "Information is usually presented linearly via streams of words and sentences. Similarly, arguments are generally presented as "prose", which is considered as "the medium of philosophical argumentation" (van Gelder, 2002: 85). However, students are likely to have difficulty cognitively processing the prose for the purpose of learning and later recall (Dwyer, 2011). That is, to make the central point of the main argument explicit requires serious thinking and some reading (Davies, 2009). Harrell (2005) considers one reason to be the inability of students to recognize the argument presented in the text and therefore misunderstanding it as a story instead. **Furthermore, 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: 2). Accordingly, assimilating relevant information in argumentative prose (e.g. propositions supporting a claim in an argument that are often located in different paragraphs) is problematic (van Gelder, 2003), impeding successful comprehension and recall of materials. In terms of complex arguments, students are even engaged in "circular verbal dispute or maze-like structure of forbidding volumes of prose" (Monk, 2001: 8). Likewise, Davies (2012) asserts that prose is not an efficient means of transmitting complex information as a result of memory limitations."
Eftekhari, M. et al. (2018)

9 The traditional name for this type of diagram is "argument map". We prefer the term "argument graph" because "graph" is the correct term for this type of structure – studied in a branch of mathematics known as graph theory. A "map" is normally a 1-to-1 representation of a geography, whereas geographical features such as location and angle have no meaning in this diagram – only its topology matters.

"In an argument map … a text-based argument is visually represented using a 'box-and-arrow' style flow-chart wherein the boxes are used to highlight propositions and the arrows are used to highlight the inferential relationships that link the propositions together" (van Gelder 2003).

10 Chunking https://en.wikipedia.org/wiki/Chunking_(psychology)

11 Scaffolding https://www.edglossary.org/scaffolding/

12 Graphic Organiser https://en.wikipedia.org/wiki/Graphic_organizer

13 Stephen Toulmin https://en.wikipedia.org/wiki/Stephen_Toulmin

14 Prof. Doug Walton http://www.dougwalton.ca/index.htm

15 See - Walton, Douglas; Reed, Chris; Macagno, Fabrizio (2008). Argumentation Schemes. New York: Cambridge University Press. pp. 94–95.

16 Educational research including argument diagramming studies is generally of two types: "learning to argue" and "arguing to learn". "Learning to argue" is research into critical thinking training. "Arguing to learn" is research based on the idea that students learn best when they can live debate with one another. Argument diagrams have occasionally been used as scaffolding for this objective. This latter use is outside the scope of this document.

17 Of course, there is an A-level in Critical Thinking. But the problem with such courses is that they are divorced from the subject-content that the student actually wants to learn. We think it is much better to improve critical thinking skills by constructing arguments in Endoxa that are relevant to the politics, history, geography… content that the student has to learn.

"The [Critical Thinking] A-level tests candidates on their ability to think critically about, and analyse, arguments on their deductive or inductive validity, as well as producing their own arguments. It also tests their ability to analyse certain related topics such as credibility and ethical decision-making. However, due to its comparative lack of subject content, many universities do not accept it as a main A-level for admissions."
(Critical thinking FAQ's from Oxford Cambridge and RSA Examinations, 2008)

18 Some instructional procedures may impose a heavy extraneous cognitive load that interferes with learning. In particular, tasks that require learners to associate and mentally integrate multiple pieces of information place high cognitive demands on working memory, especially when this information comes from more than one resource.
Vekiri, I. (2002)

19 "*Working memory,* in which all conscious cognitive processing occurs, can handle only a very limited number - possibly no more than two or three - of novel interacting elements. This number is far below the number of interacting elements that occurs in most substantive area of human intellectual activity."
Paas et al (2003)

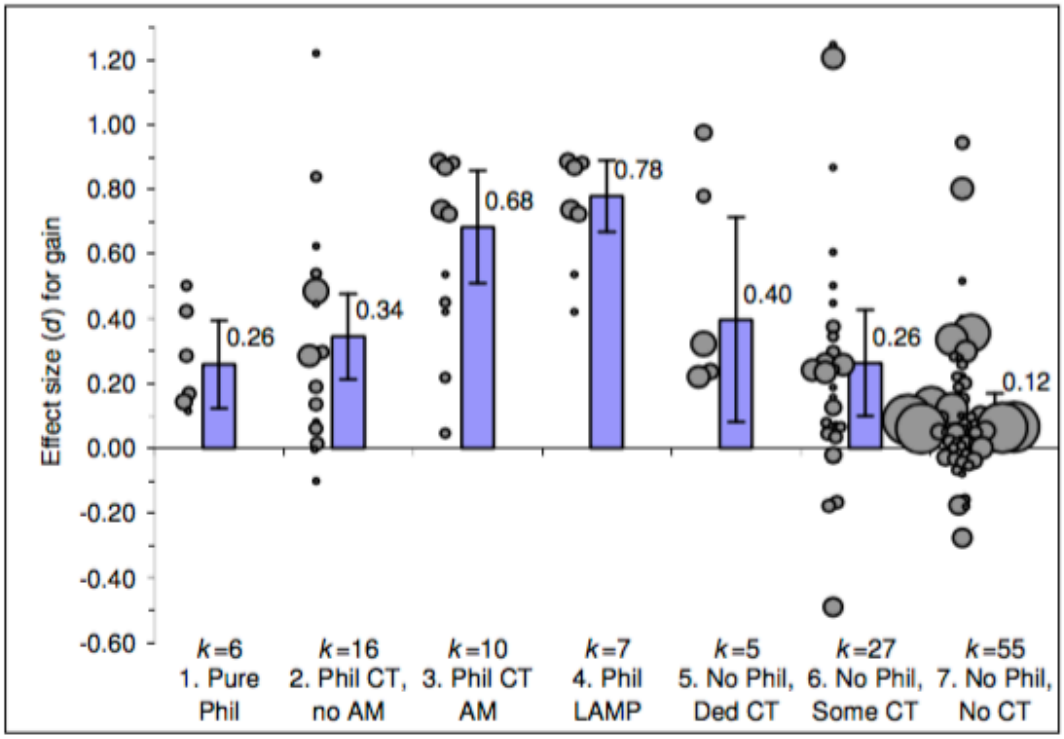
20 Standardised critical thinking tests – a well-known example is the CCTST:
https://www.insightassessment.com/Products/Products-Summary/Critical-Thinking-Skills-Tests/California-Critical-Thinking-Skills-Test-CCTST

Appendix - Results & Quotes from Academic Literature
Argument Diagrams in Education

Álvarez Ortiz, C. M. (2007)
A meta-analysis of 55 studies of learning critical thinking skills. This included comparison between studies using argument mapping vs traditional methods.

"CT (Critical Thinking) courses taught using lots of argument mapping (LAMP) with the support of software tools, and concentrating on exercises that call only on general knowledge, seem to be the most effective of all current methods for improving CTS (Critical Thinking Skills)."

Figure 5. Chart of effect sizes calculated using our best estimates of SD for each test instrument.



Cullen et al (2018)
Study of whether learning argument diagramming techniques improves analytical and reasoning abilities, compared to normal teaching methods.

"We aimed to improve students' generalized analytical-reasoning abilities by teaching them to visualize logical structures implicit in argumentative texts. We found that students' abilities, as measured by parallel LSAT logical reasoning forms, improved substantially compared to students who did not take the seminar, d = 0.71, 95% CI: [0.37, 1.04]. Since actual LSAT administrations include two logical reasoning sections, the improvement in seminar students' scores roughly corresponds to the difference between median scores at a US law school ranked in the top-10 and one ranked in the top-30. Moreover, Seminar students' essays were more clearly written and evinced better understanding of the course readings than control students' essays."

"We found that seminar students (a) structured their essays more effectively, (b) presented the arguments more accurately, and (c) better understood the relevant arguments (Table 1) than did control students, t(57) = 2.9, p = 0.005, d = 0.87, 95% CI: [0.26, 1.48], with 81% of seminar essays earning a higher score than the mean-scoring control essay. In addition to scoring more highly on these dimensions,

essays written by seminar students also received higher letter grades than those written by control students."

"In sum, participating in our intensive argument-visualization seminar led to meaningful improvements in students' analytical-reasoning skills relative to the baseline of receiving a standard university education at the same institution. This result is important because such skills are foundational for university-level study across the disciplines and improving them is the most commonly cited goal of undergraduate education."

Dwyer, C.P. et al (2012)
Study of effect of a critical thinking e-course delivered using argument mapping techniques on critical thinking skills as measured by a standardised test. Includes a discussion of the theoretical underpinning for using argument maps in education.

"Specifically, results revealed that those in the AM [Argument Mapping] group showed a significantly larger gain from pre- to post-testing than those in the control group on overall CT [Critical Thinking] ability and the CT sub-scale of argument analysis."

"AM has been developed with the explicit intention to lessen cognitive load and facilitate both the learning and the cultivation of CT skills (van Gelder and Rizzo 2001; van Gelder 2003). First, unlike standard text, AMs represent arguments through dual modalities (visual- spatial/diagrammatic and verbal/propositional), thus facilitating the latent information pro- cessing capacity of individual learners. Second, AMs utilise Gestalt grouping principles that facilitate the organisation of information in working memory and long-term memory, which in turn facilitates ongoing CT processes. Third, AMs present information in a hierarchical manner which also facilitates the organisation of information in working memory and long- term memory for purposes of enhancing and promoting CT.
In relation to the first reason, dual-coding theory and research (Paivio 1971, 1986), Mayer's (1997) conceptualisation and empirical analysis of multimedia learning, and Sweller and colleagues' research on cognitive load (Sweller 2010), suggests that learning can be enhanced and cognitive load decreased by the presentation of information in a visual-verbal dual-modality format (e.g. diagram and text), provided that both visual and verbal forms of representation are adequately integrated (i.e. to avoid attention-switching demands). Given that AMs 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 AMs, which in turn facilitates CT (van Gelder 2003).
The second related reason for why AM is hypothesised to enhance overall learning is that AM also makes use of Gestalt grouping principles. Research suggests that when to-be- learned items are grouped according to Gestalt cues, such as proximity and similarity, they are better stored in visual working memory (Woodman et al. 2003; Jiang et al. 2000). For example, Jiang et al. (2000) found that when the spatial organisation, or relational grouping cues denoting organisation (i.e. similar colour, close proximity) are absent, working memory performance is worse, and that when multiple spatial organisation cues (such as colour and location) are used, performance is better. These findings suggest that visually-based information in working memory is not represented independently, but in relation to other pieces of presented information; and that the relational properties of visual and spatial information are critical drivers of successful working memory and subsequently, CT (Halpern 2003; Maybery et al. 1986). Given that related propositions within an AM are located close to one another, the spatial arrangement complies with the Gestalt grouping principle of proximity."

Eftekhari, M. et al. (2018)
Study of Iranian students learning English as a foreign language – effect on comprehension and recall of using argument maps delivered by a computer app vs. delivered by pen and paper.
Summary: The students using the computer package had significantly better results.

"The better performance of the software group is therefore due to the usability of the software package (van Gelder, 2007), which facilitates the construction and arrangement of propositions more rapidly than the pen-and-paper method. Thus, it leaves more time for assimilating and comprehending the structure of the arguments and makes the subsequent recall of information easier."

Harrell, M. (2012)
Both papers from Harrell relate to a study of whether argument diagrams help students learn.
Summary: Those who master argument diagrams get better at critical thinking.

"We also conclude that learning how to construct argument diagrams significantly raises a student's ability to analyse, comprehend, and evaluate arguments."

"What this study shows is that students do improve substantially their critical thinking skills if they are taught how to construct argument diagrams to aid in the understanding and evaluation of arguments."

Harrell, M. (?)
"…both the gain and the relative gain from the pre-test to post-test of the students who were taught argument diagramming were significantly higher than the gain and relative gain of the students who were taught argument analysis using more traditional methods. Thus, we conclude that the students who were taught argument diagramming improved their argument analysis skills more, over the course of the semester, than the students who were not."

Harrell, M. (2013)
"As argument diagrams represent arguments through dual modalities (visual-spatial/diagrammatic and verbal/positional), they facilitate the latent information processing capacity of individual leaners. Given that the use of argument diagrams supports 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, organized and integrated representation are 'freed up' and can be used to facilitate deeper encoding of arguments within argument diagrams, which in turn facilitates later recall as well as subsequent, higher-order thinking processes, such as critical thinking.
Use of argument diagrams results in students being able to identify relevant premises that offer support to the authors conclusion and explain more explicitly how the premises are supported and work together, than student who were not taught how to use the diagramming technique."

Morgan, A. (2006)
A review article for the use of computer-supported argumentation learning of geography.
Summary: Dealing with difficult "wicked" problems imposes a high cognitive load. Argument mapping tools can help manage this and improve thinking.

"Advantages of argument maps:

- mapping promotes clarity and rigour in thinking, and leads to deeper understanding of the issues
- Argument maps greatly improve sharing of knowledge among members of a team
- Argument maps are extremely efficient ways to present overviews of complex argumentation to another person
- An argument map makes the boundaries of current knowledge or debate visually apparent
- Argument maps make meetings more efficient by helping focus discussion
- Argument maps promote better decision making by ensuring that a higher proportion of relevant considerations are taken into account
- Mapping arguments produces a permanent record of the thinking on a topic, thus addressing the challenge of maintaining organisational memory"

"The complexity of 'wicked problems' makes considerable intrapersonal and interpersonal demands on participants/learners due to the heavy cognitive load (van Bruggen *et al.*, 2003) which could exceed the 'community of argumentation's' collective capacity to handle it. … computer supported argument visualisation (CSAV) facilitates the generation of argument(ation) maps – visuo-spatial images that model the argument and which can be manipulated and modified. These kinds of software support the evolution, consolidation and metacognitive understanding of the relevant argument specifically, and of argumentation generally."

Twardy, C.R. (2004)
Study comparing teaching of critical thinking using argument maps vs. traditional methods.
Summary: The results with argument maps are by far superior.

"Computer-based argument mapping greatly enhances student critical thinking, more than tripling absolute gains made by other methods."

Graphic Organisers in Education (includes Concept Maps, Mind Maps, etc.)

Mochizuki, et al (2019)
A study of an app that allows students to highlight sentences in a text and then transfer these to a knowledge map – and then write an essay based on the map.

"The results revealed that students who drew a knowledge map based on the underlining and/or highlighting of the target text developed more argumentative essays than those who did not draw maps. Further analyses revealed that developing knowledge maps fostered an ability to capture the target text's argument, and linking students' ideas to the text's argument directly on the knowledge map helped students develop more constructive essays."

"The average score of essay constructiveness in the knowledge-mapping class was significantly higher than that in the non-knowledge-mapping class, with a fairly large effect size (d=1.073), while the difference in the logical coherence scores between the two classes was significant. Overall, we can conclude that using this software with knowledge mapping from underlined and/or highlighted text is effective for fostering argumentative reading and writing for novice students. "

Nesbit, J.C, and Adesope, O.O (2006)
A meta-study of learning using concept maps. An argument graph can be thought of as a specialised form of a concept map in which the nodes are statements and the links are logical relations.
Summary: Concept maps have a positive effect on learning. This is particularly the case for:

- students constructing maps (vs. merely studying them);
- those with low ability or studying in a non-native language;
- humanities & social sciences subjects (vs. science).

Concept maps out-perform other summary devices such as lists and outlines. The benefits are consistent with the theory of reducing conceptual load.

"Concept maps are diagrams that represent ideas as node-link assemblies."

"The meta-analysis found that, in comparison with activities such as reading text passages, attending lectures, and participating in class discussions, concept mapping activities are more effective for attaining knowledge retention and transfer."

"The result that studying concept maps is somewhat more effective that studying lists and outlines contradicts the hypothesis that all summary formats confer the same benefits, and is consistent with theories claiming that concept maps lower extrinsic cognitive load… The evidence that concept maps can

be more effective than text passages for conveying detailed information reinforces the notion that concept maps have more to offer than the mere reduction of information."

Theory of Visual Learning

Vekiri, I. (2002)
Review of theoretical interpretations of studies of visual learning.
Summary: The paper gives some design principles for graphical displays based on a Dual Coding and Visual Argument theories.

"*Visual argument* is a term introduced by Waller (1981) to characterize the way graphics communicate information. According to the visual argument hypothesis, graphical representations are effective because, owing to their visuospatial properties, their processing requires fewer cognitive transformations than does text processing and does not exceed the limitations of working memory. Specifically, it has been argued that diagrams, maps, charts, and graphs communicate information through both their individual elements and the way their elements are arranged in space."

"Dual coding theory proposes that there are two distinct and independent but interconnected cognitive systems for processing and storing information: an imagery or nonverbal system for nonverbal information and a verbal system for linguistic information."

"Visual argument [hypothesis] concentrates on the perceptual and interpretation processes that take place when learners extract meaning from graphical representations. It claims that graphical displays are more effective than text for communicating complex content because processing displays can be less demanding than processing text. On the other hand, both dual coding theory and the conjoint retention hypothesis focus on the memory storage of visual and verbal information. According to these views, the presence of graphics along with text has additive effects on learning because visual information is represented separately from verbal information in long-term memory."

"Design Principles for Instructional Displays

- Graphical displays should be spatially and timely coordinated with text to minimize cognitive load
- Graphical displays are not effective without explanations that guide learners to observe key details, especially when they are intended for low-knowledge students
- Effective graphical displays are designed based on Gestalt principles of perceptual organization (principles of connectedness and proximity). This minimises cognitive processing and allows viewers to perceive relations or data patterns and trends using visual perception mechanisms"

Critical Thinking in the Workplace

Saaverda and Opfer, (2012)
Summary: merely learning information is not the way forward.

"The outdated transmission model of education, through which teachers transmit factual knowledge to students via lectures and text books, remains the dominant approach to education" (OECD, 2009). Through the transmission model, students can learn information, but typically don't have much practice applying the knowledge to new contexts, communicating it in complex ways, using it to solve problems, or using it as a platform to develop creativity. Therefore, transmission is not the most effective way to teach 21st century skills."

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