THE PRACTICAL USE OF ANALOGIES TO MENTOR THE ENGINEER OF 2020

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Abstract

The rapidly changing engineering curriculum due to the advancement in technology is necessitating engineering educators to be in pace with educating the future engineers. One of the methods that aid in teaching more in a limited time frame is the effective use of analogies. Increased student motivation, better participation in class and laboratory exercises, better rapport between the student and instructional group, increased creative thinking of the students', and active student participation in providing valuable course feedback are some of the immediate positive outcomes in using these analogies. This paper elaborates on the analogy usage in two of our classes, one at the entering first-year level and the other at the senior and graduate combined level.

1. Introduction

With the rapid advancement in technology and globalization, the required skill set of an engineer has been collimately increasing. To accommodate this requirement, the engineering curriculum needs to be contrived to meet the critical changes in technology and society. In order for the engineering education profession to thrive, it must adapt to cultivate innovative characteristics such as cognitive and analytical skills, creativity that is essential for the future engineers who are the global citizens and leaders in business and public service[1].

A salient feature of today's educational methods is integrating theory and practice. Students retain 90% of what they learn through direct experience[2]. This can be through hands-on experience or through other teaching methods[3,4,5]. Considerable amount of literature is available on effective ways to implement hands-on activity in the classroom. However this literature recommends incorporation of these activities outside the classroom, in labs and projects. Pong[6] in his paper has suggested that engineering educators need to think creatively in order to educate students to be innovative and thus, lead to the through of engineering technology. One of the effectual ways to meet this challenge is with the use of analogies while teaching in and outside the classroom. The use of analogies shall facilitate with teaching more concepts in limited time while encouraging the creative thinking process of the students.

Over the past two years we have successfully incorporated analogy usage in two of our classes, the Fundamentals of Engineering and Computer Science (FECS) course at the entering first-year level and Digital Systems Design (DSD) at the senior/graduate level. In this paper we will discuss the importance of using analogies while teaching in and outside of classroom. Furthermore, we present effective ways through which analogies can be used to aid in student motivation, involvement and student retention. Finally we provide several recommendations from our initial findings and discuss the observed impact and outcome.

2. Effective Teaching using Analogies

Teaching and Learning are two important parts in the life of a student. Teaching methods used in the classroom have to continually accommodate innovative developments to enhance student learning. Literature review have shown that effective teachers have succeeded in making students feel good about school and learning, thus increasing student achievement[5]. Popham[7] has stated in his paper that it is important to present content to students in a meaningful manner that shall foster better understanding while not necessarily delivering additional knowledge or coursework in the content area. The effective use of analogies in teaching provides instructors with an efficacious tool to meet the various challenges expected in the new engineering curriculums.

The use of analogies has been found to motivate students to actively involve in classroom discussions. It has successfully inculcated a better understanding by relating theoretical knowledge to real world experiences. This has helped students understand the importance of the concept being taught along with its various applications. Now more than ever before, students must be taught in a manner that will connect each topic with their own lives[4]. This helps in meliorating student understanding. A simple situation where a real life experience can be used as an analogy is the water flow in a pipe to explain Kirchoff's Current Law. Similarly, various other analogies can be used while introducing new concepts to students. However, care has to be taken while designing these analogies as they have to be based on the students' prior knowledge in that respective area. The future engineering curriculum shall house a very heterogeneous and transcontinental student population, and the design of effective analogies will play a key role in student participation and retention. Formulation of effective analogies takes significant time and effort, but the time spent in formulation can be equipoise by the benefits.

Effective teachers of the future will have to practice fairness and respect to all students in the classroom by observing cultural respect, understanding, racial and cultural impartiality[3]. With the increasing global importance of engineering as a positive force for the future, the conceptualization of effective analogies shall hold the key to successfully educating the increasing diverse student population.

3. Implementation

The FECS course is a requirement for all incoming first-year engineering students except computer science majors at Wright State University. It is also the largest course in the College of Engineering and Computer Science (CECS) with a cumulative annual enrollment of approximately 300 students. It is designed to introduce the incoming first-year students to the various fields of engineering and computer science. The intent of the course is to provide insights to the first-year students to assist them in selecting further courses that they may wish to pursue while in college. One of the major goals of this course is increasing first-year retention. This has been an immediate challenge upon the instructional group as the university has open enrollment policy. Currently, more than 90% of the incoming first-year engineering students have no prior knowledge in engineering concepts. This challenge of increasing retention was successfully met with effective use of analogies in and outside classroom teaching.

The FECS class starts with a teaming project where students are required to build a bridge using a limited number of K'NEX parts that is later tested to determine the loading capacity. As this bridge is tested for loading capacity, students were explained the importance of stress points. They were provided with several analogies of collapsed structures as shown in Table 1, and were then helped to find the stress points in their bridges. Through this process, students not only understood the concept of stress points, but also improvised on methods to create a better design. One interesting outcome through this project was that the gradual increase in the maximum loading capacity of bridges built by students. Initially the maximum loading capacity was 90 pounds and recent tests have shown an improvement to 150 pounds.

Table 1: A few analogies used in the FECS course

Concept Introduced	Analogy Used
Collapsed Structures	Tacoma Narrows Bridge
Moments and center of gravity	An airplane design was used to demonstrate the result of nose or tail heavy.
Kirchoff's Current Law	Water flow in a pipe.

The later part of the FECS course introduces students to the internet, world wide web, basics of airplane design, computer aided design, circuits, stress & strain and engineering math. Initially all these concepts were taught in the classroom. To help the students understand better, these concepts were again taught during the labs. During labs, it was made a practice that analogies are used to explain the concepts better. As the class comprised of students with a wide range of abilities, multiple analogies for each concept were formulated. Every lab session began with the initial minutes spent on student explanations on the concepts taught in the lecture. It was observed that even though there were students who had understood the concept well, there were also who had not. Based on the number of students who did not understand the concepts, the teaching assistant made a point to explain them again using several analogies.

The Digital System Design (DSD) course is an engineering elective for senior and graduate students at Wright State University. As per the course pre-requisites, students enrolling for the course are expected to posses a sound engineering understanding. It has been designed to motivate and educate electrical and computer science majors with selecting their area of research for further studies. The immediate challenge upon the instructional group was in retaining the student motivation by providing them with innovative research ideas while curing their understanding.

The DSD course provided an ideal platform to test the impact of the use of various types of analogies. Three separate experiments were conducted over three separate academic terms (quarters) and the results were observed and compared. During the first academic term the laboratory instructional group revised concepts taught in the classroom session with absolutely no analogies. Thereafter, in another academic term the laboratory instructional group revised concepts taught in the classroom session with discipline-based analogies. A few of the discipline-based analogies are provided in Table 2. Finally, in yet another academic term the laboratory instructional group revised concepts taught in the classroom session with non-discipline-based analogies as shown in Table 2. The student feedback at the end of each term is shown in Fig. 1.

Table 2: A few analogies used in the DSD course

Concept Introduced	Discipline-based analogies	Non-discipline-based analogies
Multiplexer	Internet Router	Rail Road Track Changer
Sequence Detector	Pacemaker	Gym Locker Combination
ASM charts	Programming Algorithms	Cooking Recipes
Hierarchy	Scalable ALU designs	Maps

Over a period of time the instructional group of both the courses found that the variability in the learning style of students was wide. Some students understood the concepts when discipline-based analogies were used, while others were more comfortable with non-discipline-based analogies. The lab instructional group made it a practice of formulating both types of analogies to be handy for use as necessary.

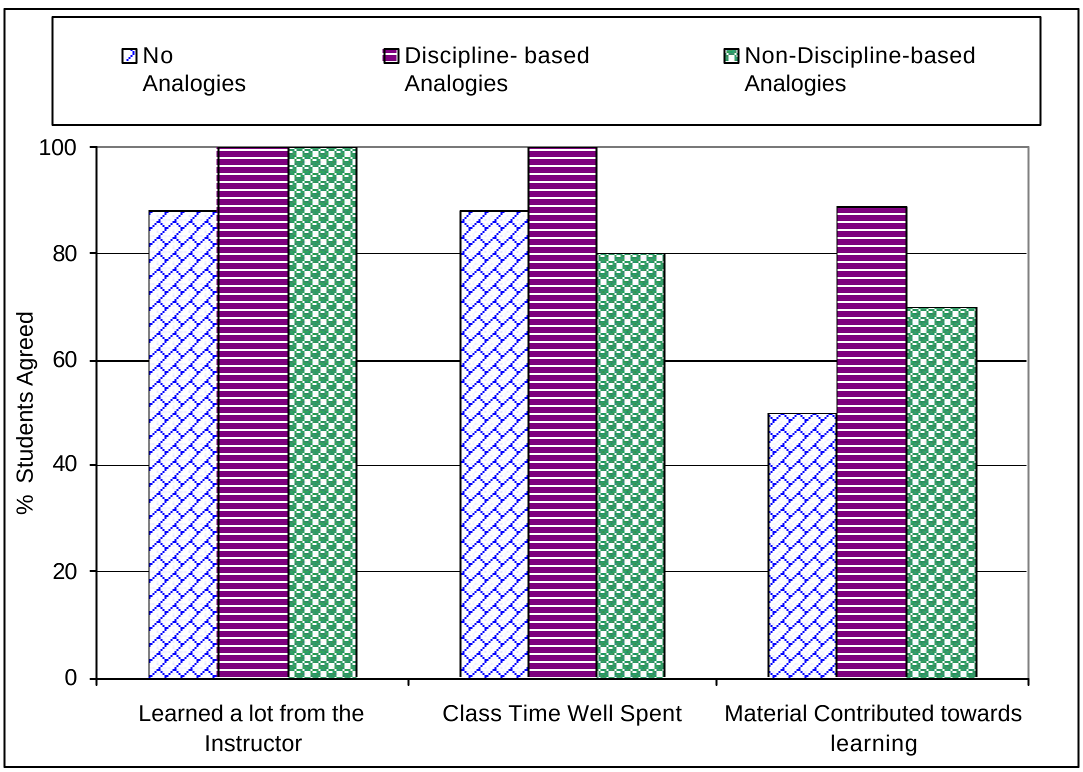

Figure 1: Student survey results from the DSD course

4. Results

An immediate positive student response was observed with students of both the courses when analogies were used for instruction. Most students arrived to lab early and there was a lot of conversation between the students and the lab instructor. On several occasions the instructors were approached by students and appreciated for the use of analogies. General student-teacher rapport was enhanced and student involvement was a definite positive outcome.

The results obtained when different types of analogies was interesting. As shown in Fig. 1, when analogies of either type were used, all the students agreed that they had learned a lot from the instructor. On the other hand, results varied for other factors. When disciplinary analogies were used, every student agreed that class time was well spent. However, when non-disciplinary analogies were used, there was a decline in the number of students agreeing that class time was well spent.

Students' performance in the FECS course is shown in Fig. 2. The instructional group has been using analogies for all five academic terms. It can be clearly observed how the continuous formulation of new analogies over time has enhanced the creativity of the instructional group which in turn has made them effective educators. After having introduced the use of analogies in the FECS course, the student participation and attendance has seen a gradual increase, with an exception in winter 2005 for reasons unknown. The FECS course has a 'F' grade policy for student who miss more than two sessions to encourage student attendance and retention. Fig.2 shows the gradual decline in the number of 'F' grades assigned, with reasons in part of increased student participation and motivation. With analogies as one of the key factors, the first-year engineering retention has increased from 40% to 69%.

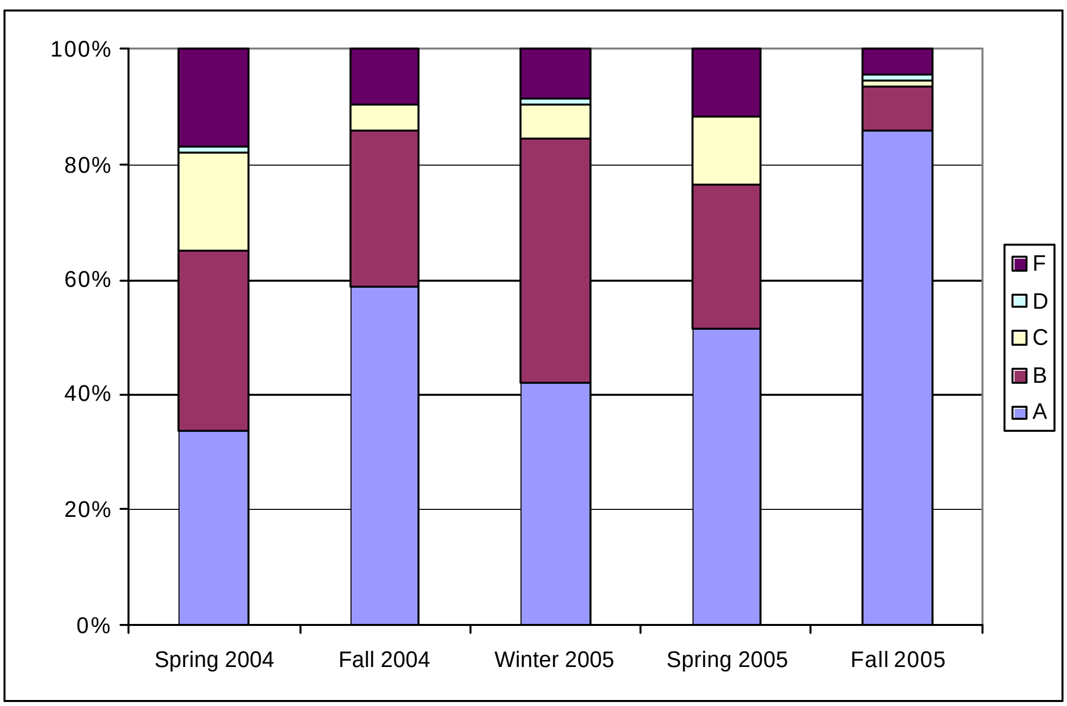

Figure 2: Results of Student Grades in FECS class over Five Quarters

5. Conclusions and Future Work

The initial results from this pilot study using analogies have opened several avenues for further research. Having observed the benefits on the instructional group with having to formulate analogies, it has been decided to give periodic analogy formulation exercises to students themselves. This experiment holds the potential of understanding about how the students have understood the concepts discussed in classroom sessions. Another distinct advantage is the availability of analogies for the instructional group to use at a later term.

In future, we plan on employing other effective means of measuring student performance while repeating the experiment. We also plan on experimenting by combining other novel teaching methods while continuing the use of analogies in our instruction. In our future work, we will address the difference of effective analogies as a teaching method compared to just using really good examples.

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