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EASILY ADOPTABLE INTERACTIVE TEACHING PRACTICES AND STUDENTS PROGRESS MONITORING STRATEGIES

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ABSTRACT

An active class room teaching practice can become highly rewarding for students. An instructor practicing active learning approaches may get significantly higher success in inculcating course materials deeply as compared to a lecture based teaching. However, transitioning from prevailing lecture based instruction to an active learning approach can be hampered by the reservations and prejudices of an engineering educator; a tenure track faculty may find it even more challenging to leave the traditional lecture based teaching approach and adopt an active teaching approach. This paper will describe the active teaching techniques that I, a tenure track faculty, has been practicing to teach mechanical engineering courses; the main discussion will focus on the Fuel Cell Science and Technology course. I have devised my current deep learning and teaching strategies through a yearlong Myrtilla Miner Faculty Fellowship cohort under Dr. Ken Bain and a number of workshops on the group based active teaching and peer interaction based teaching. This paper describes the strategies for developing a teaching and assessment plan for the courses I teach by emphasizing on (i) designing significant learning outcomes before starting a class, (ii) the long term retention of key concepts of a course by fostering student centered deep learning course activities, and (iii) far transfer of the skills students gain from a course. The first topic of this paper is about various strategies to understand students' motivations and inhibitions that may govern their learning curve in a course. The second topic of this paper discusses the crucial aspect of designing a promising syllabus to give students a bigger purpose for learning the course material; a promising syllabus attempt to connect students' long held curiosities and career ambitions with the course to be offered. The third topic delves into the strategies to engage students in self-preparation to assimilate the key concepts to be discussed in a class. This paper will also highlight the approach to design conceptual quizzes to guide student preparation before they come to the class and then use the same conceptual quizzes to conduct peer discussion and define the flow of a class; this strategy is derived from Dr. Eric Mazur's work on peer interaction based teaching. The fourth topic is about the utility of one pager feedback form to be filled by the students after every class. This paper will discuss structure and effectiveness of the feedback form in improving student attention and participation in the class discussions. I have offered two workshops on effective teaching at the University of the District of Columbia to promote active student learning in a wide range of courses. I plan to conduct workshops for the middle and high school teachers to share the effective teaching skills.

INTRODUCTION

An active learning approach is considered a better means to teach course concepts more effectively than traditional lecture based teaching [1]. Active learning is any activity that involves students in doing things and thinking about the things they are doing. Felder & Brent describe active learning as "anything course-related that all students in a class session are called upon to do other than simply watching, listening and taking notes" [2]. There are several strong reasons to advocate the selection of an active learning based class room teaching.

An active learning approach can encompass both isolated and highly structured activities to motivate students to take charge of their deep learning [3]. Active learning can be applied to both small [3] and big [4] classes; active learning was found to produce higher and long lasting student learning as compared to the traditional lecture format based teaching [5]. Research studies show that the audience's attention in lectures starts to decline after 10-20 minutes [3, 4, 6, 7]. Incorporating active learning techniques encourage student engagement throughout the class [8]. Active learning also reinforces course contents, concepts, and skills and their long term retention [3]. During active learning students get more frequent and immediate feedback about the depth and accuracy of the material they are focusing [9]. An active learning approach is very effective in addressing students' stereotypes and different student learning styles [10]; a lecture based teaching may give nil to negligible consideration to these crucial factors in the student learning [11]. Active learning can be very effective in creating personal connections between students and the course material, which strongly increases the student's motivation to learn proactively [11]. In addition to the course content, Active learning develops life skills like improving with others feedback, collaboration, and brainstorming to reach the most rational answers. An active learning approach also promotes a sense of community in the classroom by augmenting student-student and instructor-student interaction.

After realizing the aforementioned advantages I started learning various active learning approaches. To learn about various aspects of active learning I attended several workshops by a number of active learning proponents like Dr. Erik Mazur, Dr. Dee Fink, Dr. Prince and Dr. Ken Bain. This paper discusses different approaches I have adopted for my class room teaching. Here I mainly focus on 'MECH 488 Fuel Cell Science and Technology' course which is an elective course and generally has a small enrollment.

TEACHING STRATEGY

Before the commencement of this course in spring 2013, I explored the answers to the following questions: What are my student learning objectives for this course? How to understand student's negative stereotypes and learning style? How to connect students to the course topic early on to motivate them to learn course material? How to ensure students are present in the class? How to continuously motivate students to do their best without blackmailing them for grade? How to make learning fun in the class? How to effectively access and measure depth of their learning? The rest of this paper is organized as answers to these questions and the final outcome.

1.What are my student learning objectives for this course?: After completing this course I expect that students should be able to (1) understand global warming issues and how to address it by using renewable energy technologies like fuel cells, (2) understand the basic components and various types of fuel cells systems and have the ability to decide the suitability of these fuel cells for different applications, (3) understand the thermodynamics concepts behind converting chemical energy into electrical voltage, (4) understand the electrode kinetics concepts behind converting fuel into electrical current, (5) ability to design fuel cell components like electrodes and electrolytes to improve fuel cells, (6) characterize fuel cell systems and electrodes experimentally, and (7) communicate in writing and orally, the science and engineering concepts. After defining the course objectives I focused on the following question.

2. How to understand student's negative stereotypes and learning style?: To understand students mentality and their level of preparedness I conduct a pre-course survey and ask questions, which directly or indirectly gauge students' familiarity with the topic. Other questions focus on how they learn best, what is their primary motivation to attend this course etc. I also asked about the students' hobbies and their most cherished moments; discussing nontechnical points enable students to connect with other students and start becoming comfortable in communication. This survey contains direct or subtle questions to understand the students' motivation and aptitude.

3. How to connect students to the course topic and learning objectives in the beginning of the class?: The Maslow chart is widely acknowledged to describe a hierarchy of needs which motivate humans to do any activity. The first three categories are considered basic needs and the last two categories are considered as higher level needs. Every student is different and presumably influenced by one or more categories of the motivations described in Table 1.

Table 1: Maslow chart of hierarchy of needs providing motivation for human action.

Order of motivation	Category of needs	Action
1	Physiological	Breathing, food, water, sleep,
2	Safety	Security of body, family, employment, health, property
3	Love and belongingness	Friendship, family, community.
4	Esteem	recognition by others Self-esteem, confidence,
5	Self-actualization	Inner bliss from own work, creativity, lack of prejudice

To connect students with the course content I start the first class by telling a motivational story that encompasses a wide range of the motivational categories mentioned in Table 1. This story is also known as 'promising syllabus' [12] and basically designed to boost the student's interest in the subject matter. The sample I used in spring 2013 and 2014 is the following:

Promising syllabus story for the first day of the class:

Question [1] Can there be a single technology producing energy to power small appliances like laptops as well as giant industries; automobile to space ship application?
Steer students' focus on the topic in the course and tell a vivid story.

Let me share one story of a struggling engineer who saw a new hope for his life and society in fuel cell technology that you will learn from this course

Recently I met an engineer named John. After two years of service, John lost his job in a coal power plant in 2008. Actually, this coal plant was a major culprit in polluting air and water and was no longer operational as per the new environmental regulations and economic reasons. John tried hard to get a sustainable and exciting job for six months. According to his credentials, he qualified for the job in a nuclear power plant. In spite of his unwillingness he had to accept the offer to serve as a process engineer in the nuclear power plant. Unfortunately, only after three months of working on the job this nuclear power plant started emitting radioactive pollutants due to a crack in the reactor. John was forced to quit the job with a small compensation.

Question#2: What will you do if you are in John's situation?
After commenting on students' responses I start telling the next phase of the story on what John did.

John started looking for a sustainable job once again. During this uncertain phase, John attended an open house about renewable energy and their social and economic benefits. However, John was suspicious about the fickleness of the renewable energy resources like solar and wind etc. But he decided anyway to explore career opportunities in renewable energybecause this field is good for the environment and is rapidly growing.

Question#3: What are the main renewable energy technologies and what are their advantages?
Like you, John got impressed with the undeniable importance of renewable energy resources and technology.

John realized a new passion for becoming an expert in the renewable energy production. However, John wanted to make sure that his chosen area in the renewable energy field has robust and sustainable career prospects.

Question #4: If you were in John's place, what would you like to know about different renewable technologies before choosing one of them as your career?
Take students' comments and steer their attention towards the unique advantages of Fuel cell technologies-the topic of course.

For some expert advice, he planned to visit the Mechanical Engineering department at UDC. One fine day John took a bus. From an informal discussion with the bus driver he came to know that this bus was using hydrogen as a fuel and emitted water, instead of carbon di-oxide that causes global warming. This water was so clean that he could fill it in a bottle and drink it like spring water from Colorado Springs. While travelling in this special bus he observed that a neighboring female passenger was working on a fancy laptop, which was powered by a fuel cell battery. John could not confine his curiosity about the fuel cell battery and he asked the lady about the advantages of fuel cell battery. John discovered that unlike a conventional battery, you can keep using a fuel cell battery endlessly, and hence they don't produce battery waste and heavy metal pollution. Then, John arrived at the bus stop and walked across the street to catch a connecting bus. Right behind the bus stop was a Wall Mart superstore. Its signboard said that this Wall Mart produces all the electricity within the store by a fuel cell generator. John really got pleasantly surprised that the same fuel cell technology that was powering a laptop was also powering a big superstore. Even before getting to the ME department at UDC, John made up his mind to become an expert of this amazing technology, which is not only full of career prospects, but is also sustainable, and environmentally friendly.

Question #5: What will you do next if you are so excited about the career prospects of the fuel cell technology and its uniqueness?
Steer students' attention towards understanding the fundamentals of this technology tohelp the become familiar with the concepts..

Now dear students you have the opportunity to learn the core principles of the amazing fuel cell technology, which may empower you to solve some of the most pressing problems USA and global community is facing. I invite you to deeply understand the science and technology of Fuel Cells by actively participating in this semester long course.

I currently don't have data to show the effectiveness of the promising syllabus in motivating students. However, according to previous research the 'promising syllabus' activity plays a pivotal role [12].

4.How to ensure students are present in the class?: At UDC many engineering students work full time or part time. It is sometimes a challenging task to ensure their presence in the

course. An ven more important task is to ensure that they actively learn when present in the class. To increase students' active presence I ask students to fill out a five minute survey form after the every class; this survey form is given to students within the first 10 minutes of the class and is filled out in the presence of the instructor. This survey has three questions. (i) What were the main concepts we discussed today, (ii) where can you apply these concepts, and (iii) Do you have any questions about the concepts we discussed today. These after-class surveys are graded after each class and account for 10% marks counted toward their grade. Before I started using these, the average student missed ~10 classes/semester. These surveys helped reduce the absence (Fig. 1). Figure 1 indicates that only one student missed more than two classes. However, one possible reason for the higher attendance may be students' sincerity and self-motivation. More studies are being planned to investigate the effect of end-of the class feedback forms. One possible study may be to study students of the same class for a certain number of classes with and without using a feedback form. In 2014 five students attended the fuel cell course. It was noted that students exhibited low tendency of missing classes without prior notice.

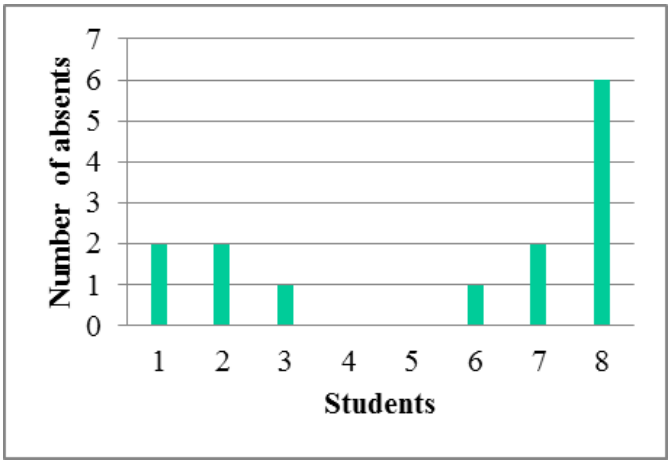

Fig. 1: Number of absents during MECH 488: Fuel Cell Science and Technology course, spring 2013.

5.How to continuously motivate students to do their best to learn the course concepts?: The Major teaching strategy is based on conceptual questions on the major topics. For every chapter or module, major concepts are identified and a number of original conceptual questions are framed. Conceptual questions are generally multiple answers type questions and arranged in terms of a pre-class quiz; however, recently I started asking students to write few lines or sketch about the theme of conceptual questions as necessary. This pre-class quiz and associated reading assignments are prescribed to students before the commencement of the class. Answers to these pre-class quizzes are required to be submitted before the discussion in the class and are also used for grading purposes. These conceptual quizzes ensure that students make themselves prepared for the module to be discussed and become well qualified to grasp the content and concepts during the class discussion.

During the class, conceptual quizzes were used to guide the flow of discussion. Every question on the quiz was first discussed by a small group of students; subsequently students shared their views or argued with each other about the conceptual questions. After the group discussion I invite one representative from each group to share their cumulative or mutually agreed solution and underlying reason with the whole class. I elaborate on student groups' responses and generally add missing reasoning, logic, and information to complete the discussion about the conceptual question of interest.

I also noticed that sometimes a module or math intensive topic may be quite challenging for students to grasp themselves by independent reading. For such modules I ask students to do timed reading and comprehension and share their understanding with the group members. The one representative from the group summarizes the cumulative group understanding. For such difficult topics no gradable pre-class quiz is asked to be completed. However, a reading assignment is given. For such difficult or heavy math based concepts I turn to semi-interactive lecturing about that topic. However, I tried to incorporate multiple interactive strategies to keep students engaged during the class.

6.How to make learning fun in the class?: To ensure that students are actively learning, a number of students activities are set up for them. Since most of the important concepts of this course are dynamic in nature and students are highly likely to benefit by actively participating in it. Occasionally I ask students to design and play small skits about the key course concepts. Wherever possible I also play a role in the skit. I liberally use YouTube videos to aid the comprehension of complicated concepts. To keep the class discussion dynamic I frequently ask students to present whatever they understand about the concept of interest. I also bring commercial components/products and organize industrial visits to industries. For instance, in spring 2013 an industrial visit was organized to visit the fuel cell application. To further deepen the understanding of key concepts, I include a number of experiments to provide experiential learning such as a fuel cell trainer, Versastat electrochemical setup, hydrogen fueling station, fuel cell car etc. To cover a number of important and interesting topics associated with the course theme, students are asked to write a term paper on related topics.

7.How to effectively assess and measure student learning?: In order to assess student learning a number of means were employed. A student's response to the pre-class quizzes before and during the class is one direct measure to do so. The five

minute feedback form after the class is another effective means to determine the students' understanding and address any questions they have about the discussion on concept. Traditional home assignments are also assigned to promote collaboration and extensive understanding about the underlying principles of main concepts. I have made significant modifications in the method of giving midterm and final exams. Nearly 60% marks of an exam are based on the quality and depth of the written solutions. In addition, 40% of the marks are based on in class presentation pertaining to the exam questions. For example if a midterm or final exam is 20 marks in total, then 12 marks (60% of total 20 marks) will be assigned for the written answers and 8 marks (40% of total 20 marks) will be assigned for the student presentation and discussion on the exam questions. Typically two randomly selected questions are asked for the in-class discussion.

In addition, I also conducted a survey about the active learning approach. For instance, seven students who participated in the survey during spring 2013 rated active learning approach to be highly desirable (Fig. 2). Similar student response was recorded in 2014. However, student enrollment was only five students. The student rating for the active learning was 4.2±0.83.

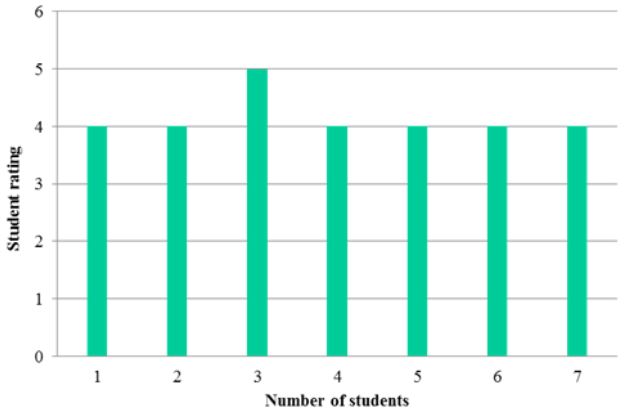

Fig. 2: Student rating for the active learning approach adopted in MECH 488 Fuel cell Science and Technology course (2013).

CONCLUSION

This paper discussed the active learning approaches used in MECH 488 Fuel Cell Science and Technology course at the University of the District of Columbia. Promising syllabus, peer interactions, end-of-class feedback forms, skits, and experiential learning were employed to deepen students' understanding and make learning enjoyable. According to the end of the course survey students enrolled in spring 2013 and 2014 courses gave high ratings to the active learning approach. The author has also organized two workshops about the "Easily adoptable active teaching approaches" at UDC as a part of faculties' professional development event. Both workshops were independently evaluated and found to be highly effective in catalyzing interest in active teaching at UDC.

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