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Improving Knowledge Retention in a Technical Subject by Diversifying The Learning Experience

Abstract

There is no silver bullet when it comes to successful teaching. Some scholars believe that traditional lectures are the panacea, while others are firm believers in active and cooperative learning. In this paper I report on my experience with the two approaches and explore the idea of combining them. In particular, I will argue that diversifying the avenues in which students are exposed to knowledge in a technical discipline, such as computer science, can spark their enthusiasm and make the learning experience more enjoyable and productive.

1 Introduction

Traditionally, computer science and mathematics have been taught primarily through lectures presented by the course instructor. Emphasis was put on memorizing complex theorems, algorithms, or programming techniques. Even though this approach reduces the risk of students misinterpreting the course material, it can make the learning experience tedious and significantly reduce the students' enthusiasm.

Recently, some computer science teachers have embraced the idea of active and cooperative learning (Budd 2006), which is not a new idea (Johnson and Johnson 1975). While encouraging students to self-explore concepts and share ideas with peers can make the learning experience more enjoyable, such techniques must be carefully guided by the instructor. For example, all too often we have seen students use poor programming style, which hinders readability and maintainability, based on suggestions from their peers.

In this paper I will describe my experience with combining an assortment of approaches to achieve the learning objectives of a course. I will then argue that no single approach can outperform a well-balanced medley of teaching techniques.

1.1 Related Research

There is substantial evidence that learning in groups is a successful approach to teaching (e.g., (Miller and Groccia 1997), (Dougherty, et al. 1995)). Similarly, there is abundance of evidence that active and cooperative learning can reduce racial and gender bias and retain nontraditional students (see (Anderson and Adams 1992), (Adams 1992), (Sandler, Silverberg and Hall 1996), and (Treisman 1983)). However, as explained in (McConell 2005), there are risks associated with active and cooperative learning. Even though there are techniques for mitigating these risks, I am not aware of a solution that prevents students from being exposed to inadequate or inferior procedures by their peers. My teaching experience is that active and collaborative learning in a technical discipline, such as computer science, is most successful when applied to low-risk situations where the majority of students have already mastered the course material.

1.2 Paper Overview

In Section 2, I will outline my experience with the traditional approach of presenting the course material solely through lecture slides and blackboard writing. In Section 3, I will describe my observations about teaching through active and cooperative learning. Next, in Section 4, I will tell what happened when I combined the two approaches. In Section 5, I will show how the outcomes with the different teaching styles can be explained using research on student motivation. Lastly, in Section 6, I will summarize my observations.

2 Experience with Traditional Teaching Techniques

As a new Assistant Professor few years back, I was very excited to organize and teach my very first ever university course. I was now on the other side of the fence and I believed that the grass is greener over here. In class, I presented the course content using well-prepared slides, where explanations on the blackboard were sporadic. I expected students to immediately grasp the presented material and ask me questions when they did not understand something. I was not aware that their cultural background may inhibit them from asking questions (Lee 1999). I was assuming that all my students are smart and that they can understand even the concepts that I did not explain in great details. After all, I had believed that that was what was expected from me as a student.

At that time, I believed that students did not like assignments, projects, and tests, so I kept those to a minimum. Students had to write only two midterms and a final, although I believed that one midterm suffices. Students also had to complete three assignments that were loosely related with the course material[1]. I expected that students were mature enough to learn the course material with little guidance from me.

Unfortunately, as the astute reader has probably guessed by now, most of my assumptions were unfounded. Students did not practice exercises from the end of the textbook just because I suggested that they do so. They did not understand all the material taught in class and most students did not even know what part of the material they were struggling with until the tests. I expected them to be mature self-learners, but I discovered that this is seldom the case.

I learned from teaching this course that simply presenting the course material does not suffice to achieve the learning objectives. I turned to colleagues and available literature for advice. After doing my due diligence, I incorporated regular methods for evaluating performance and increased the interactive exercises.

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[1] The course was Data Communications and the assignments were to perform labs on network simulation software

3 Experience with Active and Cooperative Learning

The next semester I was very determined to improve my student evaluations and improve my success in achieving the learning objectives. I took all the suggestions that I could find at heart and, as a consequence, I redesigned the structure of my courses. I introduced many new activities, although here I will only focus on those activities that relate to active and cooperative learning.

The most significant change that I incorporated was to introduce regular short quizzes (once a week or once every two weeks). After every quiz, I asked students to write their solutions on the board and then I asked them to peer-review the solutions. As a result, students explored actively the course material, which helped them better understand and retain knowledge. This was a low-risk exercise because I was there to ensure that any misconceptions about the solutions to the problems were corrected on the spot. As a whole, this exercise was well perceived by the students and it helped me keep track of their progress. The only downfall that I found was that valuable class time was used to perform the quizzes. In subsequent classes, I substituted the quizzes with take-home assignments.

I also performed several high-risk active learning activities. One of them was introducing projects that required students to self-discover certain concepts. Some students were successful in performing the required tasks, while others struggled with making significant progress. Even worse, some students spent days going in the "wrong direction". They implemented procedures that they read somewhere online or were suggested by their friends, but these were inferior procedures. I believe that my mistake was that I allowed them to self-explore concepts before they were mature enough to do so.

In upper level and graduate level courses, I allowed students to work in teams to complete complex projects. Since teaching students how to cooperate in developing a complex system is part of the course objective for these courses, I did not have an alternative to this activity. However, students were mature enough to create proper code designs and they did come to seek help when they were uncertain about the process. To reduce the risk, I had regular meetings with each team and gave them guidance to keep them on track.

As a whole, I was pleased with my success in incorporating active and cooperative learning in my courses. The student evaluations were much higher and I was more successful in achieving the learning outcomes, which were measured in terms of performance on tests.

4. Combining a Medley of Teaching Activities

Encouraged with the modest success with applying active and cooperative learning techniques, I decided to diversify the avenues in which students were exposed to knowledge. I realized that if students deal with a certain material only once, they are

unlikely to understand it and remember it in the long term. Therefore, I tried to expose students to the same subject matter multiple times in different ways.

First, I presented the material. Next, I asked the students to solve assignments based on it. After each assignment, I asked them to solve the assignment on the board and allowed them to correct each other's mistakes. I included the same material in the midterms and then allowed students to write solutions to different midterm questions on the board and correct each other. There were also class projects covering the same content. I sometimes also started class discussions on different subjects related to the course, where I tried to use analogies students can related to. Moreover, in introductory programming courses students had open labs where they were asked to solve fun problems related to games. Students did not receive any credit for their work, but they appreciated the opportunity to exercise their programming skills and receive help from the teacher in a low-stress environment in which they were not graded.

To summarize, this makes a total of ten different ways that students were exposed to the very same material. We all know that each individual is different and they perceive information differently. However, diversifying the ways in which students are exposed to new knowledge showed remarkable results. Midterm and final exams showed that all students that performed the required work grasped the course material regardless of their programming background before taking the introductory programming course.

5 Explanation of Observed Results with Different Teaching Techniques

In this section I will refer to research on student motivation in order to try to explain the different outcomes that were observed with the three different teaching strategies.

As a general classification, there are two types of student motivation: *extrinsic* and *intrinsic*. Extrinsically motivated students are more interested in external rewards, such as getting a good grade and maintaining their scholarship. Intrinsically motivated students are more interested in the course material because they find it intellectually appealing. Research states (Pinatrich and Garcia 1991) that intrinsically motivated students are much more likely to understand the material at a deeper level. I believe that this is the reason why students responded favorably to exposure to the same material multiple times. Every time they were able to discover new nuances and get deeper appreciation for the subject.

The ungraded computer labs were very successful in motivating students. There, students got a chance to show their programming skills without the pressure of being graded. They realized that creating a working program is a reward in itself, that the learning experience can be fun, and that their objective is not just passing the course or getting a good grade.

I have also found that developing applications that students are passionate about is a great way to foster their intrinsic motivation. For example, in an introductory programming course I created several labs that build on creating an interactive game that uses the material taught in class. Students were excited to complete the labs and they bragged to

their peers about their success. What was more amazing is that many students continued to work on the game after the labs. They did not do this to get a better grade in the course, but because they enjoyed the project and enhancing it with new features was a reward in itself.

Cognitive researchers have determined that the motivation of a student is correlated to how she perceives an activity. They will be highly motivated only when they are convinced that it will bring them rewards and the probability of success is high (Wigfiled and Eccles 2000). This is why students respond positively when they are given multiple opportunities to learn the same material. They believe that: (1) The teacher cares and she is determined to teach them the course material and (2) Once students start understanding pieces of the material, they start to believe that the material is not that hard and that they are capable of completing the assigned tasks.

I incorporate a lot of games and fun exercises in the assigned projects. This allows students to appreciate the intrinsic reward of completing the project. Another way I motivate students to learn is by giving them past midterms and finals. After they solve them at home, they see that they are not that difficult and it helps them build confidence. On the other hand, solving a past midterm at home is yet another way that students are exposed to the course material in a low-stress situation, which can foster their intrinsic motivation.

Another factor that affects motivation is attribution theory (Winer 2001). In particular, students can attribute their success or failure to themselves or external factors (*locus*), can characterize it as permanent or temporary (*stability*), and infer how much control they have (*responsibility*). Activities that students perform without being directly supervised or graded can foster their feeling that their success is in their own hands and does not depend on external factors. The teacher can be there to help them, but students believe that she has no direct stake in their outcome if she is not grading them. This is exactly the type of environment that I try to encourage in the programming labs that are not graded. The fact that students are exposed to the same knowledge multiple times also gives them the chance to engage in numerous activities, which in most cases convinces them that they have full control over their success or failure.

6. Conclusion

In this paper I have described my experience with teaching computer science courses though the traditional lecturing method, through active and collaboration learning activities, and through applying a medley of different teaching techniques. My observations are that the third approach is superior because it gives students multiple opportunities to learn the course material and it gives them intrinsic motivation to achieve the learning objectives of the course.

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