The Effects of Multilevel Examples

Austin W Burrus, University of Oklahoma

As an undergraduate, I have been given the opportunity for research and class room experience. I will go to graduate school for complex systems engineering in order to begin a track to a professorship.

Dr. Diana Bairaktarova, University of Oklahoma, Norman, OK

Dr. Diana Bairaktarova is an Assistant Professor of Engineering Practice in the College of Engineering at University of Oklahoma. Through real-world engineering applications, Dr. Bairaktarova's experiential learning research spans from engineering to psychology to learning sciences, as she uncovers how individual performance is influenced by aptitudes, spatial skills, personal interests and direct manipulation of mechanical objects.

The Effects of Multilevel Examples in Engineering

Abstract

This pilot study was created to test the effectiveness of using multiple levels of examples in fundamental engineering courses. Findings from the study implied that more than 70% of the students being taught under this method will have comprehension of the material for subjects such as entropy. This shows that the majority of the class may be reached using this method while allowing for more specific tools to be used for the rest.

1. Introduction

As a disclaimer and assurance of the validity of this study, one must have an understanding of Maslow's Hierarchy of Needs. This theory is a model for the motivators of a student. The Hierarchy is applied in such a way that if one's more basic needs are not met, the less basic needs cannot and will not be fulfilled. Education does fit into this model and is relatively high on Maslow's Pyramid.

Figure 1: Maslow's Hierarchy of Needs[1]

The pyramid's foundation is physiological needs. These call for homeostasis and a food supply. The next level of the pyramid is safety where the mental assurance that the physiological needs will not increase drastically. Third, people need acceptance or love. This forces change in oneself in order to fit into a culture or system. Fourth, humans require self-esteem when all prior needs are met. This can be actualized through pursuits such as education, community service, and general achievement. Lastly, a person will remain unmotivated without the last level, self-actualization; this is the ability to turn one's possibilities into realities.[2] This refers to the ability of students becoming doctors, high school athletes becoming pro-bowlers, and guitarists becoming superstars. Without the possibility of success, students will remain unmotivated.

If a student does not have the first three levels of this pyramid, it will be difficult to succeed within the educational structure. Other pursuits may draw more interest, or the need for money, safety, or attention can require more of their time in order to get to a level where they can learn. This may leave them with little to no time to take advantage of the educational programs, classes, and communities required to succeed. Once a student makes it to this level, there is a new gamut to run: Bloom's Taxonomy. This model analyzes the path required by students to gain full comprehension and mastery of a subject.[3]

Figure 2: Bloom's Taxonomy[4]

Bloom's Taxonomy was originally theorized by Benjamin Bloom around the 1950s. The levels of the model describe a higher level of learning with each ascending level.[3] Once all levels of the taxonomy are completed; the model implies that the student has mastery of the subject. The levels of Bloom's Taxonomy, in order, are: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. Primarily, educators use lower level questions and examples for assignments and teaching as they are easier to understand and grade. It is tedious to grade higher level questions as they have many more possibilities for correct answers. This may be problems such as projects, papers, and oral reports that require rubrics for easier grading.[3] Educators have rarely been given the opportunity to apply Bloom's Taxonomy due to this time constraint involved in the education process. This results in lower comprehension with higher grades on a large scale.

Different pedagogical approaches with the use of multilevel examples in the classroom can help scale Bloom's pyramid and the multitude of different levels, such as memorization, understanding, and creating. This approach utilizes a similar scale as levels of testing questions with three different types of questions focusing on: 1). concept, 2). application, and 3). intuition.

For example, the first type - conceptual problems will rarely have numbers, but they will force the student to either memorize or understand a new concept such as the definition of entropy or how to apply a system boundary, satisfying the first two levels of Bloom's taxonomy. The second type - application problems will use the problems that students would normally see on homework where the conceptual ideas are applied to real life problems such as analyzing the effect of entropy when changing energy from heat to electricity or vice versa. These examples will satisfy the third and fourth levels, applying and analyzing. The third type - examples requiring an intuitive leap to a new concept from a concept recently learned, such as jumping from understanding how to apply conservation of energy in a system to how to apply conservation of entropy, are the most conceptually difficult for students, but they exemplify mastery of a subject while finalizing the synthesizing and evaluating levels of Bloom's pyramid.

2. Purpose of the Study

In engineering courses taught by traditional methods, the education process involves a single level approach to each topic; the professor attempts to offer the method that helps the greatest number of students. When we look at the Bloom Taxonomy Pyramid, however, both a traditionally taught course and a course using the proposed method require that a student go through multiple methods to master a topic. This is achieved by the student through note-taking methods, flash cards, study groups, internships, research, and various opportunities around the campus. Nevertheless, students still struggle with learning fundamental material in engineering because they do not understand that they need to diversify their methods of learning. This can result in little return with a higher effort on part of the student.

This study sought to characterize a possible solution to this problem in engineering fundamental courses. This was done through an observance of the Revised Bloom's Taxonomy and its application in the classroom under the time constraints of a collegiate semester. This pilot study serves to imply the validity of the Revised Bloom's Taxonomy and to propose new possibilities for engineering instruction. The new style allows a professor that is not content with the results of their current teaching method to attempt another style with a degree of assurance for success.

3. Method

Data Collection

In this study, fifty nine students, enrolled in a Thermodynamics course at a Midwest university, are the participants. In alignment with the flipped classroom, students have been asked to work examples while in class. At the end of class, a copy of their work was submitted and later analyzed by the researchers. Students were given the three types of problems during homework and asked to solve each of them. The number of students that answer correctly correlates to the rate of understanding for each concept. At the end of the semester, the students were tested on the concepts in which they were taught using the different levels of examples in order to measure the rate of learning. The entropy portion of the Thermodynamics course was used to measure benchmarks in the students learning through the new pedagogy. Qualitative data was collected from the work shown in the assignment and through peer learning assistants to help reduce unintentional difficulties for future examples while providing opportunity to observe the students as they progressed.

On the final exam, students were given five questions relating to the concept of entropy. The proportions of the questions were as follows: two conceptual, two application, and one intuitive questions.[5] This allowed the researchers to measure which of the students' learning benchmarks were completed. Questions that students gave the best answer were given a "1". Answers that were correct, but not the best, answer were given a "0.5", and wrong answers were given a "0." This can be seen in Table 1 in Appendix A.

Data Analysis

Using the data gathered from the final, students that answered at least one question correct for each level are considered to have a mastery of the subject. This gives them a rating of "1", meaning a mastery of the subject. Students who failed to answer all three levels are given a "0" rating. The average of this number is the percentage of students who had a mastery of the subject. By using a probabilistic uncertainty measurement with 58 degrees of freedom and a ninety five percent confidence level, the uncertainty of the average can be obtained through Equation 1

$$\boldsymbol{P = t_{v,p} s_x} \qquad \text{Equation 1}$$

where $t_{v,p}$ is the t-value with "v," degrees of freedom, and "p," percentage of confidence and s_x is the sample standard deviation using the sample size, "n."

4. Results

Students involved in the course were tested specifically on their knowledge of entropy. This subject was chosen due to the abstractness of the subject. It is a difficult subject for many students to understand and is therefore an extreme used to test the limits of the study. There were three major opportunities to track their knowledge: homework, in-class problem solving, and the final test. There were five multiple choice questions that were asked on the final that related to entropy. Each student's answers were recorded in Table 1 in Appendix A and are summarized in figure 3

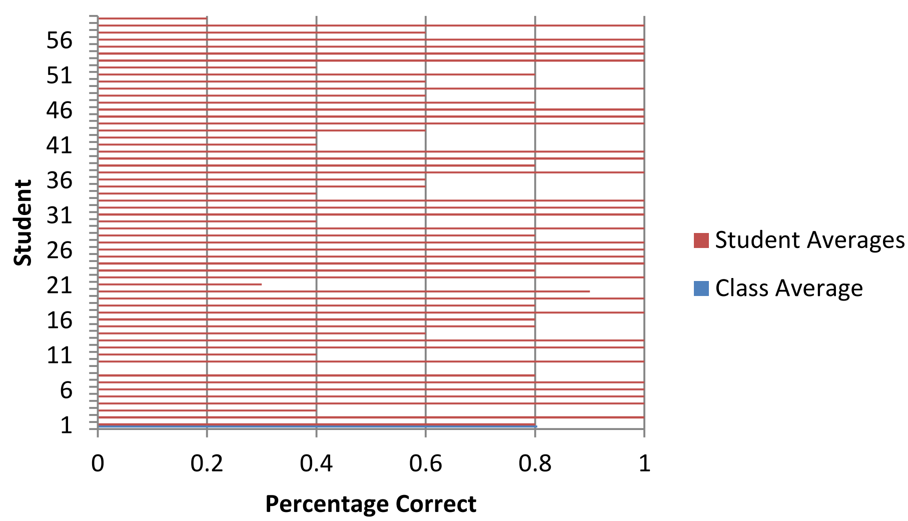

Figure 3: Each student's score compared to the class average.

where the red bars are the percentage answered correctly by each student and the blue bar on the bottom is the class average.

The quantitative data was compounded by qualitative data through student interaction during in-class problem-solving sessions and university tutoring programs led by researchers. During class sessions, researchers observed the class, answered questions, and provided alternate examples.

5. Discussion

Using the test sample of fifty nine students, between 71.4% and 89.2% of the students comprehended and could apply the concept of entropy. The uncertainty was found using a standard t-table.[6] Looking at the lower extreme, this means that more than two thirds of the students in the class were taught entropy using a single method. Given the higher extreme and considering issues arising for Maslow's Hierarchy of Need, nearly all students in the course were receptive to the teaching style.

6. Conclusion

Based on the findings from this pilot study, our first suggestion is that this approach can be tested with a larger sample. The relatively small number of participants of fifty nine is not enough to be statistically significant for generalization of the results. However, the study did indicate, through basic correlational statistics and observations, that Thermodynamics, more specifically the topic of entropy, can be taught to a large majority of a mid-sized class using this approach.

More importantly, this study needs to be tested on a traditionally taught class in thermodynamics in order to assess the advantage and disadvantage of the teaching styles compared to one another. Afterwards, this approach may also be applied to similar engineering courses such as Solid Mechanics, Fluid Mechanics, Heat Transfer, etc. for further research. If the data implies consistency across multiple courses, larger course sizes and different subject types, such as Math or Ethics, are needed to validate the preliminary findings and the proposed approach.

Looking farther into the future, research involving this approach as a tutoring style could be beneficial for students who are struggling in a traditionally implemented course. Conversely, for implementing this method, resources such as trained tutors can offer a different teaching style, online references and homework, or in-class exercises can be used to supplement this pedagogy in order to provide assurance that every possibility of education has been met.

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Appendix A

Table 1. The results of the final test using five questions taken from a standard undergraduate thermodynamics text book.[5]

Student	**1**	**2**	**3**	**4**	**5**	Average
1	0	1	1	1	1	0.8
2	1	1	1	1	1	1
3	0	0	0	1	1	0.4
4	1	1	1	1	1	1
5	1	1	1	1	1	1
6	1	1	1	1	1	1
7	1	1	1	1	1	1
8	1	1	0	1	1	0.8
9	0	0	0	0	0	0
10	1	1	1	1	1	1
11	0	1	0	0	1	0.4
12	1	1	1	1	1	1
13	1	1	1	1	1	1
14	0	1	1	0	1	0.6
15	1	0	1	1	1	0.8
16	1	1	0	1	1	0.8
17	1	1	1	1	1	1
18	1	1	1	0	1	0.8
19	1	1	1	1	1	1
20	1	1	1	0.5	1	0.9
21	0	1	0.5	0	0	0.3
22	1	1	1	1	1	1
23	1	1	0	1	1	0.8
24	1	1	1	1	1	1
25	1	1	1	1	1	1
26	1	1	1	1	1	1
27	1	1	1	1	1	1
28	1	1	0	1	1	0.8
29	1	1	1	1	1	1
30	0	1	1	0	0	0.4
31	1	1	1	1	1	1
32	1	1	1	1	1	1
33	1	1	1	1	1	1
34	1	0	0	1	0	0.4
35	1	0	0	1	1	0.6

36	1	0	1	0	1	0.6
37	1	1	1	1	1	1
38	1	0	1	1	1	0.8
39	1	1	1	1	1	1
40	1	1	1	1	1	1
41	0	0	1	0	1	0.4
42	0	0	1	0	1	0.4
43	1	1	0	0	1	0.6
44	1	1	1	1	1	1
45	1	1	1	1	1	1
46	1	1	1	1	1	1
47	0	1	1	1	1	0.8
48	0	1	1	0	1	0.6
49	1	1	1	1	1	1
50	0	0	1	1	1	0.6
51	1	1	0	1	1	0.8
52	0	0	0	1	1	0.4
53	1	1	1	1	1	1
54	1	1	1	1	1	1
55	1	1	1	1	1	1
56	1	1	1	1	1	1
57	0	0	1	1	1	0.6
58	1	1	1	1	1	1
59	0	0	0	1	0	0.2
					Average:	0.80339
					Std. Dev:	0.259287