Assessing ABET ANSAC and EAC Learning Outcome (2) in Introductory Physics

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Abstract

The physics and engineering physics programs at Arkansas Tech University (ATU) are currently in the process of preparing to apply for ABET accreditation through the Applied and Natural Science Accreditation Commission (ANSAC) and Engineering Accreditation Commission (EAC), respectively. These programs follow an "Introduce, Reinforce, Master" curriculum map as part of the assessment plan where each student learning outcome (SLO) is assessed in at least three courses of different levels, so that each SLO is assessed at each of the three levels (introduced, reinforced, and mastered). We seek to effectively assess, at the introductory level, the proposed ANSAC SLO (2) and the new EAC SLO (2) with a single project and rubric in our introductory physics courses. The primary difference between the SLO (2) from the two commissions is that the EAC is more specific in that students must apply "engineering design to produce solutions that meet specified needs with consideration of public health, safety, welfare, as well as global, cultural, social, environmental, and economic factors" whereas the ANSAC only requires that the design must meet "desired needs." With this in mind, we have implemented a project that is completed by students at the end of the second semester of introductory physics where students are required to follow engineering design principles to design and build simple speakers that must meet given specifications. In this paper, we discuss the details of the student project specifications, the rubric developed to assess the student projects, and show select student projects from the first two cohorts assigned this project. Additionally, we will discuss changes that will be implemented to the assignment and assessment processes so that student learning of the skills and concepts required of SLOs will improve.

Introduction

Our department is relatively small, graduating 3-5 physics and engineering physics majors per year. We have five full-time and one half-time physics faculty members with a majority of our teaching load being service courses. Our department, specifically the engineering physics degree, is at an obvious recruiting disadvantage compared to the other engineering degrees offered at ATU because it is not currently ABET accredited. With the goal in mind to increase recruitment and retention and strengthening our program, we have been investigating seeking ABET accreditation through the Engineering Accreditation Commission (EAC) for the Engineering Physics program. Because ABET similarly offers accreditation for Physics programs through their Applied and Natural Science Accreditation Commission (ANSAC), we will also seek ABET accreditation for our Physics program. The decision to seek accreditation for both is feasible and practical because there is a significant amount of overlap between the curriculum for the Physics and the Engineering Physics programs as well as overlap between the EAC's and ANSAC's Criterion 3, Student Learning Outcomes [1]. In an effort to streamline assessment efforts for the two programs, while meeting the Student Learning Outcomes (SLOs) from two different ABET commissions, it is our goal to determine performance indicators that will assess similar SLOs from the two commissions simultaneously. In this paper, we discuss an assignment that was created and assigned to students enrolled in the second semester of calculus-based physics with the goal of assessing all of the performance indicators associated with SLO (2) from both commissions at an appropriate level for an introductory course. An additional goal of adding the assignment to the introductory physics course is to increase student ownership of learning and therefore increase student learning. Literature has shown that project-based learning is one of the best ways to achieve this goal [2]. As such, the assignment created to assess SLO (2) at this level is a project where students are required to apply basic physics and engineering principles to build a simple speaker. The only change made to this course this semester was the addition of the project assignment. The course has a three credit hour “lecture” component and a one credit hour laboratory component. The project scores were incorporated as part of the lecture component of the course. This paper briefly discusses our department’s assessment plan and a description of the speaker project assignment, including how SLO (2) is assessed and sample student work.

Physics and Engineering Physics assessment plan at Our University

The assessment plans of most programs ATU rely on an "I, R, M” (introduce, reinforce, master) curriculum mapping. This type of curriculum matrix maps all of a program’s SLOs to the courses required for a degree, specifying in which courses the skills required of each learning outcome are first introduced, where the skills are reinforced, and where they should be mastered. See [3] for more information about this type of curriculum map. As an example, Table 1 is an excerpt from our Physics program curriculum map that illustrates in which courses three of our learning outcomes are introduced, reinforced, and mastered. For each SLO, performance indicators (measurable actions or knowledge) are assigned that are commensurate with each level.

Course	**Learning Outcome 1**	**Learning Outcome 2**	**Learning Outcome 3**
General Physics I	Introduced		Introduced
General Physics II		Introduced	
Modern Physics	Reinforced		
Quantum Mechanics			Reinforced
Advanced Lab	Mastered	Reinforced	
Independent Research		Mastered	Mastered

Table 1: Excerpt from our Physics Program’s curriculum alignment matrix.

The student project reported here was assigned in the second semester of our Calculus-based Introductory Physics course (Physics II), to assess, at the "introduce" level, both SLO (2) from the ANSAC and SLO (2) from the EAC. The student learning outcomes from the two commissions are given in Table 2. At this level, it was decided that our department’s performance indicators for both commission’s learning outcome (2) should be: [Students should be able to] Apply design requirements, Identify safety and economic factors, and Recognize physics and engineering principles required to solve a problem.

Learning outcome assessment

Because our department utilizes the “I, R, M” curriculum mapping model for assessment, each SLO is assessed in a minimum of three different classes at the three different levels. Our department has identified one to three performance indicators per level. We will assess SLO (2) for both the EAC and ANSAC in Physics II (introduce), Electromagnetism (reinforce), and the Independent Research course (master). Table 3 gives all of the performance indicators at the

Engineering Accreditation Commission learning outcome (2)	*[Students should have] an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors*
Applied and Natural Science Accreditation Commission learning outcome (2)	*[Students should have] an ability to formulate or design a system, process, procedure or program to meet desired needs.*

Table 2: Learning Outcome (2) from ABET's EAC and ANSAC

"introduce" level and, as an example, one performance indicator for each of the "reinforce" and "master" levels. The speaker project was designed to assess all three of the "introduce" performance indicators in a single assessment. The revised Bloom's Taxonomy was used as a reference in determining appropriate performance indicators, e.g., performance indicators at the "introduce" level should require a "remembering" or "understanding" level of learning [4]. The first performance indicator, "Apply design requirements," contains the verb "apply" which is typically associated with a higher Bloom's level but the simple design requirements of this project allow us to still assess at the introduce level. Each performance indicator is assessed in a pass/fail manner as either "meets expectations" or "does not meet expectations".

Performance indicator	Assessed in	Level
Apply design requirements	Physics II	I
Identify safety and economic factors	Physics II	I
Recognize physics and engineering principles required to solve a problem	Physics II	I
Apply engineering and physics principles to analyze a problem	Electromagnetism	R
Develop realistic design requirements using physics and engineering principles	Independent research	M

Table 3: Sample of our department's performance indicators for EAC and ANSAC Student Learning Outcome (2), in which courses the performance indicators are assessed and the level they are assessed (Introduce (I), Reinforce (R), and Master (M)).

The project and performance indicator assessment

For this project, students were required to design and build a speaker with the only design requirements being that students must utilize the provided audio jack and the speaker must be audible when played from a cellphone. Students were allowed to use their phones and choice of music or the professor's phone and choice of music. The speakers were tested in front of the entire class on the last scheduled class day of the semester. In addition to presenting their working speakers to the class as a team, students were required to submit an individual written report on the day of testing. The projects were assessed based on successfully designing and building a working speaker and the content of their oral and written reports, as indicated by the project instructions given in Figure 1. The speaker project assignment was weighted to be 8% of the total overall grade for students in the course

Speaker Project Instructions

You will be required to build a speaker as a final project in Physics II. You will be provided with an audio jack to power the speaker. The materials and design you choose are 100% up to you and your partner. If you need assistance locating or acquiring any other materials, please let your professor know. The requirement for the finished speaker is that music (played from a cellphone) can easily be heard. [Sorry iPhone users, we are going to use a regular audio jack!]

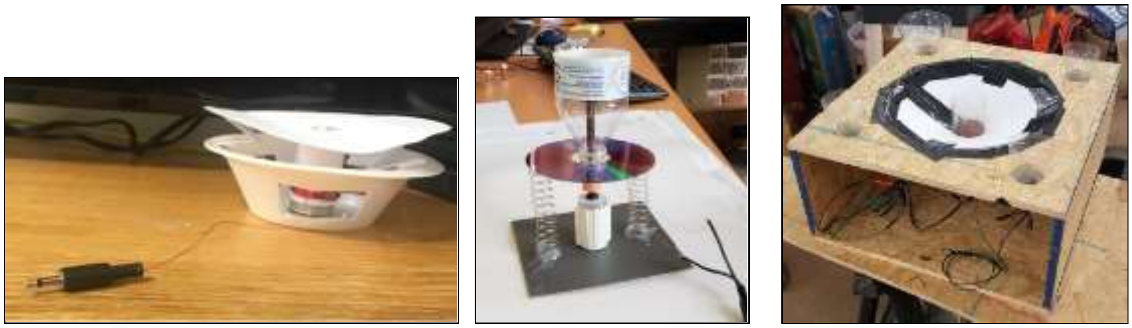
Report: All reports should be prepared **individually** and submitted via the link on Blackboard. Please include the following in your report

- How/why your team chose the design
    - Include why you chose specific materials
    - Include a parts cost list
- Photograph of your speaker
- Report on any difficulties you had designing/building the speaker
- Explain how your speaker works using concepts from Physics I and II
- Discuss ways you tried (or would) try to allow the speaker to be louder
- Report on the "safe" range sound intensity that is safe for humans (we are going to test how loud your speaker is on testing day).

Presentation: We will test speakers on the last day of class. You and your team will have a total of 4 minutes to demonstrate your working speaker and discuss the design followed by 1 minute for questions.

Figure 1: Project instructions provided to the student

Students that successfully designed a speaker that met these requirements are marked as "meeting expectations" for the first performance indicator, "Apply design requirements." While all of the student speakers successfully produced audible sound waves, there was a wide range of construction methods and materials. Figure 2 shows three examples of student speakers. Figure 2a shows a simple construction of the frame and cone from copy paper, tape, and a Styrofoam bowl. The creators of this speaker originally tried to use a cardboard plate as the diaphragm but learned that is was too heavy to move in reaction to the magnetic force created by the current in the coil supplied by a phone's audio signal and then switched to a paper diaphragm. The speaker shown in Figure 2a is marked as meeting expectations. Figure 2b shows a more complicated construction for the speaker that still uses materials easily accessible to students. The frame for this speaker was created from a water bottle, CD, and a binder. The original design for this speaker did not include the metal springs supporting the CD diaphragm. After finding the water bottle and CD too heavy to vibrate in response to the magnetic force created by the electromagnet, the team added the metal springs to make their speaker audible. Figure 2c shows one of the most complicated student speakers submitted. The frame was constructed from plywood, and a car battery was used to power the electromagnet attached to the central speaker. The plywood frame also housed four smaller speakers which used permanent magnets. The creators of this speaker initially also had the idea that the current supplied by the audio signal from the phone would create a large enough force that the cardboard diaphragm would vibrate. They learned that the current supplied by the phone would not create a strong enough magnetic field to vibrate the cardboard diaphragm. This group solved their problem with the four smaller speakers with plastic diaphragms. The speaker designs shown in Figures 2b and 2c exceeded expectations.



(a) (b) (c)

Figure 2: Photographs of student speakers. (a) Simplest speaker design, (b) more mechanically complicated design, and (c) speaker with a surprisingly complex construction that exceeded expectations.

For the second performance indicator, “Identify safety and economic factors,” students that reported reasonable values for safe sound levels and included a parts list in their reports were marked as “meeting expectations." Students demonstrated they thought about possible safety factors by reporting on the range of sound intensities that are safe for humans. The sound intensity of the speaker was measured on test day using a PASCO PASPort Sound Level Sensor and DataStudio. The sensor was placed approximately 10 cm from the speaker. At this distance, most of the speakers produced sound levels of 40-50 dBA. Students were required to compare their speaker’s sound level with what is generally considered to be “safe” in their final reports. We did not expect the student-created speakers to produce sound intensities outside of the safe range, but it is important for students to recognize that it is possible to have “unsafe” intensities of sound. (A clear distinction was not made by the students or instructors between sound intensity measured in $\mu W/m^2$ and sound level measured in dB or dBA, more specifically).

The following is an excerpt from a student report that, along with a complete parts cost list, is marked as “meeting expectations” for this performance indicator:

> *"We have chosen our design to be simple, easy to build, easy to carry around, and its reasonable cost. Basically, our design is a magnet that is placed inside a plastic food storage container and over the magnet there is a copper wire that surrounds the magnet to make a magnetic field (very simple design). We chose the copper for its high ability to conduct electric/magnetic field, the magnet is a must for our project but we have chosen our magnet for its reasonable price and the plastic container because it will make the magnet easy to carry. […] Generally, any sound more than 85db is harmful for us and that depends on how long we hear that sound and how far we are away from the object that is producing the sound, but our speaker is producing around 50db so it should be safe for humans.”*

To assess the third performance indicator, “Recognize physics and engineering principles required to solve a problem” students were asked to explain how their speaker physically works and think of ways they can make it louder. To be marked as “meeting expectations”, a student should recognize at least the following (as described in their report): 1) A changing magnetic field is created by the wire carrying the changing current supplied by the audio signal from a phone, 2) The changing field creates a changing force between a magnet and the electromagnet causing a vibration, 3) This vibration is what creates the sound, and 4) The payoff between the added mass of using more coil turns or bigger magnets to create a greater magnetic force and the greater force required to vibrate the heavier design. Below are excerpts from student papers that address items 1-4 above and are marked as "meeting expectations" for the third performance indicator.

> *The speaker creates its sound like everything else in the universe, via vibration of molecules. To obtain this pattern movement, the speaker uses three of the natural concepts of physics: force, electricity, and magnetism. The speaker utilizes an electric current through magnetic copper wire wrapped in a cylinder like fashion to generate a magnetic field, which interacts with the magnetic field generated by the neodymium magnet. These two fields interact, thus creating a force on the wire, which results in acceleration upward or downward depending on which direction the current is flowing. The continuous change in direction of current results in vibration of the plate, thus creating sound. For the design to work, the current in the circuit must flow like an alternating current.*
>
> *If we had used more fine wire, then the audio production would have been louder. The strength of the magnets is also a factor of how loud our speaker was. If [we] had used industrial strength magnets (stronger), then the speaker would have been significantly louder. The magnets are the easiest and quickest option for increasing the volume of the speaker. Another significant modification would be to use non-insulating material. I believe that the styrofoam construction absorbed sound, rather than reflect more sounds outwards.*

Of the thirty-two students assigned the speaker project, only one did not "meet expectations" on the three performance indicators assessed.

Feedback from students

On the day students tested their speakers they were asked to complete an anonymous survey. The survey was administered to assess the level of connection students made between the course material and the speaker project. Additionally, it served to determine student ownership of and interest in the project. On the survey, students self-reported to have spent between 1 and 27 hours working on the project and the majority of the students spent about 5 hours total working on the project.

On the survey, students were asked to rank their level of effort on different parts of the project. They were asked to assign a 1 for 'no effort' and a 5 for 'significant effort'. The average and standard deviation of their responses are shown in Figure 3. The areas they were asked to rank can be correlated to the performance indicators assigned to this project. For example, "Building the speaker" represents the students' attempt to "Apply design requirements". Building the speaker received the highest ranking of effort from the students with all students ranking it as a 3 or higher.

The performance indicator "Recognize physics and engineering principles required to solve a problem" is related to the "Troubleshooting" ability of the students. "Troubleshooting" had the widest range of reported student effort. While ten students ranked "Troubleshooting" at an effort level of 5, seven students ranked it as a 1 or 2. Because the finished speakers were all audible, the students were successful at troubleshooting. Therefore, the student perceived effort level may not represent the ability of the students, but rather represent their level of engagement in that area.

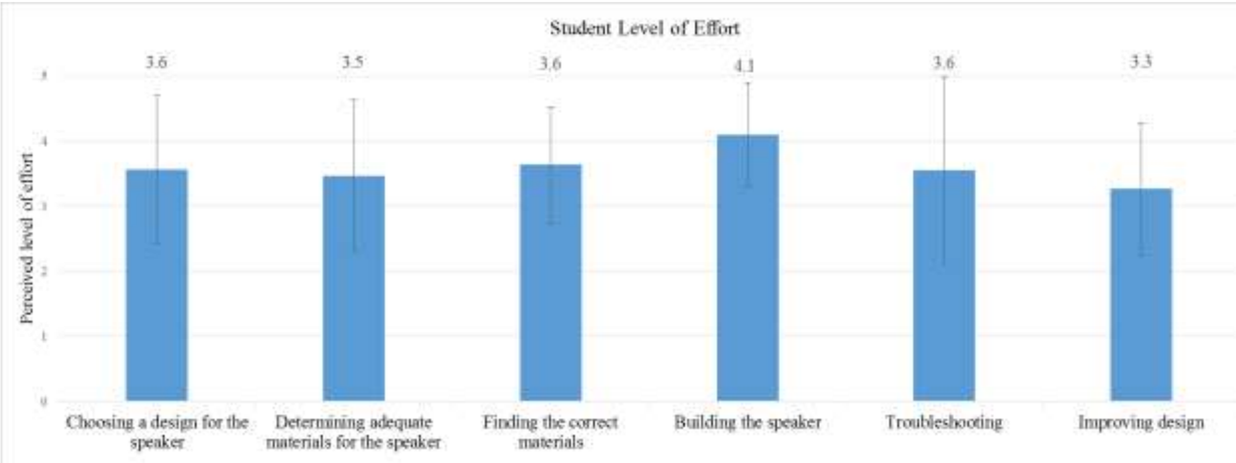


Figure 3: Plot of average student responses to “rank your level of effort in the following areas on a scale of 1 to 5 where 1 is no effort and 5 is significant effort: 1) Choosing a design for the speaker, 2) Determining adequate materials for the speaker, 3) Finding the correct materials to build the speaker, 4) Building the speaker, 5) Troubleshooting, 6) Improving the design.

When asked "did you directly apply any concepts from Physics II when designing or improving your speaker?" and "if yes, name the concepts" most students answered that they did apply concepts from physics II and used terms like, "electromagnetics" and "current carrying wires”. While it is encouraging that most students reported that they felt like they put in an acceptable amount of effort, students would ideally put more effort into improving their design using physics learned in the course.

Finally, students had a very positive opinion about the project as a whole. When students were asked "on a scale of 1-5, 1 being not at all and 5 very, how interesting did you find the project?" the average student response was a 4.5. Overall, the students seemed to have taken ownership of and enjoyed the speaker project.

Conclusion

The speaker project, as assigned, met the goal of assessing SLO (2) at the introductory level from both the ANSAC and EAC, simultaneously in a single project. All students assessed were able to build a working speaker, given the requirement that music must be audible when played through a cellphone audio port. Most students recognized the basic physics and engineering principles required to make and operate a simple speaker. Because students were required to source all of their own material for the project and report on why they chose each component and how much they cost, students were aware of economic factors involved with designing and building a speaker. Additionally, student interest and ownership of the project was reasonably high.

The speaker project will be assigned in the future with a few improvements to better serve students and give our department a better assessment tool for SLO (2) at the introductory level. Mainly, the project expectations will be raised in both the contents of the final report and the construction of the speaker. Firstly, more importance will be placed on students being able to explain, in terms of physics concepts, the operating principles of the speaker. Because, while students "met expectations" for the third performance indicator, some students passed these criteria with minimum understanding and effort (as determined by their responses in their reports). Secondly, in future semesters instead of simply requiring the sound from the speaker to be audible, a minimum dBA will be a requirement.

References

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