

A comparison of strategies to encourage regular study and foster deep learning

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ABSTRACT

One of the challenges facing engineers is efficiently using a growing number of sophisticated tools and methods. This requires not only procedural knowledge on how to use them, but conditional knowledge, which determines under which conditions a given tool or method should be used (when, by whom, where, etc.) as well as conceptual knowledge which is necessary for efficient learning and use of tools and methods as well as for knowledge transfer. This paper presents a learning activity devised to improve deep learning of conceptual knowledge. It was implemented in a second year undergraduate compulsory course in mechanical engineering using three different strategies. Students were:

1. asked to draw a map of the course material that was to be covered in the coming week;
2. asked to produce an individual map of the material covered the previous week;
3. given the choice between drawing a map, writing a summary or attending a 10 minute quiz given at the beginning of the lecture, all on the material covered the previous week.

The third strategy proved the most effective. To explain this result, it is hypothesized that motivation played an important role. When students have a better sense of control over their learning – for example, by having a choice of learning strategies and selecting the one which corresponds most to their learning style – their motivation increases. Furthermore, sense of competence was increased for the students who handed in maps or summaries by performing well in the quizzes. These conditions foster a deep approach to learning.

KEYWORDS

learning activity, concept mapping, topic mapping, motivation, deep leaning

INTRODUCTION

One of the goals of the CDIO initiative is to educate students who are able to master a deeper working knowledge of technical fundamentals. This paper proposes a learning activity resulting in an increased sense of control and competence, conditions fostering a deeper approach to learning.

One of the challenges facing engineers is efficiently using a growing number of sophisticated tools and methods. This required not only procedural knowledge on how to use them, but conditional knowledge, which determines under which conditions a given tool or method should be used (when, by whom, where, etc.) as well as conceptual knowledge which is necessary for efficient learning and use of tools and methods as well as for knowledge transfer.

This paper pursues two goals, firstly to present a learning activity designed with the purpose of fostering deep learning and secondly to hypothesize on the mechanisms on which the success of the activity lies. The first goal is achieved through the description of a case study while the second relies on research literature.

To better understand the context leading to this study, the next section presents ETS and its student population. It is followed by a short explanation of different forms of graphical knowledge representation, namely mind, topic, concept and knowledge maps. Follows a description of a learning activity devised to foster deep learning and the presentation of results for three different implementation strategies. Finally, an explanation of implementation results is given before concluding.

PRESENTATION OF ETS AND OF ITS STUDENT POPULATION

ETS (Ecole de technologie supérieure) is located in Montreal, province of Quebec, Canada. It was founded in 1974 at the bequest of industry and until 1989, it graduated technologists. Since then, it has been transformed in a fully accredited engineering school and now offers seven undergraduate programs (mechanical, electrical, construction, automated production, operations and logistics, software and information technology engineering).

To fully understand the context, a few words about the Quebec education system is necessary. The system is organized in 4 levels: primary school (6 years), secondary school (5 years), college (2 or 3 years) and university. In college, students can choose between general (natural, administrative or health sciences, arts and humanities) or vocational technical training. Upon completing college, students who followed the general track normally enter university and those with technical training normally join the work force.

The following statistics characterize our student population:

- over 85% graduated from professional college. ETS is the only engineering school or faculty in Quebec which caters to this student population. It shares this feature with only one other school of faculty in Canada (Ryerson Polytechnic). The remaining 15%, coming from general college, must undergo 1 year of technical training before entering our regular engineering programs;
- 13.5% of students hold a full-time job and study on a part-time basis;
- roughly 80% work on a part-time basis at least 15 hours per week;
- about 25% of students enter ETS after at least 2 years spent working full time as a technician.

All undergraduate programs at ETS possess the following characteristics:

- **strong emphasis on the practical aspects of engineering.** The school favors the acquisition of knowledge and skills through experimentation. All courses offered at ÉTS include two to three hours of laboratory or practical assignments per week. This much contact time devoted to practice is unique among engineering training programs in Quebec;
- **mandatory co-op workterms.** All bachelors-level programs include three mandatory work terms in industry, the last of which must strongly emphasize design. In 2010, ÉTS students carried out over 2000 paid work terms in over 900 companies. In addition, the School offers the possibility of doing an optional research-oriented fourth work term.

ETS is a state university and does not apply a selection policy upon entrance other than verifying that candidates have completed college or demonstrate the equivalent. At the beginning of the 2010-2011 academic year, 3700 students were registered at ETS in an

accredited engineering program. Over 700 students graduate from ETS each year, making this institution one of the five largest engineering schools or faculties in Canada.

The student population profile confers a number of teaching challenges:

- prior training is strongly geared towards procedural knowledge. A proportion of the student population resists acquisition of conceptual knowledge or have not developed efficient learning strategies to deal with this type of knowledge. More often than not, this is voiced by the question: *What is the recipe?*
- personal observation leads to believe that most students at ETS learn by induction rather than deduction, preferring building generalizations from a number of specific cases, moving from a set of specific facts to a general conclusion, from examples to theory. According to Kolb's model of learning styles [1], they would be considered as Accommodators as they prefer to use concrete experience and active experimentation. They are good at actively engaging with the world and actually doing things instead of merely reading about and studying them. This reveals to be a true challenge as classical text books are structured deductively. It is further hypothesized that most professors favour other learning styles and fail to adapt their teaching strategies, favouring strategies with which they themselves feel comfortable.

GRAPHICAL REPRESENTATION OF KNOWLEDGE

Mapping has been proposed as a means to promote deep understanding [2, 3, 4]. Different techniques and tools can be used to represent knowledge, ranging in complexity and subtlety. At one end of the spectrum, one finds mind maps followed by topic maps, concept maps and finally knowledge maps.

Mind maps are graphical representations where secondary ideas irradiate from a central idea, thereby forming a constellation of spokes. Ideas form nodes from which new nodes are formed. Another characteristic of mind maps is the spontaneity with which they are formed. They are therefore often used during brainstorming activities or to rapidly capture and categorize ideas.

When mind maps form networks, they become topic maps, revealing richer connexions between ideas. They share this characteristic with concept maps. Developed by Novak in the 1970's [2], a concept map aims at answering a central conceptual question (What is the finite element method? What is a nonlinear equation? etc.) through a network of concepts, represented by nodes. Nodes or concepts are related to one another by linking words, often verbs. Two nodes and a link form a proposition. One of the difficulties of concept mapping is finding the proper words to link concepts necessary to build these propositions. As the name implies, concept maps are used to represent conceptual knowledge.

Knowledge mapping is even more complex as it is used to represent different types of knowledge (factual, conceptual, procedural, conditional) [3]. A given network often contains different types of knowledge which can be distinguished by different shape of boxes and relationships between knowledge entities form a grammar. For example, conditional knowledge regulates procedural knowledge. Concepts are used as inputs or form outputs of procedures. Facts are instantiations of concepts. Significant training is necessary to create meaningful knowledge maps.

CASE STUDY

The case study concerns a second year undergraduate compulsory course in mechanical engineering. Entitled "Computer assisted engineering", the goal of this course is to gain theoretical and practical knowledge in the use of numerical methods for solving problems

represented by linear and non-linear partial differential equations. Students are thus exposed to finite elements, finite differences and a variety of linearization methods. Each week, students are offered three hours of lecture and exercises during which theory is presented and three hours of laboratory during which they learn MATLAB and ANSYS, a finite element software. Theoretical and practical knowledge are integrated in three mini-projects. An example of a finite element project is to design and dimension a lifting device to extract motors from vehicles.

Adaptation of teaching and learning strategies

An example of how the teaching strategy was adapted to the preferred student population learning style resides in how the mini-projects were introduced. Classically, a professor will teach the theory in class and examples solved with a teaching assistant later in the week. After all or most of the theory is covered, students are assigned a more complex problem to be solved as part of a project. However, in this course, the sequence was reversed. One of the first activities at the beginning of the semester was to hand out the three mini-project statements. Students were asked to discuss strategies and knowledge required to solve the problems. The result of this discussion was related to course material. Every week, links were made between theory and the problem at hand.

This strategy was certainly useful to heighten interest for theory as it was now rooted in a practical problem. However, after giving the course two semesters, it became apparent that, while students picked up the procedural knowledge quite readily, they lacked depth in conceptual and conditional knowledge. Furthermore, many students mentioned that they were fooled by the ease with which they could follow the lectures and baffled when it came time to study for exams or even apply the knowledge in the mini-projects, revealing lack of understanding.

To redress these problems, a new learning activity was introduced in the course. It aimed at encouraging regular weekly study. Each week, every student was asked to produce an individual proof of study. Each proof was marked and students could accumulate a maximum of 10 points over the semester.

Over three semesters, three different strategies were used. In an effort to improve the acquisition of conceptual and, to a lesser degree, conditional knowledge, students were:

1. asked to draw a topic map of the course material that was to be covered in the coming week;
2. asked to produce an individual topic map of the material covered the previous week;
3. given the choice between drawing a map, writing a summary or attending a 10 minute quiz, composed of 5 multiple choice questions on conceptual and conditional knowledge, given at the beginning of the lecture, all on the material covered the previous week.

Topic mapping was selected over mind mapping in order to encourage the emergence of networks, without the formal requirement of having to create propositions as in concept mapping. Knowledge mapping was set aside because of its great complexity.

Qualitative results of regular study strategies

For the moment, no quantitative results as to the effectiveness of these strategies is available. However, changes in attitudes and level of active involvement in the classroom was observed. These qualitative changes are presented for the three different strategies.

Strategy #1: topic map of upcoming course material

This strategy proved to be the least successful. The first few weeks, the resulting maps were average as some students could relate new material to material covered in previous courses. However, as time drew on, it became quickly apparent that they had more and more difficulty linking new knowledge to knowledge covered in previous weeks as evidenced by most maps taking the form of a tree mimicking the reference material chapter subtitles.

Strategy #2: topic map course material covered the previous week

A second strategy was tried the next semester. Every student was asked to produce and hand in an individual map of the material covered the previous week. This strategy was much more efficient. It achieved the goal of maintaining a constant study pace and more students were able to produce meaningful maps as demonstrated by the quantity of concepts presents in the maps as well as the number and quality of links between the concepts.

Four weeks into the course, an informal assessment of how students appreciated the course was conducted. They were asked to write down three items they enjoyed about the course and three items they would like see changed. Out of 54 students, 8 students mentioned that they appreciated the concepts maps, 3 that they didn't mind either way or 6 that they preferred not having this activity. For the rest of the class, it did not appear to be a major issue.

Upon discussion, it became apparent that some students had difficulty drawing the maps, possibly because it did not appeal to their learning style. Furthermore, it was deemed not sufficiently strategic for another group, in the sense that they could not see how it helped them obtain better marks at exams and therefore did not judge it was worth the time spent drawing the map.

Strategy #3: choice of topic map, summary or quiz

Students were given the choice between drawing a map, writing a summary or attending a 10 minute quiz given at the beginning of the lecture, all on the material covered the previous week. Quizzes were composed of 5 multiple choice questions on conceptual or conditional knowledge.

Results were quite surprising. Out of 33 students, 24 students handed-in topic maps and 2 wrote summaries. Most topic maps contained concepts and few procedures. All students attended the 10 minute quiz. However, the 7 students who neither handed in the maps nor the summary systematically had the worst results by the end of the semester. Two of them ended up abandoning the course.

This third strategy proved the most effective in terms of student acceptance. There were no more complaints about having to hand in a weekly assignment. If student interaction during lectures is construed as evidence of deeper learning, this strategy was also the most effective in terms of deep knowledge acquisition. The number and quality of questions asked by students during lectures as well as the readiness with which they performed active learning tasks during class far surpassed those observed with the first two strategies.

EXPLANATION OF SUCCESS

Novak and Gowin [2] contend that approximately 5 to 20% of students respond negatively to instruction that requires meaningful learning and will resist strategies such as mapping, while about the same percentage are enthused by such strategies.

The results in this study showed that acceptance varied greatly with implementation strategy. Acceptance was even lower than expected compared to Novak and Gowin's claim for the first strategy, about the same for the second and much higher for the third.

To explain these results, we turn to the theory of motivation. If intrinsic motivation is an essential condition for deep learning [5], the next question becomes: what are the conditions that foster intrinsic motivation? Viau [6] teaches us that three factors influence student motivation, based on their perception of :

1. the value of a learning activity,
2. their capability to accomplish the task,
3. the control they can exercise on the task at hand.

Table 1
Characteristics of three implementation strategies with respect to motivational variables

Strategy	Motivational variables		
	value	capability	control
1- Mapping of upcoming material	low	low	low
2-Mapping of past material	medium	medium	low
3-Mapping, summary or quiz	high	high	high

With implementation strategies 1 and 2, students were given no choice other than handing in an individual map, giving them a low sense of control over the activity. When given the choice, students could select the tool they most felt suited their learning style, heightening their sense of control.

In the third strategy most students elected to hand in either a map or a summary **AND** perform the quiz. These students systematically had a mark of 4/5 or more, where as the students who chose to perform only the tests did poorly. These results surely increased the sense of competence of those who studied regularly and encouraged them to pursue with this learning activity. It also surely played a role in their perception of the value of the activity in that not only did they perform well in weekly tests, but they also could follow and participate more actively during lectures, thereby reinforcing their perception of capability.

Mapping of upcoming material proved too difficult, affecting the perception of capability downwards. Furthermore, because it did not seem to help them in anyway, students did not value it. This was somewhat alleviated by mapping past material, where students had a better grasp of the content but a number of students resisted the method of knowledge representation.

CONCLUSION

This paper presented a learning activity devised to encourage regular study and foster deep learning. It consisted of handing in a proof of study on a weekly basis. Three implementation strategies were tested. The third strategy, whereby students were given the choice to either hand in a topic map, a summary or attend a 10 minute quiz proved the most effective in terms of student acceptance and acquisition of knowledge.

One of the irritants of all three strategies employed resides in the fact that the assignment was to be done individually. An improvement over existent strategies would be to offer students the possibility to produce a collective concept map.

One limitation of the current study is that it is mostly qualitative in nature. However, the experience is considered sufficiently significant to warrant further study for which metrics or instruments should be devised for a more robust research protocol. The type of maps (topic vs concept maps) handed in, as well as the analysis of their content structure (spoke or radial organization, chain structure or networks [7]) are potential metrics.

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Biographical Information

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