Effective teaching of economics: A constrained optimization problem?

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ABSTRACT
One of the fundamental tenets of economics is that decisions are often the result of optimization problems subject to resource constraints. Consumers optimize utility, subject to constraints imposed by prices and income. As economics faculty, instructors attempt to maximize student learning while being constrained by their own and students’ limited resources. Some resources are familiar and might be under instructors’ control, such as time, class size, and access to technology. Beyond their control is an often neglected resource: students’ limited cognitive processing capacity. Ceteris paribus, how can instructors effectively manage the limited processing capacity of students’ working memory in order to optimize long-term learning through effective instructional design?

As economists, we teach (and perhaps sincerely believe) that most (if not all) decisions are the result of an optimization problem subject to one or more constraints. We teach that consumers choose how much to consume of goods and services in an effort to maximize their utility, subject to constraints imposed by prices and income. As individual wage earners, we find the optimal combination of leisure and income, given the wage rate and available hours. A firm maximizes its profit, subject to resource constraints and input prices. This is very familiar to economists.

Economists certainly apply constrained optimization techniques to most of the issues individuals and society face, but what about economists as instructors? In the pages that follow, it will be argued that the decision to teach economics also may potentially be a constrained optimization problem. According to cognitive load theory, the major goal of instructional design is to manage a learner’s limited cognitive load while maximizing achievement of learning outcomes. Cognitive load refers to the amount of information that the working memory can hold at a given time and relates to the way that we process and handle information. Too much unprocessed information leads to an overload of the working memory and a loss of that information. In contrast, successfully processed new information is organized, hierarchized, and stored in the long-term memory as domain-specific knowledge or schemas, and can effortlessly be retrieved at a later stage. The purpose of instructional design and teaching is therefore to alleviate working memory’s cognitive burden and optimize construction of schemas to support effective retention and learning.

In this article, we briefly introduce cognitive load theory before interpreting this theory as a constrained optimization problem. Most importantly, the article offers a number of practical suggestions for how to present economic concepts to our students that promote student engagement and processing of such concepts (active learning), and thus help maximize long-term memory and transfer of knowledge. Effective instructional design requires the economics instructor to guide and constructively align...
material presented to students with their prior familiarity with (expertise of) the content (control intrinsic cognitive load). In addition, any instructional material that does not directly contribute to learning should be reduced to a minimum (reduce extraneous cognitive load). The objective here is to create space for the introduction of evidence-based learning strategies that promote and enhance learning (raise germane cognitive load) without overloading a student’s limited working memory.

**Cognitive architecture**

Human cognitive architecture is often described as the necessary memory structures, such as working and long-term memory, to input, process, store, and retrieve information in order to learn, think, and solve a problem. Humans are only conscious of the contents of their working memory. All other cognitive functions are hidden in long-term memory until retrieved into working memory, where they can once again be processed (Sweller, Van Merriënboer, and Paas 1998). This is critical due to working memory’s severe capacity and duration shortcomings: our working memory is only capable of holding about seven elements of information at a time and only for about 30 seconds without rehearsal (Miller 1956; Sweller 2004). These limits hold for both novice and expert learners. Experts can, however, “chunk” many pieces of information into a single element allowing them to process more information in working memory. Because working memory also processes information, the actual capacity of working memory is even more limited, thus reducing the number of items that can be dealt with simultaneously.

These limitations on working memory imply that instructional design must take into consideration our limited capacity. However, effective use of long-term memory may circumvent these restrictions because long-term memory is considered to be practically unlimited. Long-term memory can store information (facts and skills) in schemas of varying degrees of complexity and automation. A schema is defined as a set of elements of information categorized according to their potential future application. Performance (learning) comes from the construction of large numbers of complex and sophisticated schemas with high degrees of automaticity (Sweller, Van Merriënboer, and Paas 1998). That is, generating increasing numbers of ever more complex schemas by combining elements of lower-level schemas into higher-level schemas is what creates expertise and skilled performance. The importance of schemas is thus that a single schema can help combine together many elements (pieces of information) that are then considered as a single element by our limited working memory. In addition, automated schemas require less conscious processing, which also frees up working memory space. By creating ever more complex schemas, and making such schemas ever more automated, humans are able to increasingly process information in our limited working memory and thus avoid overload (Van Merriënboer and Kester 2005).

Automated schemas allow for automatic performance on familiar tasks, and by reducing the load on working memory, it allows for higher levels of performance. Automaticity occurs after extensive practice, including retrieval and deliberate practice (Ericsson 2008, 991). With sufficient practice, a procedure (use of information) can be carried out with minimal conscious effort (i.e., with minimal working memory cognitive load). In summary, learning consists of storing automated schemas in long-term memory (Sweller 1994).

As an illustrative example, consider an international trade course with the goal for students to master international trade theory and policy in order to remember, assimilate, and transfer such knowledge to future situations. To achieve this goal, a student must acquire a complex schema built from previous knowledge of economics, as well as new concepts from the field of international trade. Any attempt to introduce a student to the entire complexity of the field, by for example providing real-world examples or quickly discussing the “interesting part” of trade theory, will hamper student learning by creating cognitive overload. Instead, the economics instructor finds a “simple” entry point and then patiently helps the student create a complex schema from parts to the whole, from simple to complex.

It is important to emphasize that schemas are stored in long-term memory. The usefulness of sophisticated and automated schemas thus depends on a student’s ability to store and retrieve these schemas on demand in the future. The task of instructional design is therefore to manage the cognitive load of the student’s working memory in order to allow for the required processing that leads to the construction
of schemas and their automation. That is, instructional design must promote schema construction and automation, while ensuring that students’ cognitive limit is not saturated.

**Cognitive load theory**

Cognitive load theory was developed out of the study of problem solving by John Sweller in the late 1980s. Sweller (1988) argued that instructional design may be used to reduce cognitive load in learners. According to the theory, during learning, information must be held in the working memory until it has been sufficiently processed and transferred into long-term memory. As working memory’s capacity is insufficient, presenting too much or too complex information at once might overwhelm students, resulting in ineffective information retention. Cognitive load theory thus argues that for individuals to learn effectively, their cognitive architecture and the learning environment must be aligned. The ability of working memory to effectively process information is thus the main concern of cognitive load theory.

According to cognitive load theory, there are three types of cognitive load: intrinsic, extraneous, and germane cognitive load.

**Intrinsic cognitive load** is determined by the effort associated with the complexity of the material and the level of interactivity between elements. An element is anything that has been or must be learned, such as an economic concept. Element interactivity is a measure of the number of elements that must be processed simultaneously in the working memory in order to learn the specific concept (construct a schema). Low-element interactivity tasks require low cognitive load (e.g., learning basic facts such as the definition of demand). These elements can be learned serially, rather than simultaneously. High-element interactivity tasks must be processed simultaneously in order to be learned and understood. Economics, as a subject matter, tends to have a high intrinsic load because many concepts require multiple steps for understanding and are nonintuitive (Davis 2015).

The intrinsic cognitive load of information cannot be altered by instructional design, but an instructor is able to control the intrinsic load by presenting content and material in certain ways (e.g., simple to complex or part-whole sequencing). A student’s level of expertise will also affect the degree of intrinsic cognitive load of particular materials. A large number of interactive elements for a novice learner may be a single element (a schema) for someone with more expertise, which implies that the cognitive load of the novice will be higher for the same material. As suggested by Schnotz and Kürschner (2007), instructional design should identify the zone of proximal development that aligns intrinsic load to the level of expertise of the learner in order to optimize working memory.

**Extraneous cognitive load** is related to the way content or tasks are presented to students, while not directly contributing to learning. Purposeful instructional decisions and interventions can therefore help reduce extraneous cognitive load, which will allow students to either process more elements in working memory or elements of higher interactivity. Irrelevant and peripheral information or poor layout may, for instance, cause overloads in the working memory and negatively affect students’ storage of information. The most important feature of low extraneous load is the possibility of introducing instructional designs that lead to greater schema construction or automation (Artino 2008). That is, it supports an increase in germane cognitive load.

**Germane cognitive load** is cognitive load that facilitates the construction and automation of schemas. It can be difficult to make a clear distinction between different types of cognitive load, especially between intrinsic and germane loads (Debue and Van de Leemput 2014), and what might be categorized as germane load for an expert learner may be extraneous load for the novice learner (De Jong 2010). Nevertheless, the distinction is still operationally relevant, and the implication is that the instructional design should aim to decrease extraneous cognitive load and increase germane cognitive load, while maintaining total cognitive load at manageable levels (avoid cognitive overload).

In summary, the nature, complexity, and element interactivity of a task (intrinsic load) will impact students’ cognitive load. Extraneous load is caused by unnecessary activities or superfluous information presented in the learning environment. Germane load is the process of information that contributes to learning. The goal of instructional design is therefore to adopt a number of purposeful strategies whose
role is to control intrinsic load, reduce extraneous load, and increase germane load. Figure 1 presents a graphical overview of these ideas.

The problem of effective teaching

We frame the problem of effective teaching as a constrained optimization problem where the main objective is to maximize student learning, described by cognitive load theory as schema acquisition and automation. One major constraint is the limited cognitive load of student working memory. This problem can be expressed as in equation (1).

\[
\begin{align*}
\max_{E,G} & \quad L(E, G, I) \\
\text{s.t.} & \quad I + E + G \leq CL \\
& \quad E \geq 0 \\
& \quad G \geq 0,
\end{align*}
\]

where \(L\) measures Learning, which depends on the level of \(E\), Extraneous cognitive load, and \(G\), Germane cognitive load, and the invariable level of Intrinsic cognitive load, \(I\). The terms \(E\) and \(G\) are positive, but the partial derivative of \(L\) with respect to \(E\) is negative, \(\frac{\partial L}{\partial E} < 0\), while the partial derivative of \(L\) with respect to \(G\) is positive, \(\frac{\partial L}{\partial G} > 0\). That is, an increase in extraneous load reduces learning, while an increase in germane load increases learning.

The solution to this optimization problem is straightforward, given the level of complexity (element interactivity) of the economics concept, \(I\), the economics instructor should choose \(E\) and \(G\) that optimize learning, while satisfying the cognitive processing constraint, \(CL\). Clearly the optimal solution is to set \(E = 0\) and \(G = CL-I\).

Although a given economics concept for a particular student is invariable, there might be ways to reduce \(I\) by changing the sequencing or even the choice of topics covered, which would then allow for
even greater levels of $G$, and hence greater learning. This problem and its theoretical solution thus illustrate the goal of teaching and learning of economics, but what can the economics instructor do to choose the optimal levels of $I$, $E$, and $G$?

Careful recognition of the constraints allow for better instructional design decisions. There are trade-offs associated with every instructional choice made. There are thus opportunity costs associated with a poorly designed PowerPoint or exclusive use of lecturing (extraneous load), or material presented at an inappropriate level given the student audience (intrinsic load). At the same time, any instructional technique suffers from diminishing returns; for example, repetition is useful, but such practice will be more effective if concepts are properly sequenced and distributed over time (germane load).

### Practical suggestions

Given such things as the physical space, class size, and access to technology, the economics instructor attempts to design the learning environment in an optimal way; that is, designing instruction to yield the greatest amount of student learning. As the optimization problem shows in equation (1), this entails controlling the intrinsic load, reducing the extraneous load, and raising the germane load, while at the same time keeping the total cognitive load under working memory capacity.

### Control intrinsic load

The first step is to control or manage the intrinsic cognitive load of the economics material presented. In general, the nature of the material determines the intrinsic cognitive load: a basic fact (say the definition of scarcity) carries a lower cognitive load than a complex economic concept (say the equilibrium of demand and supply or the mechanisms by which the central bank controls short-term interest rates). The reason is that a fact can be learned separately and serially, and therefore has low-element interactivity. Novice students who are required to understand the concepts of demand and supply must simultaneously process many facts and ideas in working memory, which raises the intrinsic cognitive load. In this sense, the intrinsic load is determined by the complexity of the material covered relative to the expertise of the student.

There are ways to control this load. Because learning consists of schema acquisition and a constructed schema becomes a single element in working memory, by allowing students to gradually “build up” their schemas, from basic facts to more complex concepts, students are able to keep more information in their working memory. The practical suggestion is thus to present material sequentially: either from simple to complex or by presenting parts that are then combined to a whole. Both of these approaches start with few elements and gradually build up the degree of complexity (De Jong 2010). The economics instructor may be tempted to begin the discussion of the demand-and-supply framework by addressing “real-world” examples, the labor market, the housing market, the market for Uber, and asking students to “apply” the framework in these situations. Cognitive load theory suggests, however, that first-year students are likely to be overwhelmed due to the high intrinsic load, given their current level of expertise (schema). Instead, by patiently introducing students to demand first, then to supply, and finally to equilibrium (parts-whole sequencing), they acquire the necessary schema to apply the demand-and-supply framework to real-world situations.

An alternative approach is to give students more time to process the material, which allows them to serially master parts of the material, as well as switch back and forth between information, thus avoiding cognitive overload (De Jong 2010). This approach suggests the use of active learning activities, as opposed to lecturing, so that students have the opportunity and the time to deeply engage with novel economic concepts. A similar approach is to allow students to “offload” their working memory while engaging in new material. By giving students an opportunity to write ideas down (e.g., in a notebook [De Jong 2010]), the intrinsic cognitive load of the economic concepts is reduced because the student must not keep all elements in working memory simultaneously. In addition, some teaching approaches, such as the flipped classroom model, may facilitate management of the intrinsic load by allowing
Table 1. Practical suggestions for controlling the intrinsic cognitive load.

- Match the complexity of the material (degree of element interactivity) with prior knowledge/expertise of the student. Conduct a knowledge analysis of the student by, for example, offering a diagnostic test or a prompt that students can respond to by writing down their understanding of the concept.
- Use simple-to-complex sequencing and parts-whole sequencing when presenting new material. For example, learning the concept of negative externality and understanding the possible need for government intervention requires sophisticated thinking by the student. The student must be familiar with the concept of a market, as well as the demand-and-supply framework. Moreover, the student must understand that the supply curve represents the private marginal cost of production. In addition, the student ought to understand the concept of market equilibrium and how market forces bring the market to equilibrium. Then, the student must realize that private decisions by producers result in a situation of over-production because the negative externality is a market failure. That is, producers are not taking into account the true cost of producing their products; they fail to internalize the marginal external cost. To induce the producers to internalize this external cost, a government intervention might be needed. A novice economics student will not be able to process all these “elements” in his/her working memory, unless previous learning has generated a schema that incorporates several pieces of information as a single “element.”
- Provide the necessary amount of time to process concepts serially, and give students the opportunity to switch back and forth between materials. By imposing strict time constraints, we force students to use their working memory to process all material at once (to keep all elements in mind simultaneously). By extending the time allotted, students can focus on certain parts and go back and forth between these parts. One effective way to give students more time to process the information is to move content delivery at least partially outside of the classroom. By delivering content through lectures, the instructor imposes a strict constraint on the student’s ability to process new concepts and relationships, namely the pace of the lecture, and thereby increases cognitive load. Cognitive load can therefore be reduced through various pre-lecture activities (Chen, Stelzer, and Gladding 2010) or alternatively switching to more of a flipped classroom approach where students engage in the material before class, either through video lectures (which a student can pause and rewind) or through a textbook.
- Allow devices (notepad, laptops) that offload memory. This reduces the amount of elements being processed in working memory simultaneously.

Allowing students to write down partial solutions on their way to solving steps or sub-goals is part of the process of solving the whole problem. This helps students to offload some of the elements, so that all elements are not kept in working memory simultaneously. This does not mean that encouraging students to type notes on their laptops or (slightly better) taking notes by hand during lectures will result in learning. Rather, giving the students the space and time to write things down as they engage in various active learning activities will reduce the intrinsic cognitive load of the activity.

| Reduce extraneous load |
|-| |

Extraneous cognitive load is determined by how content or tasks are presented to students. Purposeful instructional decisions can help reduce extraneous cognitive load, which allows students to either process more elements in working memory or process elements of higher interactivity. Thus, the economics instructor should carefully consider how material is presented, both during lectures and in problem sets. To reduce the extraneous cognitive load during content delivery, the instructor should in general manage split-attention effects, lack of schema-based knowledge, redundancy, and single modality presentation. See table 2 for examples of how to reduce these effects.
Minimizes split-attention effect by integrating material (Cook 2006). Do not present multiple sources of information that require the student to search for information. Integrating all information in one source frees up scarce working memory.

Eliminate redundant material (Sweller, Van Merriënboer, and Paas 1998). Do not present multiple sources of information if each can be used without reference to the other. For example, avoid giving a diagram that incorporates some information with a text paragraph that supplies additional, relevant information. Rather, integrate all relevant information into the diagram and remove the text paragraph, or vice versa.

Reduce means-ends analysis by incorporating worked examples and completion examples (Sweller 1988). Means-ends analysis uses a high cognitive load due to students having to keep many elements in working memory simultaneously. Provide problems to-be-solved after a phase of example study (Renkl and Atkinson 2003). To avoid this excessive cognitive load, present worked problems and completion problems until the students have acquired the sufficient schema to process the entire problem. For example, provide a solved example for the welfare analysis of a per-unit tax (worked example). Then, provide a completion problem where students must identify only the welfare areas. Then, ask students to draw in the per-unit tax and identify the new equilibrium and associated welfare effects. Finally, give students a word problem that asks them to explore the welfare effects of a sales tax imposed on a particular good. Learning also can be improved by annotating the worked examples with the concepts they illustrate (Sweller, Van Merriënboer, and Paas 1998). This approach is more useful compared to giving students a worksheet of, say, five problems related to welfare analysis because studying completed or partially completed problems results in more rapid schema acquisition compared to using means-analysis to solve conventional problems (Sweller 1994). Sweller, Van Merriënboer, and Paas (1998) discussed additional studies that showed that worked examples reduced extraneous load, increased schema acquisition, and led to higher transfer performance than conventional use of problems.

Too much focus on worked examples, however, may reduce training of genuine problem-solving skills, which can affect both motivation and creative problem-solving skills. A mix of worked examples, completion problems, and conventional problems should therefore be used. Students should be discouraged from ignoring worked problems until they attempt to solve conventional problems. Such “search for answers” learning strategies carry a high cognitive load and do not promote schema acquisition.

Increase students’ processing capacity by using two modalities when presenting material (Cook 2006). The modality effect occurs when information is presented through two different sensory modalities (Kirschner, Kirschner, and Paas 2009). Take advantage of the fact that working memory can be subdivided into auditory and visual processing components by presenting some material visually and some material verbally contiguously. For example, show the graph of the economic concept on the board (PowerPoint) while simultaneously describing it verbally to the students, rather than accompanying the graph with a written explanation.

The split-attention effect refers to the cognitive load associated with mentally integrating disparate sources of information. For example, by simultaneously presenting a graph of a concept and a written explanation of the concept immediately below (which is often common practice), a student’s attention will be “split” between the graph and the text. This split-attention results in raising the cognitive load of working memory.

When students who lack schema-based knowledge are presented with the task to analyze complex material to address an issue, they tend to adopt a means-ends analysis approach. Means-ends analysis is a common, and efficient, problem solving approach that entails trying to establish differences between the problem state and the goal state, and then finding problem solving operators that can reduce or eliminate those differences (Sweller 1994). This problem-solving approach, although often effective, requires iterations and many elements to be kept in mind simultaneously, and therefore increases cognitive load. The implication is that a student may be able to ultimately solve the problem, but will not digest the material because the approach bears little resemblance to schema construction. The means-ends approach is therefore different and indeed incompatible with learning (Sweller, Van Merriënboer, and Paas 1998). This incompatibility can be offset by reducing goal-specificity, in particular, by using worked problems and completion problems. Worked (solved) examples focus a student’s attention on the problem states and the correct operators for their solutions. The cognitive load is thus very low (Sweller, Van Merriënboer, and Paas 1998). A potential issue with worked problems is that students may ignore them, or only look at them when searching for the solution to an unsolved problem. An intermediate approach is therefore completion problems where the first step or two has been solved and the student must only complete the last step (see table 2).

A redundancy effect is present when the instructional design incorporates multiple sources of material that contain the same information (Mayer 2005, 62). An example would be to show a graph of how to shift the demand curve, as well as a written paragraph that describes exactly what is occurring in the graph.
This is a common approach, but the common sense notion that presenting the material twice should be helpful is not accurate.\textsuperscript{3} The redundancy effect can be counteracted by coordinating or eliminating the unnecessary and often distracting overlapping material. This is referred to as the Coherence Principle. Similarly, Clark and Mayer (2008) argued that people remembered better from a multimedia presentation if extraneous words, pictures, and sounds were excluded.

Finally, because the working memory actually consists of two subsystems, an auditory system and a visual system, presentations that use only one of the subsystems are more likely to cause cognitive overload. The effect can, however, be mitigated; that is, available cognitive capacity can be increased by presenting material as a combination of visual and auditory material (De Jong 2010). This is often referred to as dual coding. When lecturing, the economics instructor can display a graph on the board and verbally describe it, presenting some of the material in auditory form and some of the material visually (Mayer 2005). However, presenting a PowerPoint slide with text (or bullet points) while the instructor simultaneously reads the text is an example of split-attention, rather than dual coding. Table 2 proposes additional practical suggestions for reducing the extraneous cognitive load.

By adopting some or all of the instructional practices discussed above, the economics instructor is able to control the intrinsic and reduce the extraneous load sufficiently to allow for an increase in the germane cognitive load, without causing cognitive overload among students. That is, the economics instructor has an opportunity to adopt well-proven instructional techniques that facilitate schema acquisition and automation (in short, instructional designs that promote learning).

### Increase germane cognitive load

**Germane cognitive load** is cognitive load related to the effort required to construct and automate schemas. The main implication here is that instructional design should aim to optimize germane cognitive load, given the limited and fixed cognitive capacity of working memory.

Cognitive and educational psychology offer many learning strategies that might be helpful for learning, but relatively few are actually supported by evidence. We do know that a few common techniques are ineffective, in particular highlighting and rereading text (Dunlosky et al. 2013, 18–21). Five evidence-based active learning strategies have been shown effective: distributive practice (spacing), interleaving practice, retrieval practice, elaboration, and self-explanation (Roediger 2013). Of these, spacing and retrieval practice are most effective. Given the empirical evidence, we can conclude that using these five approaches will increase the germane cognitive load of our students, which will improve learning (schema acquisition and automation).

Distributive practice, or spacing, involves spreading a fixed amount of study time over a longer period of time. It is the opposite of cramming. Instructional design should incorporate this principle by encouraging students to review material continuously, perhaps by spacing out assignments in a way that forces students to practice their knowledge and skills over time. The economics instructor can also space out learning by including brief reviews of material in each class (Lowe 2016). See table 3 for additional examples.

Interleaving is the practice of mixing related but distinct material during learning sessions, forcing students to discriminate between problems and select the correct solution method given the context (Brown, Roediger, and McDaniel 2014, 65). Learning improves if students study and switch between multiple concepts or problems during a single study session, and the general rule is to switch to a second concept before having mastered the first concept (Lang 2016, 68).

Interleaving principles should not be confused with multitasking. To help students practice interleaving, the economics instructor can design assignments that address several concepts and alternative solutions (e.g., profit maximization under different market structures), rather than worksheets covering a single type of problem. Class sessions can also be divided into segments that focus on different topics. An easy change is to provide questions that cover previously learned material during formative assessments. Students also should be given opportunities to make connections between the different types of topics that they study, thus promoting their ability to recognize contexts and underlying structures, as well as discriminate between solution procedures. Interleaving incorporates the spacing and retrieval
practice principles; together they promote content learning that lasts beyond the exam and even the confines of the particular course. Results of a science, technology, engineering, and mathematics (STEM) classroom experiment (Butler et al. 2014) have shown “compelling evidence” (339) that combining repeated retrieval practice, spacing, and feedback “had a powerful effect on student learning” and significantly increased student performance on exams.

Spacing and interleaving also can be combined with deliberate practice, activities of limited duration that have been especially designed to improve performance and achieve mastery (Ericsson 2008). Ericsson stated that practice, “engagement in domain-related activities,” with feedback is paramount “to attain high levels of performance” (990). In the economics class, students can, for example, be provided with tasks and questions (problem-based learning), such as using supply-and-demand factors to reason like economists to solve various problems, individually or in a team.

Retrieval practice involves asking students to recreate something learned in the past from memory. The retrieval must occur after initial learning and partial forgetting. It is crucial to ensure that the process of retrieving the material is challenging to students because such effort supports learning and fosters transferability; that is, the student is more likely to remember and be able to reapply the information in a new future situation. To help students practice retrieval, the economics instructor can design formative assessment material (practice tests, ungraded quizzes, etc.) at pivotal points during the semester and provide feedback (Becker 2000). Students also can be encouraged to make up their own practice test, to use detailed flash cards, to write down everything they remember about a topic on a piece of paper, to draw a concept map, or other activities that force them to recreate something learned in the past from

### Table 3. Practical suggestions for enhancing the germane cognitive load.

- Distributed practice or spacing (Benjamin and Tullis 2010).
  - To retain information, students must generally study economic concepts on several occasions, but the timing of these learning episodes matters (Cepeda et al. 2008). Present and review economic concepts over time in order to interrupt inevitable gradual forgetting. Encourage students to continuously review economic concepts throughout the course by spacing out learning events. Discourage cramming the night before by introducing timely assignments that prompt students to practice knowledge and skills multiple times over the course. Consider beginning classes with a brief review (by instructor or, preferably, by students) of material previously covered (Lowe 2016). For example, when teaching demand and supply, aim to continuously distribute students’ practice throughout the term. Purposefully use demand and supply when discussing equilibrium price and quantity, price elasticity, international trade, market failures, market structures, and so forth, to foster connections. Spaced practice also supports retrieval practice and interleaving (see below).

- Interleaving practice (Roehler 2012).
  - An important characteristic of deep learning and understanding is the ability of the student to correctly identify and apply appropriate solution steps for a particular problem. To support learning, ask students to mix related but distinct material during learning sessions. This promotes their ability to discriminate between problems, and helps them select appropriate solutions and methods given the context (Brown, Roediger, and McDaniel 2014). Presenting distinct economic concepts serially, even if students are asked to apply their new knowledge, hampers students’ ability to recognize the underlying structure of the questions and problems, and hence reduces the flexibility and transferability of the information. Introduce interleaving in your course by designing assignments that cover more than one topic, and perhaps do the same for each class session. As an example, we might combine problems related to perfectly competitive firms with problems related to monopolists, rather than treating these two topics separately and addressing them sequentially (only).

- Retrieval practice (Roediger, Putnam, and Smith 2011).
  - Students’ level and usefulness of learning depend on their ability to apply material in the future, either in an assessment situation or (more importantly) when transferring their skills to new situations faced in life. This ability requires practice, so aim to continuously, frequently, and carefully ask students to retrieve information from their memory by giving them the opportunity to review material in assignments, in formative assessment activities, during presentations and teamwork, and in testing situations. Testing, formative and summative, has been shown to greatly improve student performance, enhancing retention and increasing flexibility and transferability of concepts. Tests also help students organize information (acquire schemas) and motivate students to study more and with more regularity. Finally, testing allows students to discover gaps in their knowledge (Roediger, Putnam, and Smith 2011).

- Elaboration and self-explanation (McDaniel and Donnelly 1996).
  - Ask students to explain and describe ideas and concepts with as many details as possible, and ask them to make connections to previously studied material and their own lives. By making these connections and “finding additional layers of meaning in new material” (Brown, Roediger, and McDaniel 2014), recall and transfer of knowledge will improve. Reflection is a combination of retrieval practice and elaboration as students must first recall what was learned, then reflect or elaborate on these experiences. To encourage elaboration, the instructor can ask students to write reflection essays, answer short reflection questions, or even use a one-minute paper at the end of the class. Students can also respond to economics-related quotes or analyze news articles related to economic concepts covered. A third approach is to ask students to create a Mind Map that connects one economic concept to other economic ideas and personal experiences.

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memory. The economics instructor or (more importantly) the students should check how accurate and complete their recollections are by comparing their recollections to notes or textbooks, and discussing with fellow classmates.

Elaboration and self-explanation refer to the practice of students asking themselves why the information studied is accurate, as well as trying to explain the concept or procedure to themselves (Roediger 2013). By explaining and describing ideas with many details, as well as making connections to own experiences and previous materials, students are able to acquire more complex schemas (i.e., learn more). The economics instructor can ask students to carefully reflect on how and why concepts and ideas work, as well as how they are connected to each other. Students also should be prompted to explore how current concepts are connected to ideas discussed previously, as well as their own lives and experiences. Finally, the instructor should ensure that students double-check their “elaborations” to make sure that they correctly describe ideas and concepts.

Although some of the ideas presented are compatible with lecturing, we suggest using these strategies as part of active learning approaches. In fact, these concepts can be viewed as describing why active learning works. They are also consistent with the flipped classroom model where content delivery is moved out of class in order to use class time for active learning activities based on the learning strategies presented in the tables (Abeysekera and Dawson 2015). Table 3 proposes practical suggestions for enhancing the germane cognitive load.

Conclusions

Cognitive load theory presents the economics instructor with a constrained optimization problem: how to maximize student learning by designing an effective instructional environment without violating the constraint caused by the scarce capacity of students’ working memory. The optimal solution is to control intrinsic load of the material by carefully matching the level of complexity (element interactivity) of the information presented to the knowledge base of students. That is, instructors should gauge students’ prior knowledge and present material from simple to complex or, alternatively, in parts to whole. The economics instructor should also strategically consider an appropriate timeframe during content delivery and engagement.

Most importantly, the cognitive load imposed by the instructor’s teaching approach should be considered with the goal of reducing all extraneous cognitive load. Instructional material that does not contribute to learning should be reduced in favor of learning strategies that promote schema acquisition and automation, the main purposes of which are to increase germane cognitive load. In fact, the optimal solution to the learning maximization problem is to completely eliminate extraneous load, while raising germane load up to the point of working memory processing capacity, given the intrinsic load of the particular student. This article offers several potential strategies for how to achieve, or at least move toward, this optimal solution. In particular, a case is made for incorporating distributed practice, interleaving, retrieval practice, dual coding, and elaboration, preferably in an active learning context.

Notes

1. This approach might be helpful for learning in a different way, however Brown and colleagues (2014, 221) argued that “generation” of knowledge is useful as it engages the brain in connecting previous knowledge to the problem at hand. That is, this preview prepares the student to learn the material.
2. Another method is the goal-free approach, which eliminates the goal state. The goal-free approach, in general, provides students with a problem and asks them to find as many unknowns as they can. This eliminates the number of elements required to be held in working memory (Sweller 1988).
3. Note that this is not an argument against repetition per se. The act of repeating information previously presented is redundant; it increases cognitive load and reduces learning. Repetition is, in fact, helpful if used in accordance with the learning strategies promoted, such as spacing, interleaving, and retrieval practice. Repetition also plays a role in practices of elaboration and reflection, all of which are helpful to learning.
References


Lowe, D. 2016. Remembrance of philosophy classes past: Why cognitive science suggests that a brief recap is the best way to start each class day. Teaching Philosophy 39 (3): 279–89.


