Paper ID #36022

Student Self-Assessment Questionnaires using Hierarchical Bloom's Taxonomy

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Abstract

Regardless of the discipline, every college student is expected to provide feedback at the end of the semester. This feedback is highly important for the continuous refinement of every course. One aspect of these end-of-semester feedback forms is the self-assessment of students. This work presents a newly developed student self-assessment form based on the hierarchical Bloom's taxonomy. Here, the students identify their level of knowledge using the action verbs presented in Bloom's hierarchy, as basic (able to explain, define, describe, etc), mid-level (able to calculate, compute, apply, etc) or high level if they think they are capable of designing, creating or integrating. This self-assessment was implemented twice at the University of Southern Maine for ELE 351: Electromagnetic fields and student feedback showed the effectiveness of this implementation.

Introduction

At every university, at the end of each semester, students need to fill out a questionnaire to provide feedback to the faculty. Typically, those questionnaires contain questions related to the course as well as the instructor of the course. An important section of these questionnaires is the assessment of students' knowledge [1-5]. In those sections, there are questions such as how challenging the course was and or how much new knowledge was gained through the course. This student assessment piece not only gives the instructor information on how to adjust the course in future semesters it is also an essential element in program accreditations as well. Each university, each program, and each course administer this feedback collection process differently, using specific questions. This work presents a new student self-assessment questionnaire developed using the hierarchical Bloom's taxonomy [6-7]. The purpose and the advantages of this new questionnaire are discussed in the following paragraphs.

This questionnaire was developed for an engineering electromagnetic course ELE 351: Electromagnetic Fields at the University of Southern Maine. Electromagnetics is mathematically intensive. When it comes to engineering students, although they have gone through calculus courses in their first few years, approaching a problem from a different perspective might be difficult. At the same time, electromagnetic fields courses require visualizing mathematical concepts in 3D, which might be challenging for many students as well [8-10]. . In addition, the majority of engineering students can be kinesthetic learners; hence, they would prefer to see more hands-on work embedded into a course. For them, the required and unavoidable mathematics can be intimidating. Hence, the instructor needs to know the learning style and the knowledge of the students.

In a regular semester, it is challenging for the instructor to balance the subject content, hands-on experiences, and work examples within 16 weeks. At the same time, it is important to know what works and what does or did not work for the students. In addition, in engineering, the students and the accreditation institutions require kinesthetic learning [11-14]. Therefore, an instructor needs to get genuine feedback from the students on the level they are at, so the changes can be made in the future semesters. This self-assessment questionnaire is developed to identify the level of the students correctly. In this questionnaire, rather than rating the level on a slider-scale or rating the course on a scale, the student can identify the level they are at based on their ability. Hence, this questionnaire provides more focused and accurate information to the instructor on the student's knowledge. The traditional sliding scale or the rating methods are interpreted by students differently. Therefore, in those methods, the instructor might not be getting accurate information. However, in this case, since the students are grading their ability in a more focused method, the instructor can get accurate information. The wording to describe each ability was selected from the different levels of Bloom's taxonomy. The full development of this self-assessment questionnaire is given in [15]. The following sections discuss the content of the questionnaire, administered method, and the results.

Method

The developed questionnaire asked students to indicate their ability on the six main topics covered in the course. Rather than rating the knowledge on each aspect, here students have to select an option that represents their true ability on each topic. Figure 1 below shows the questionnaire administered to the students.

The four options for each topic covered were based on Bloom's taxonomy. The basic or a low level of comprehension was indicated by verbs explain, describe, define, state, discuss and identify. The verbs, calculate, compute, analyze, manipulate, apply and solve were selected to represent mid-level comprehension. The highest level of comprehension was represented by verbs: build, design, create, synthesize, integrate, and construct. Figure 1 shows the self-assessment questionnaire given to the students.

The four options were developed as follows: for example, under the first topic Gauss's law for electrostatic fields, and Maxwell's first equation: the first option refers to students who have not gained any ability on that topic. These students are not even able to explain the concept properly. Hence, they have not even reached the level of understanding a topic. The second option represents the students who have reached the level of understanding, but not at the level of applying it. The third option is developed to represent students who have gained an understanding of the topic and can apply it to solve real-world problems. This option indicates a higher level of knowledge compared to the first two options since this third option shows the ability of a student to apply the learned material and draw conclusions. The fourth option is developed to capture the highest level of knowledge: the ability to create. This is an extremely important field, especially for engineering. When a student reaches that level, the student has gained the highest level of comprehension and has a very sounding knowledge of that concept.

The completed form was sent out to students as a google form in addition to the formal faculty course questionnaire administered by the university. Students had the chance to indicate their choices anonymously.

Please select an option that mathes your true ability.

1 . Gauss's Law for electrostatic fields and Maxwell's first equation.

- I can neither explain, apply nor design an application based on Maxwell's first equation.
- I can explain Maxwell's first equation. But I can neither apply nor design an application based on it.
- I can explain and apply Maxwell's first equation. But I cannot design an application based on it.
- I can explain, apply and design an application using Maxwell's first equation.

2. Gauss's Law for magneto-static fields and Maxwell's second equation

- I can neither discuss the implications, solve problems nor create an application based on Maxwell's second equation.
- I can discuss the implications of Maxwell's second equation. But I can neither solve problems nor create an application using it.
- I can discuss and solve problems using Maxwell's second equation. But I cannot create an application based on it.
- I can discuss the implications, solve problems and create an application based on Maxwell's second equation.

3. Faraday's Law for time-varying electric fields and Maxwell's third equation.

- I can neither describe, compute nor build an application based on Faraday's law.
- I can describe Faraday's law. But I can neither compute nor build an application based on it.
- I can describe and compute values for a practical problem. But I cannot build an application.
- I can describe, compute and build an application to demonstrate Faraday's law.

4. Ampere's Law for time-varying electromagnetic fields and Maxwell's fourth equation

- I can neither, define, calculate values nor construct an application using Ampere's law.
- I can define Ampere's law. But I cannot calculate values or construct an application.
- I can define and calculate values for problems, using Ampere's law. But I cannot construct an application.
- I can define, calculate values and construct an application based on Ampere's law.

5. Plane wave solution

- I can neither state, manipulate nor synthesize plane wave solution.
- I can state plane wave solution. But I cannot manipulate or synthesize it.
- I can state and manipulate plane wave solution. But I cannot synthesize it.
- I can state, manipulate and synthesize plane wave solution.

6. Poynting theory, electromagnetic power, basic electromagnetic radiation principles, and their applications.

- I can neither identify, analyze nor integrate practical applications of EM wave propagation concepts.
- I can identify EM concepts for real-world scenarios. But I can neither analyze nor integrate concepts.
- I can identify and analyze EM concepts for real-world scenarios. But I cannot integrate those for implementations.
- I can identify, analyze and integrate EM appropriate EM concepts to implement solutions.

Figure 1: the self-assessment questionnaire developed using the hierarchical Bloom's taxonomy.

Results

This questionnaire was administered in the fall 2020 and fall 2021 semesters for ELE 351: electromagnetic fields course. As mentioned above, this questionnaire was administered in addition to the official faculty course questionnaire sent by the University of Southern Maine. A total of 53 students took the course in fall 2020 and fall 2021, and a total of 28 students responded to this questionnaire. Out of the 28 students who responded to the questionnaire, 25 were from fall 2020, and 3 were from fall 2021. In Figure 2, presented are the combined results from the two semesters.

One common trend on all topics is that the majority of the students have selected option 3 (shown in yellow). This means they have indicated that they can compute, calculate and apply the knowledge gained in the course.

The second common trend is that more than 25% of the students who provided feedback have indicated that they have the highest comprehension level of creating, synthesizing, building, and/or designing for all six topics covered (shown in green). These students have mastered the subject material and have completed all levels of knowledge starting from understanding to creating.

For the first topic: Gauss's Law for electrostatic fields, 11 students (39.3%) have indicated that they have the highest comprehension level of the subject. They can not only apply the knowledge but also design new applications. Fifteen students (53.6%) have indicated that they can apply the knowledge and draw conclusions based on it. This indicates mid-level comprehension. Two students (7.1%) have indicated a basic or a low level of comprehension (marked in red). According to this indication, these students understand the concept but are unable to apply it to solve a real-world problem.

The pattern of results obtained for the second topic: Gauss's Law for magnetostatic fields, is similar to the results obtained for the first case. With 7 students (25%) indicating the highest comprehension level, 19 students (67.9%) indicating mid-level comprehension, and 2 students (7.1%) indicating the basic level comprehension.

This trend continues for the third topic as well, with 9 students (32.1%) indicating the highest comprehension level, 18 students (64.3%) with mid comprehension, and 1 student (3.6%) with a low or basic comprehension of the topic. For the first three topics, out of the 28 students who provided feedback, no one has indicated the no-compression (lowest).

For the fourth topic of Ampere's law 11 students (39.3%) have indicated the highest comprehension level with the majority of 15 students (53.6%) indicating mid-comprehension. For this topic, one student (3.6%) has indicated low comprehension and one student (3.6%) has indicated no comprehension as shown in blue.

The fifth topic: plane wave solution has the most diverse distribution of choices. There were 8 students (28.6%) indicating that they have the highest comprehension, 10 students (35.7%) with mid-level comprehension, 6 students (21.4%) with low-level comprehension, and 4 students (14.3%) with no-comprehension of that particular topic.

The sixth main topic of Poynting theory and electromagnetic power had 8 students (28.6%) with the highest level of comprehension, 13 students (46.4%) with mid-level comprehension, and 6 students (21.4%) with low-level comprehension, and 1 student (3.6%) with no-comprehension.

Discussion

According to the student's self-assessment, the majority of them have a good comprehension of the subject material. The majority of them can apply the subject content to real-world problems. Moreover, about 25% or more of them have indicated that they have the highest comprehension of designing, building, or creating an application, using the knowledge they have gained. For the first three topics, no-student have indicated no-comprehension level. As for the fourth, fifth, and sixth topics, a minority of students have indicated the no-comprehension level. This might be due to the chronological order in which the topics were presented. Since Gauss's Law and Faraday's Law are taught at the beginning of the semester, the students have more time to master that material. Whereas the last three topics were discussed starting from the mid-semester when the semester workload for the students increases. Therefore, they do not have much time to focus on one subject and get an in-depth of a topic while handing multiple courses. This is a common trend that can be observed at any university, regardless of the discipline. The author assumes this is the reason for the consistently high level of mastery of the first four topics.

It was mentioned in the informal feedback that this self-assessment questionnaire was a good way to express how the students felt about their skill levels.

As for improvement, starting from fall 2022 there the ELE 351 course will have an embedded lab. The vision of this lab is to provide a higher-level learning experience for students in terms of designing, simulating, synthesizing, and building. At this lab, students will be able to design and build new applications using theoretical knowledge, and mid-level calculations. Once, that implementation is complete, this self-assessment questionnaire will be administered again, and compared with the current results.

Another important technique is to provide these questions during one topic is being covered. So far, the questionnaire was administered at the end of the semester. However, starting from fall 2022, this questionnaire will be administered one question at a time, during each topic is being taught. That way, the instructor can gain timely feedback from the students rather than waiting until the end.

As seen from the results, the majority of the students who responded to this questionnaire were from the fall of 2020 and only three students responded to it in the fall of 2021. The reason was in both times the questionnaire was administered in addition to the formal course evaluations, and in the fall of 2020, the instructor specifically mentioned this questionnaire to the students. Posting these self-assessment questions one by one to the students will avoid these disproportional results while giving the instructor sufficient time to adjust the course assignments based on the student feedback during the semester.

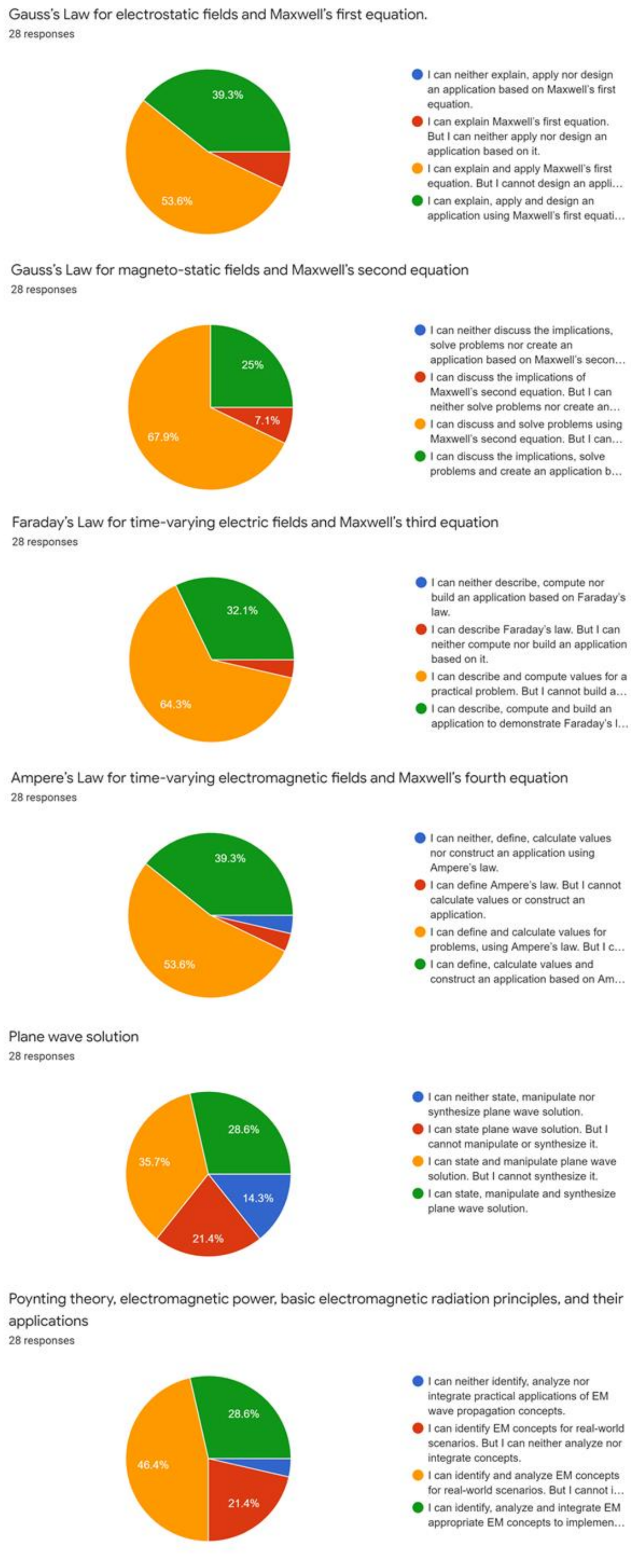

Figure 2: the results obtained for the six main topics covered in the course as percentages.

Given that, only 28 students out of 53(53%) completed the self-assessment questionnaire; it was worth comparing the self-assessment results with the final cumulative grades students received to test the accuracy of the student's self-assessment.

Table 1 shows the final grades the students received for ELE 351: Electromagnetic fields in the fall 2020 and fall 2021 semesters. These grades were based on the weighted cumulative summation of the final exam, two in-class exams, eight homework assignments, and five quizzes. The exams and the homework assignments contained design problems to test the highest level of comprehension. The majority of the assignments are intended to test the students' ability to apply, calculate or compute values or mid-level comprehension.

Based on the cumulative grades of the students 18.9% of the students have obtained the 'A' or upper 'B' (B+) grades. These students were capable of attempting a problem creatively, selecting suitable design parameters, and applying the knowledge they gained in the class to compute values. Although, more than 25% of the students who completed the self-assessment questionnaire indicated that they have the highest level of comprehension, according to the final cumulative grade distribution this percentage is only 19% when the entire student population was taken into account.

The majority (56.6%) of the students have obtained either 'B' or 'C' grades indicating that they can apply the knowledge and compute the values, but need more practice in invoking their creative abilities to design applications. Agreeing with the results shown in Figure 2, the highest percentage of the student population did fit into this category of mid-level comprehension. According to the results from the self-assessment questionnaire, the majority of the students indicated their knowledge as mid-level as well, hence here, the final grades students received agree with their self-assessment.

The poor grades (D grades) indicated that the students either had only a low or basic level comprehension of the subject matter. These students had a basic understanding of each concept but were unsure when applying the theories and computing values. In addition, 5.6% of the students had no comprehension of the concepts learned.

Overall, the comparison between the self-assessment and the final grades indicates that students assessed their knowledge accurately, although not all students completed the assessment.

Table 1: final cumulative grades received by the students in fall 2020 and fall 2021.

Letter grades	Marks range	# of students Fall 2020	# of students Fall 2021	Total number of students	Percentage %	Comprehension level
B+, A-, A	85 - 100	4	6	10	18.9	Highest
C+, B-, B	75 - 84	9	7	16	30.2	Mid-level
D+, C-, C	65 - 74	9	5	14	26.4	
D-, D	55 - 64	8	2	10	18.9	Low
F	< 54	2	1	3	5.6	No comprehension
Total		32	21	53	100	

Conclusions

This work presented the student feedback obtained by administering a self-assessment questionnaire developed using Bloom's taxonomy for ELE 351: electromagnetics course at the University of Southern Maine. In this questionnaire, the students were expected to choose an option that best represented their skill levels on the six main topics covered in the electromagnetics course. The verbs representing each skill level were selected using the hierarchical Bloom's taxonomy. The questionnaire was administered by the end of the semester in addition to the formal course questionnaires sent out by the university, hence responding to the questionnaire was optional. Based on the results, the majority of the students have had mid-comprehension (able to apply, compute, calculate, manipulate, solve or analyze) on all topics covered in the course. More than 25% of the students indicated that they have the highest level of comprehension (able to create, build, design, construct, synthesize and integrate). According to the results, the order in which the topics are covered plays a role as well, since students have not indicated no-comprehension for the first three topics. For the topics covered later in the semester, the percentage of students who have indicated low-level comprehension (able to describe, explain, discuss, define, state, and identify) has increased compared to the first three topics, because the students have had more time to master the topics taught at the beginning of the semester.

Starting in fall 2022 there will be an embedded lab for this course for students to practice their creative abilities in designing and building applications. This new lab will promote the highest level of comprehension and these presented results will be compared after the completion of the new implementation. Also, in the future, rather than posting all these questions by the end of the semester, each question will be posted to the students during the semester, while each topic is being covered to make simultaneous adjustments.

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