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Deep versus Surface Approach to Enhance Teaching Skills in Undergraduate Mathematics Courses

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Abstract*—This article discusses common problems in undergraduate college mathematics courses. One main problem is the students' retention of knowledge. The problem can be attributed to the learning pattern adopted by the students. Some students strive to attain a deeper level of learning while others often memorize the formulas and seldom make connections to different aspects of the subjects (Ausubel, 1968). This category of students will most likely have problems retaining knowledge from previous classes (Nolen, 1988). Studies suggest that students are predisposed to which learning mode they will adopt (Chin and Brown, 2000). With careful instructional changes, students can be taught to adopt a deep approach of learning (Smith, 2002). Computer Algebra System (CAS) is an approach to develop better understanding of basic concepts (Mackie, 2002). A combination of teacher-centered method along with student centered method is a useful strategy to improve college teaching (Zhang, 2003). Kolb discussed four different approaches of learning theory (Kolb, 1982). Based on the research of literatures cited in this article, I summarize and propose some specific techniques that may be useful to promote meaningful learning in mathematics.

I. HOW TO RECOGNIZE THE SURFACE APPROACH OF LEARNING

The quality of the cognitive engagement of a student is related to the student's goal and learning strategies (Lee and Brophy, 1996). In many mathematics classrooms, the mode of instruction closely resembles the textbook being used. In a typical introductory mathematics textbook, chapters are divided into sections discussing sub-topics that are composed of definitions, formulas and theorems. Some examples are illustrated for these definitions and concepts, and exercises are listed at the end of the chapter. The instructors discuss these definitions, theorems, derive the formulas, and show some examples. However, many of the students are interested in the formulas only and they concentrate mainly on the mechanics of the problem solving (Entwistle and Ramsden, 1983). Once problems are assigned, the students dive into solving them, copying the exact steps outlined in the example problems. As a result, they often use trial and error techniques and check the answer listed at the back of the textbook. If the result did not match theirs, they resort to another trial. Instructors often hear statements like, "But the answer is right". There is nothing wrong with the simple trial and error techniques, the problem is trying something without reasoning why that particular trial is being made. This is a typical sign of surface learning. The instructional method may be partly responsible for students adopting this style of learning.

Smith (Smith, 2002) discusses surface learning .In his study Smith summarized the NRC study (Bransford, et al; 1999). He attributes the result of surface learning to the following:

Excessive amount of material covered.
Lack of opportunity to pursue subjects in depth.
Lack of choice over subjects and/or methods of study.
Threatening assessment system.
Inappropriate use of technology.

Mackie (Mackie, 2002) suggest that failure to understand the concepts lead students to surface learning. She says that in calculus many teachers focus on techniques because of the obstacle in teaching abstract and difficult ideas. This ensures acceptable passing grade for the students but does not help the students in the long run.

Mackie attributes the result of surface learning to the following:

Lack of understanding to connect between different representations.
Being passive learner instead of active participants.
Use CAS as a self-contained learning package of mathematical knowledge, not to realize it is a tool only.
Inappropriate use of technology.

II. HOW TO ENGAGE STUDENTS IN DEEP APPROACH

Smith (Smith, 2002) in his paper "How People Learn … Mathematics" discusses how learning takes place and how teachers can facilitate learning. In his paper he describes how understanding of this has led to the design of learning environment that is radically different from his earlier practices. Smith suggests that teaching does not necessarily translate to learning. Students must somehow be engaged for learning to occur. Smith provides an example of a research-based design for a single lesson that helps learning. Smith states in his sited research that as research continues (Dehaene et al.) we see convergence of evidence from a number of scientific fields. Smith says that technology used inappropriately makes no significant difference. In particular, adding calculators and/or computers to a traditionally taught and assessed mathematics courses may make it marginally better or worse. Better is likely to be associated with the students finding ways to use the technology that are not necessarily planned by the instructor. Worse is likely to be associated with the time and effort devoted to yet another task, particularly if it is seen as disconnected from all the others. Smith says Technology integrated intelligently with the curriculum and pedagogy produces measurable learning gain. There is a little evidence that one technology is better than the other. There is substantial evidence that using computer algebra system for conceptual exploration and for learning how to instruct the software to carry out symbolic calculations leads to conceptual gain in solving problems that can transfer to later courses. Further, his sited other research (Keller and Hirsch 1998) states that teachers' preference seems to influence the students' adoption of a particular technology over others. Smith also advocates a change in the content of the calculus curriculum. He questions why advanced factoring technique is still a prerequisite for calculus? He suggests that many of the so-called difficult problems can be solved effortlessly using technology.

Smith discusses deep learning (Smith, 2002). He attributes the resulted deep learning to the following:

Interaction with peers, especially working in groups.

A well structured knowledge base with connection of new concepts to prior experience and knowledge.

A strong motivational context, with a choice of control and sense of ownership.

Learner activity followed by faculty connecting the activity to the abstract concept.

Smith concludes his study by emphasizing the need of continuous curriculum renewal, pedagogy, and technology for effective strategies to stimulate deep learning and goal-directed assessments for addressing the needs of would-be mathematically literate public.

Mackie (Mackie, 2002) says that learners must be actively involved in the learning process. She suggests Computer Algebra System (CAS) a new approach that serves both an opportunity and challenge of assisting students to understand better the basic concepts in calculus. This approach may change the emphasis and teaching of calculus away from techniques and routine manipulation towards higher-level cognitive skills that focus on concepts and problem solving. Mackie describes how carefully structured worksheets are used with Derive to ask questions that will allow students to provide answers so that they can construct their own knowledge. She says that it will also provide learners to discover rule, make and test conjectures and explore relationship between different representations of function and other mathematical objects using blend of visual, symbolic and computational approaches. Mackie talked about multiple linked representations. She discusses Tall's (Tall, 1991) four stages of learning by

Using a single representation.

Using more than one representation in parallel.

Making links between parallel representations.

Integrating representations and flexible switching between them.

Mackie says further that recognition of the links between parallel representations and their common properties lead to the formation of abstract concept of mathematical process. The one who understands the connection between different representations can choose the correct representation that suits the problem at hand. Mackie suggests using computer graphing utilities for visualization and exploration of many mathematical concepts and algorithms. This will expose multiple linked representations of mathematical concepts. She also suggests the use of computer algebra systems (CAS) because of their ability to facilitate multiple-linked representation using graphical, algebraic and computational approaches. She emphasizes the advantages of CAS for developing exploratory approach to learning mathematics. CAS is really efficient in graphing, doing routine algebra/calculus operations, and making repetitive calculations easy. CAS can also be used to extend the scope of the elementary courses beyond closed form solutions. One of the references cited in Mackie's paper (Norcliffe, 1996) flags a warning that extensive use of CAS will weaken students' algebraic skills. Mackie comments that certain fundamental algebraic skills are necessary to use CAS. The potential of CAS lies in its ability to improve conceptual understanding and problem solving skills. Mackie concludes that the students may enjoy the power of CAS and versatility of computer algebra and become involved in the discovery and constructing their own knowledge, thus developing conceptual understanding and a deeper approach to learning. Mackie warned that CAS is tool not a self-contained learning package of mathematical knowledge. More emphasis should be placed on student-centered learning and less on teaching. It is necessary to understand first the learning process and then design teaching and learning activities.

Kolb(Kolb, 1982) presented learning as a four-cycle process –planning, doing, thinking and understanding. Each element in this cycle emphasizes the active participation of the students. When the instructor is aware of the learning process, they can organize and deliver instructions so that four-cycle learning process takes place.

Zhang (Zhang 2003) focused on student centered teaching strategies in calculus. He suggests a combination of traditional lecture (teacher-centered) for the topics such as limit calculation, differential calculation, and integral calculation along with student-centered teaching through group tutorials. The teacher will assign task to the groups and remain as a passive participant. The students will discuss problems with their peers to find a way to accomplish the task. This will give them an opportunity to share ideas, discuss and debate and convince each other. At the end of the task one student from each group will present their finding to the entire class. This will promote communication skills as well. Zhang suggests self-study for the topics that are normally skipped. He suggests asking students to write summaries at the end of each chapter.

In this paper, I have summarized my research along with others researcher's cited in my references to implement some specific techniques mathematics instructors can use to promote meaningful teaching so that the students can retain information to use them in other courses.

Be enthusiastic: Students imitate their teachers. The enthusiasm of the instructor permeates to the students. Teaching must be carried out with enthusiasm. If the teacher is not interested in the material being taught, the students who are at the receiving end will not be interested in learning the material.

Ask questions: Asking questions is one of the key elements in the learning process (Chin and Brown, 2000). By listening to students' questions, an instructor can assess the level of understanding. If a student asks questions of a shallow nature, it can be assumed that the student has only a shallow understanding of the topic. Also, it is important that a line of communication remain open between the teacher and the students. When asked questions students often have nothing to ask or ask questions that are far from being conceptual. It is also helpful if teachers encourage students to generate their own questions and explanations. This will stimulate deeper processing strategies among the students. Of course, for deeper processing to occur, the teachers must provide conceptual guidance and motivation and encourage understanding at a level that a student may not consider otherwise (Chin and Brown, 2000).

Explain definitions and the fundamental concepts: Explaining definitions and fundamental concepts are two important tools of understanding mathematics. Make an effort to clarify that is implicit (Epp, 1986). As an example, Epp discussed a very simple mathematical concept. When asked to solve for x, Instructor can avoid phrases like "Solve the equation, $2x+3=0$", instead write "Find a number x such that $2x+3=0$" for better concept.
I want to discuss what happens in a typical calculus class to explain the definition of the derivative as a concept. Students usually do not have problems finding the derivative of a function following the definition such as,

$$f'(x)=\lim_{\Delta x\to 0}\frac{f(x+\Delta x)-f(x)}{\Delta x}$$

or, the basic differentiation rules, such as the power rule,

$$f'(x)=\frac{d}{dx}\left[x^n\right]=nx^{n-1}$$

However, if they are asked to find the slope of a tangent line of the same function, many students stumble. The reason can be attributed to a lack of understanding of the thought process regarding the definition of derivative. Although all textbooks explain and illustrate the connection between these definitions, formulas and the slope, students seem to miss the point. The instructor needs to emphasize that $f'(x)$ determines the slope of a tangent line if (x, f(x)) is specified at a given value and make sure the point is well understood by the student.

Describe the thought process for setting up a problem: Many students are passive learners. During classroom instruction students copy everything the instructor write on board. As a result, they miss completely the instructors thought process. It is important that the instructor emphasize the thought process as well as the mechanics. Make students memorize the word definitions and theorems such that they will read it carefully and be encouraged to understand the mathematics language better (Epp, 1986). As an example of thought process to find the extrema of a function using first derivative, students are asked to find critical numbers, if any. Using the critical numbers, many textbooks ask the students to fill-out a table containing rows for intervals, test values, and signs of f'(x). Filling out a table like this might seem simple enough for many, but it is challenging for others. I would suggest augmenting the table with a flow chart describing how to complete each item in the table. This flow chart might illustrate the thought process more clearly. Often the students see and remember diagrams and flow charts better than the lengthy discussion. A flow-chart for these steps might be useful as shown in Fig.1.

Ask open-ended questions during tests: Many authors have suggested open-ended questions (Chin and Brown, 2000; Epp 1986) which may promote the understanding of the subject matter.

Make learning fun: This gives student an attainable goal if it is inspired in their favor. Student loves extra credit. Give students opportunity to present solution of problems on board. Even though some students are reluctant to solve problem in front of the whole class, extra credit seems to motivate and encourage students to learn mathematics better. Group work in class is another way to make learning fun. Often students feel that they are part of the community where learning together is fun and encouraging. Student projects may be a good source of make learning fun. When students pursue this way to set goal, they are most likely to employ deep cognitive and self-regulated strategies such as integrating information and monitoring comprehension, which result in meaningful and conceptual understanding (Ames and Archer, 1988; Meece, Blumenfeld, and Hoyle, 1988; Nolen and Haladyna, 1990). This is precisely what deep learning is all about.

Be patient: By far the most important element for effective teaching is to be patient. The habit of years of learning through the surface approach is not easy to break. The instructors must be patient.

III. CONCLUSION

The characteristics associated with deep approaches to learning mathematics are many. A meaningful perspective of these approaches can be generated by thinking, asking questions, incorporating meta-cognitive activities, approaching tasks and so on (Novak, 1988). Technology integrated intelligently with the curriculum and pedagogy may produce measurable learning gains (Smith, 2002). Computer Algebra System (CAS) is a new approach to learn mathematics resource if applied right (Mackie, 2002). Students need to have a positive attitude toward learning. A good teacher is always a plus. A combination of different strategies is helpful.

Studies have shown that student-centered teaching leads to a strong tendency for students to adopt a deep learning approach focusing on meaning and understanding which results in good teaching and learning outcomes (Zhang, 2003). Students learn best if they are engaged in active learning by being forced to deal with observations and concepts before terms and facts and if they have the sense that they are apart of a community learners in a classroom environment that is very supportive of their learning (Fraser 1986; McDermott 1991). Trigwell, Prosser and Waterhouse(1999) describe the relations between teacher's approaches to teaching and student's approaches to learning. Teachers may work out the strategies that are suitable to themselves, their students, and the course content. More tutorial sessions than lecture are sometimes advantageous to students. Group work in tutorial sessions may be an effective way for many students to develop their conceptual frameworks to learn problem-solving skills. Participation helps a great deal with motivation for learning. I believe that if all of these are combined, both teaching and learning can be improved.

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