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Understanding the Processes and Challenges Students' Experience Solving an Open-Ended Problem

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Understanding the Challenges Students Experience Solving an Ill-Structured Problem

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***Abstract* – Recently there have been multiple calls to improve undergraduate engineering education and incorporate high-impact practices through the undergraduate curriculum. Within engineering education, one method to address these calls is to provide students with the opportunity to solve ill-structured problems throughout their undergraduate studies. The goals of this work are to present an ill-structured problem assignment that was used within a first-year physics course for engineering students and the outcomes of a preliminary research study to understand the challenges students face when solving an ill-structured problem. The problem assignment gave students the opportunity to write and solve an ill-structured problem of their choice related to the course context. For the research study, we analyzed students' responses to open-ended survey questions to understand how students approached specific aspects of the assignment and what they found challenging. We identified how students selected a phenomenon to analyze, what methods they selected to gather information to answer the question, why they selected these methods, and the parts of the assignment they found the easiest and most challenging. The outcomes of this work can inform future iterations of the assignment, scaffolding to support students as they solve ill-structured problems, and general course instruction.**

Index Terms – Ill-structured problems, problem-solving process, qualitative research

INTRODUCTION

There have been multiple calls to improve undergraduate engineering education in order to better prepare students to solve complex, ill-structured problems within rapidly changing, multi-disciplinary environments [1]. One method to address these challenges is to provide students with the opportunity to experience ill-structured problems throughout their undergraduate studies [2]. Shin et al. present a list of characteristics to describe ill-structured problems. A few of these characteristics are, fail to present all problem elements, possess multiple solutions, and require learners to make judgements about the problem by expressing personal opinions or beliefs about the problem interpretation [3].

Traditionally, the most common type of problem within undergraduate engineering programs are well-structured problems that have a single solution and all of the constraints are provided. Well-structured problems can help students process and apply their knowledge within a new context. However, well-structured problems do not look like the problems students will face in their future jobs [4]. As such, it is important for students to have the opportunity to solve problems that require them to collect information, evaluate sources, and provide a justification for their work. Such problems give students the opportunity to develop skills and strategies that can be transferred to larger design experiences. Since students typically see well-structured problems within their courses, incorporating ill-structured problems into a course can result in challenges for both the instructor and students [5]. Students may experience discomfort and uncertainty about how to start the problem and how they will be assessed by their instructor. Likewise, faculty may face challenges assessing student work and supporting students through the process of completing an ill-structured problem.

Within engineering education, there have been multiple studies to investigate the processes students use to solve ill-structured problems [4]–[6]. These studies begin to provide insight for how faculty can support their students and were used to inform the initial development of the assignment we present in this paper.

Previous work within engineering education has identified that students' interest in the topic of a problem impacts the goal they approach the problem with and the processes students use to complete the problem. Students who were interested in the topic of an ill-structured problem in a biomechanics course set goals related to gaining knowledge and were often willing to spend more time on the problem [6]. This work and other work related to students' interest informed the development of the assignment we present in this paper.

This paper describes a course assignment that gives first-year engineering students the opportunity to design and solve an ill-structured problem related to course material within a traditionally taught course. Our goals with the assignment that was developed were to 1) give students the chance to investigate a physical phenomenon they found interesting and 2) provide students with the opportunity to solve an ill-structured problem related to course content in a traditionally taught course.

Within this paper, we also present the results of a preliminary research study that sought to understand the processes and challenges students faced when solving their ill-structured problems. To conduct this study we analyzed students' responses to an open-ended survey that they completed after solving their ill-structured problems.

OVERVIEW OF PRACTICE IMPLEMENTED

This work is situated within a first-year physics course for engineering students. This course is taught in a traditional manner with lectures as the primary means of instruction and well-structured homework problems assigned after each lecture. The students have a lab associated with the course where they work on problem sets, labs related to the lectures, and two design problems over the course of the semester.

The assignment we studied was assigned to students as extra credit. It required students to identify and analyze a physical phenomenon of their choosing using physics' principles from the course. Students were asked to describe the phenomenon, write a problem statement, collect needed information and data, calculate a numeric answer, and justify their solution. The primary goal with this assignment was that it would give students the opportunity to solve an ill-structured problem that was about a topic they were interested in. We hoped that giving the students the opportunity to select the topic and write their own problem would mitigate some of the uncertainty and discomfort that often comes with ill-structured problems.

Students were encouraged to consult the instructors and teaching assistants of the course throughout the entire process of completing the assignment. The assignment was assigned towards the end of the semester and students had 5 weeks to complete the assignment. For completing this assignment, students could earn the equivalent of up to 15 points on an exam.

METHODS FOR DATA COLLECTION AND ANALYSIS

Given that this problem was different in nature than other course problems, we sought to understand more about the processes and challenges the students faced in order to inform future versions of the assignment and to develop scaffolding to support students solving ill-structured problems. During the semester in which this study was conducted, the assignment was given as extra credit. After finishing their problem, students were asked to complete an open-ended survey. No identifying information was collected on the survey, and students were not required to complete the survey to receive extra credit.

The survey included items to understand how students identified a physical phenomenon to analyze, where and how they collected the required information, and what aspects of the assignment were the easiest and most challenging. Students' responses to the open-ended items were analyzed using conventional qualitative content analysis in which codes were developed from the data. First, all of the survey responses were read to gain a general understanding of the data. Next, each participant's responses were reread and coded question by question. We developed the codes based on participants' responses rather than using a priori codes. After analyzing the responses from each participant, a constant comparative approach was taken to understand areas of similarity and difference between students.

RESULTS AND DISCUSSION

From the open-ended surveys, we were able to understand how students selected a phenomenon to analyze, how they went about getting the information to analyze the phenomenon, why they selected the methods they described to get the information needed, how difficult they found each aspect of the problem, and the parts of the assignment that they found the easiest and most challenging.

Two themes emerged surrounding how students selected a phenomenon to analyze: personal connection and connection to a course. Within personal connection, students described selecting a phenomenon related to something they had personally experienced, such as finding it difficult to open an automatic door that is closing. Students also described selecting a phenomenon that they were genuinely interested in. Within the theme connection to a course, students mentioned picking a phenomenon that allowed them to apply more concepts or specific concepts from the course. One student selected their phenomenon because it allowed them to further investigate a topic that they were interested in further exploring from a different course. For all of the students, the assignment gave them an opportunity to further explore a phenomenon they were interested in because of a personal connection or connection to a class. These results align with what we expected and hoped students would do to select a phenomenon to analyze.

To analyze their selected phenomenon, students had to gather information and collect data. This required students to make decisions about where they would go to get information and the methods they would use to collect data. As part of the survey, students were asked to describe how they got the information they needed and why they selected the methods they described. All of the students described looking their topic up online to get initial information. They did not go into detail about what specific sources they were looking for online and how they decided if the information was reliable. Given the data that we have it is difficult to say whether or not students have an understanding of what an appropriate online source is and how they can go about making sure the information they are using is reliable. In future iterations of this assignment, it may be helpful to give students some guidance about how assess the reliability of information online.

For information they could not find online, students used observations and direct data collection using tools from labs that were done in class. The students provided limited details about why they selected the methods and information sources they used over other possible sources. It is interesting to note that one student who looked up specific measurements online and collected their own measurement data based on observation, believed the online data to be "true scientific data". This student's statement and the lack of justification provided by the other students suggests that there is a need to encourage students to critically think about the information they are using online and how to decide if it is valid information.

On the survey, students were asked to rank the following in terms of the level of difficulty, from extremely easy (1) to extremely difficult (7): identifying a phenomena to analyze, collecting information needed to complete the analysis, calculating a numeric answer, assessing the reasonableness of the numeric answer, and writing up the assignment to submit (Table 1).

Table 1: Summary of quantitative survey responses. Numbers are based on the scale extremely easy (1) to extremely difficult (7).

Item	Mean
Identifying a phenomenon to analyze	4.00
Collecting the information needed to complete the analysis	4.17
Calculating a numeric answer	4.33
Assessing the reasonableness of the numeric answer	5.17
Writing up the assignment to submit	4.00

Students were also asked to describe the easiest and most challenging aspect of the assignment in an open-ended format. Both writing up the assignment and identifying the phenomenon had an average score of 4. Collecting the information needed had an average of 4.17 and calculating a numeric answer had an average of 4.33. One of the students reported the calculation to be the most difficult part because the geometry need to analyze their phenomenon was very complex. Another student described calculating the numeric answer as just plugging numbers into a formula. The level of difficulty for calculating the answer is dependent on the specific phenomenon selected. The most difficult aspect of the assignment for most of the students was assessing the reasonableness of the numeric answer, which had an average of 5.33. One of the reasons this seemed to be so challenging was because of the scale of some of the students' answers and the fact that in the course ideal states and conditions are assumed, making it difficult for the students to know how much the real behavior might deviate from the ideal. Based on these results more attention should be given to helping students develop the skills to assess the reasonableness of numeric answers. This is not something that is asked of the students on other assignments in the course, but is a very valuable skill for engineers to have.

Conclusions and Future Work

One of our initial concerns with this assignment was whether or not students would be able to easily identify a phenomenon to analyze. Based on the outcomes of this preliminary study, students found selecting a phenomenon to be one of the easiest parts of the assignment. Additionally, all of the students selected a topic that they were interested in either because of a personal experience or a topic in a course.

The students reported struggling the most with assessing the reasonableness of their numeric answer. This outcome is not surprising, as students are not required to show evidence of assessing the reasonableness of answers to other questions within this course. Incorporating discussions about how to assess the reasonableness of an answer throughout the class would likely be beneficial to students. Instructors often talk about this as a tool that students can use to help them check for mistakes; however, students may not have the tools they need to be able to do this.

Additionally, we found that most of the students used online resources to gather information; however, the students provided very little detail about the specific sources they were looking for and justification for why these were reliable sources. More data is needed to fully understand students' beliefs about sources of information and how they go about selecting information to use to complete an ill-structured problem. It would likely be beneficial to students to provide specific instruction about how to assess the validity of online information sources. Assessing the validity of information is an invaluable skill within engineering and everyday life.

In terms of the assignment, we plan to incorporate class time to discuss assessing the validity of information online and the reasonableness of an answer. We also plan to make this assignment required for all students in the course. We will continue to collect data to gain a better understanding of the challenges students face with this assignment to inform our instruction and problem description. We also plan to collect student work and interview data to gain a better understanding of the processes students use to solve an ill-structured problem to further inform the development of instructional practices that can support students and faculty with ill-structured problems.

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References

[1] PCAST and President's Council of Advisors on Science and Techology, "Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics," 2012.

[2] G. D. Kuh, "High-impact educational practices: What they are, who has access to them, and why they matter," *Assoc. Am. Coll. Univ.*, 2008.

[3] N. Shin, D. H. Jonassen, and S. McGee, "Predictors of well-structured and ill-structured problem solving in an astronomy simulation," *J. Res. Sci. Teaching2*, vol. 40, no. 1, pp. 6–33, 2003.

[4] N. J. Mourtos, N. Dejong-Okamoto, J. Rhee, N. D. Okamoto, and J. Rhee, "Open-Ended Problem-Solving Skills in Thermal- Fluids Engineering," *Glob. J. Eng. Educ. Glob. J. Engng. Educ*, vol. 8, no. 2, pp. 189–199, 2004.

[5] E. P. Douglas, M. Koro-ljungberg, N. J. Mcneill, Z. T. Malcolm, and D. J. Therriault, "Moving beyond formulas and fixations : solving open-ended engineering problems," *Eur. J. Eng.*, vol. 37, no. December, pp. 627–651, 2012.

[6] C. J. Faber, "Epistemic Cognition during Problem Solving," Clemson University, 2015.

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