A Methodology For Teaching Mathematical Topics Utilizing Active Learning Techniques

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Abstract

It has been consistently shown in literature that the traditional lecturing technique is an inefficient way to teach college courses. Unfortunately, most publications give good advice on effective techniques but do not provide specific instructions on how to implement what they recommend. Many professors simply do not know how to implement changes into their courses. This paper describes a six-step process for teaching concepts that includes using videos, concept reinforcement, active learning techniques, and puzzle/game-like problems to solve.

Introduction

The goal of this methodology is to help learning occur in the classroom rather than the student only learning how to apply a concept while working during homework after class. By having students learn in class, instructors can foster meaningful learning, which can be defined as an understanding of the material that includes the important aspects of the subject, mentally organizing it into coherent cognitive structures (schemata), and integrating it with relative existing knowledge with the ability to apply the knowledge to new situations (Mayer and Moreno 2003). It has been shown that teachers want to know how to instruct more efficiently but many times do not know how to implement changes (Hille 2011). This work provides a specific methodology for how to incorporate active learning techniques to teach mathematical fire science topics. The proposed methodology shown has been used successfully in both freshman and junior level classes with students of a wide range of ability and nationality.

Literature Review

The least efficient methods for inducing learning are by passive reading and passive listening to lectures which are some of the most common methods for teaching college courses (Middendorf and Kalish 1995). The continuation of this traditional teaching style is typically because: people teach the way they were taught, students who succeeded in the traditional method went on to become professors, and coverage of material is often valued over material retention (Straumanis 2011). To maintain the student's attention during the traditional 50-75 minute lecture it should be broken up into smaller segments to prevent lapses of attention (Middendorf and Kalish 1995) because typical students have attention spans of around 15-20 minutes (Johnstone and Percival 1976; Burns 1985). This methodology can also help teach students with learning disabilities because it does many of the things that have been shown to help teach math to people with a learning disability (Sullivan 2005) including: making the mathematics content relevant and authentic; employing a concrete-to-abstract sequence that starts with a demonstration, goes to a specific example, and ends with an abstract generalization; providing rules or proven theorems; providing opportunities for guided practice in solving problems prior to independent practice; and providing opportunities for students to verbalize their process to other students and practice writing solutions.

Methodology

The methodology proposed here involves six steps: explain the basics of the concept, show a video of the concept, explain any equations for use with concept, work an example problem, have students complete an in-class activity in groups, and assign homework similar to the example problem and in-class activity.

Step 1 – Explain the Basics of the Concept

To teach a student an idea, you have to explain the concept, but this involves more than just direct memorization of definitions. The context of the idea should be explained along with why the student should learn it to show applicability. The limits of the current science and methodologies should be explained along with why the issues are handled the way that they are. Including misconceptions is an important part of the learning process (Muller, Bewes et al. 2008). If electronic presentations are used, the author recommends providing partial notes as it is very difficult for the instructor to proceed at a pace that the students can follow. Provide partial notes with equations, definitions, drawings, and major bullet points. This way, students can write down what the professor says and the example problems, but avoid typical errors in copying basic information like equations, figures, and tables.

Step 2 – Show Video of Concept

The usefulness of using videos in classes has been shown in a wide range of subjects including social studies, science, mathematics, English/language arts, reading, and language (Bell and Bull 2010). Showing a video does a number of things to help the instruction of a class: reinforces the concept, helps visual learners, and gives the students a break from listening to the professor talk. Today's students are more visually oriented than in previous generations (Tucker and Courts 2010). Chicago's public schools (Gillespie 2007) and Philadelphia's College of Medicine (DiLullo, Coughlin et al. 2006) have shown improvement in student test scores with the use of in-class videos. These types of in-class videos have been found to provide additional clarity and guidelines to students beyond traditional lectures (Lachs 2002). One reason for this observed improvement is that videos and other multimedia provide an opportunity to visualize abstract concepts. The advent of free, streaming media has drastically increased the availability of instructional media for the classroom. Streaming videos off of websites, such as YouTube, has been shown to be beneficial for educational purposes by Timar et al. (Timar, Karpati et al. 2011).

Step 3 – Explain any Equations for use with Concept

To show the applicability of the knowledge the student is trying to learn they need to be able to do something with it. This could be a math problem, logistical problem, or behavioral problem, but they need to be able to accomplish some sort of analysis with the information they are being taught so that it has a concrete meaning. Any assumptions and limitations used with the equations should be explained and included in the problems used to teach the concept.

Step 4 – Work an Example Problem

In this step, an example problem using whatever was shown in step 3 should be used to solve a real world problem. Showing the solution method has been shown to increase learning with some students (Maccini and Hughes 2000). The goal is to have learning occur in the classroom rather than the student having to actually learn how to apply a concept while working on homework. When used correctly, example problems have been shown to be a powerful learning tool (Chi, Bassok et al. 1989; Elio and Scharf 1990; VanLehn 1998). By working this problem out by hand, the students have time to copy the example down which increases retention. If the problem is worked out from scratch without copying it from a worked solution, the students can see the solution process and can be asked to work out the individual math steps to increase class participation. This creates a cooperative group out of the entire class which is an effective technique for learning a complex skill (Heller, Keith et al. 1991). This also allows the instructor to walk through their solution methodology for the problem, which has been shown to improve students' abilities to solve problems involving integer numbers (Maccini and Hughes 2000). During the worked example, misconceptions about how the problem might be

solved incorrectly can be included if relevant. Explaining misconceptions while talking about a topic has been shown to help students recognize issues (Muller, Bewes et al. 2008).

Step 5 – Have Students Complete an In-class Activity in Groups
Doing the in-class activity provides the student an opportunity to do active learning, which has been shown to foster higher cognitive learning (Sorcinelli 1991) and cooperative learning, the benefit of which was shown by Goyak (Goyak 2009), and allows the students to check and see if they really understand the material (meta-cognition) (Anderson and Krathwohl 2001). Research has shown that when students have a chance to think about whether they know a subject or not they tend to learn better (Bransford, Brown et al. 1999). The benefits of group work itself include gaining positive interdependence, face-to-face promotes interaction, individual and group accountability, interpersonal and small-group skills, and group processing (Tanner, Chatman et al. 2003). These skills are important to have when going into the modern work force. The increased effectiveness of having students work cooperatively in class compared with the traditional lecture method was shown by Ghani (Ghani 2005). Some instructors wrongly equate any form of group work as cooperative learning. To be effective, the work needs to include activities that ask questions where: the answers are not simply found in text; there are multiple, open ended answers; or questions that require the students' interpretation (Lord 1998). Other benefits of in-class activities are discussed by a number of researchers (Faust and Paulson 1998; Jones and Jones 2008; UNC 2009).

The in-class activity should be similar to the example problem done on the board and be answerable within the time allotted. The author recommends letting students work out the problem without intervention for 5 minutes unless there are major questions. This lets the students instruct other students on how to solve problems which has been shown to be one of the best methods to for students to foster "robust learning" (Straumanis 2011). Watching one student teach another helps students learn as well (Muller, Bewes et al. 2008). After five minutes the class is asked for questions and any issues are explained on the board.

Step 6 – Assign Homework Similar to the Example Problem and In-class Activity
Synthesis of knowledge is the goal. Homework should be assigned to incorporate knowledge understanding as opposed to simply requiring rote memorization. Units and variable names can be written out as opposed to presented in variable state, and game like problems improve students interest in the questions (Rockwell 2013). Game like problems can have multiple solution methods, require the use of appropriate assumptions, and require students to think about the reasonability of answer their answer for the given situation. Inductive discovery helps maintain student interest and learning (Berk 2010). Productive questions are of the type where the answer is not simply found in the text, have multiple correct answers, require student interpretation, or encourage students to give their opinions (Lord 1998).

Conclusion

Using the method outlined in this work, the student has the solution to a typical problem reinforced four times in a single class. Repetition is one of the keys to learning and this type of work keeps the repetition from being simple busy work as the students see concepts explained, used in the example problem, use the concept themselves during the in-class activity, and then use it again in the homework. This repetition allows for schema development which is one method of reducing cognitive load during problem solving (Sweller 1988). The methodology presented here reduces cognitive load by allowing reinforcement of topics and repeated types of calculations. Using the type of strategy shown here is not only beneficial for the learning in the current course but also helps teach learning strategies (McKeachie, Pintrich et al. 1985) to the students. Active learning creates excitement in the classroom (Bonwell and Eison 1991) which in turn encourages students to participate and focus on the material being taught.

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