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Work in Progress: Got Intuition? Exploring Student Intuition in Response to Technology-aided Problem Solving

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WIP: Got Intuition? Exploring Student Intuition in Response to Technology-aided Problem-solving

Abstract

Technology is an essential tool in modern engineering problem-solving. Complex calculations are easily computed, but failure to recognize if the solution is "reasonable or ridiculous" can have serious repercussions. As part of "engineering intuition," getting students to assess the appropriateness of a solution is a somewhat vague, but critical, teaching goal. Intuition is commonly thought to be developed through experience; thus, we are interested in identifying the experiences that have strong correlations with high engineering intuition in students. Ultimately, we seek to use this knowledge to develop course interventions that promote the development of engineering intuition in all students, regardless of access to outside-the-classroom opportunities.

Our previous work has suggested that students' cumulative GPA and internship experience can be a predictor of both whether a student will attempt a problem that tests engineering intuition and their subsequent success on that problem. In this work, we report on updated results from Fall 2017, as well as describe our future study design. The next phase of this work will be a larger-scale study of engineering intuition across multiple disciplines and institutions that will propel us towards developing classroom interventions for "teaching" intuition.

Introduction

As technology-aided problem solving has become standard practice, an engineers' ability to "intuit" the results obtained through technology grows increasingly urgent. Studies on classroom learning gains from technology use report both shallow learning [1] and deeper learning [2-5]. The technology that aids today's engineers in problem solution is not without limitations, as these tools are based on underlying assumptions that may or may not hold true. Thus, engineering students must learn to use technology intelligently and critically, and the ability to intuit whether a technology solution is reasonable or ridiculous, feasible or infeasible, is key.

Intuition is commonly thought to be developed through experience and can lead to better decisions in complex situations [6]. Intuition can be explained as subconsciously following a set of rules [7-9]. Often difficult to teach, intuition development can be linked to a number of theories. According to Fuzzy-Trace theory, learning transitions from literal interpretation (verbatim) to non-literal interpretation (gist). Intuition is closely related to gist transfer where learners create links across different contexts and are less likely to be deterred by superficial cues [10]. In the Dreyfus model, a novice (who may unthinkingly follow the rules) progresses to an expert (who analyzes the results) through intuition before ultimate achieving mastery [11].

Since intuition is commonly thought to be developed through practice or experience, we seek to identify experiences which have strong correlations to engineering intuition in students, first by identifying shared experiences of students who appear to be naturally strong intuitors. In subsequent work, we will seek to characterize these experiences and isolate the aspects that promote intuition development before using this knowledge to develop course activities that foster the development of engineering intuition.

In previous work, we found correlations between strong engineering intuition on “stretch” problems and students’ overall (not STEM or ENGR) GPA and internship experience. Our measure for engineering intuition is whether students get the correct answer and reasoning on the problem of interest. We define “stretch” problems as problems that require information beyond the direct scope of the problem, but related to prior knowledge and easily accessible via student resources (textbook, internet) [12]. In our original study, we did not explicitly focus on “stretch” problems, but this result prompted us to investigate these specific types of problems more thoroughly. A continuation of the study, focusing on “stretch” problems, again showed this trend between overall GPA or internship experience and student engineering intuition [13].

Here, we report updated results from the subsequent semester of study on the “stretch” problems, as well as describe our future study design. We measure engineering intuition by student success on these “stretch” questions and identify common factors (major, career aspirations, engineering internship experience, military service, learning preferences, overall GPA, engineering GPA, and overall homework score) among students who display high engineering intuition, in an effort to better understand how we may promote this skill in all students.

Methods

In this research, we aim to assess how students evaluate assumptions or results in simulations on “stretch” problems. Here simulations refer to using software to solve problems (such as spacecraft orbits) which would otherwise be difficult to model. The purpose of these simulation questions is to transform a homework problem into a real-life scenario in which students are challenged to evaluate their results in a real context.

The studied classes are a junior-level orbital mechanics course from a small western private university. The orbital mechanics class included two sections (n =28 and n = 38) taught by the same instructor. We chose to study a junior-level course because at this point in the curriculum students have basic disciplinary knowledge and some experience with open-ended questions. The junior year is also important in the shift from novice to expert as students complete the majority of their technical classes before their senior capstone design classes. The course used the simulation tool, General Mission Analysis Tool (GMAT), an open source spacecraft trajectory optimization and mission analysis tool developed by NASA and private industry [14].

Students were presented a homework “stretch” problem to be completed through simulations. At the end of the problem, they were asked an additional question, the “stretch” that essentially required them to evaluate their solution. This question essentially had two parts: (1) a yes/no evaluation of the feasibility of their solution, and (2) a reasoning behind their answer. Students answered a “stretch” question on the results of three of the ten required simulation homework assignments. The three questions were:

1. If the goal of the mission is to do a lunar fly-by and someone proposed this mission, would you approve it? Why or why not?
2. If you were planning this trajectory, would you be worried about the lifetime of the spacecraft? Why or why not? What if the trajectory had the same altitude around Earth?

3. If the goal of the fly-by was to fly in-between Saturn's rings, would you have the spacecraft perform this fly-by? Why or why not?

The questions were evaluated on two dimensions: "correct answer" (yes/no recommendation) and "correct reasoning." The "correct answer" was marked as no answer, correct, or incorrect. If the student provided the correct "correct answer", the "correct reasoning" was evaluated as correct or incorrect. The three questions spanned the semester and increased in difficulty in tandem to the course concepts. As the questions became more difficult, the differences between students with high engineering intuition were expected to become more evident.

All collected student data was coded before being analyzed for correlations between correctness and/or reasoning (our measure of engineering intuition) and the following factors: learning styles, internship experience, overall homework grade, course grade, and overall GPA. Statistical analysis was done using JMP software. Despite a reasonable sample size, the low counts in contingency table cells required categorical variables (e.g., correct answer) to be analyzed using Fisher's Exact test. Continuous numerical variables (e.g., grade percentage) were analyzed through non-parametric one-way ANOVA or t-test.

Results and Discussion

Our aforementioned results from previous work, completed between Fall 2015 and Spring 2017, are available in previous publications [12, 13]. In the most recent semester of study, we again saw trends with internship experience, as well as course grade. Interestingly, there was at least one statistically significant trend observed on each problem.

The first problem, which comes early in the semester and is therefore the "easiest" problem of the three, showed positive correlations between correct reasoning and overall grade in the course at an α of 0.10 ($p = 0.045$). Students who provided the correct answer, followed by the correct reasoning, had higher final course grades (average 90.7%) than students who provided the correct answer but faulty reasoning (84.3%). Interestingly, students who had the wrong answer had higher final grades than those with faulty reasoning (88.3%).

On the second problem, we saw a very similar trend with correct reasoning again showing a correlation with final overall grade ($p = 0.0675$). Students who had the correct answer and reasoning for problem two had similar final grades to students who had the wrong answer (90.4% and 89.6%, respectively). Students who had the correct answer, but incorrect reasoning, had final grades that were lower than the other groups (86.4%). Seeing this trend twice suggests that the ability to justify the reasoning behind an answer is perhaps more closely linked with mastery (as determined by final course grade) than the initial ability to judge answer feasibility.

Lastly, on the third problem, students with internship experience were more likely to get the problem wrong, both with respect to answer ($p = 0.042$) and reasoning ($p = 0.087$). While this is initially surprising, most of the internship experiences of the students in this course suggest an interest area (aircraft) that does not align with the course (orbital mechanics), and thus, they may be less intrinsically motivated to succeed, particularly on difficult problems near the end of semester.

Conclusions

Our results indicate several interesting factors may be at play in developing student intuition. We have seen that internship experience and GPA correlate with strong engineering intuition, and we have recently also seen some correlations with course performance. The latter suggests that other factors, including student interest in the course/course material and intrinsic motivation, may play an important role in interpreting our data and eliminating possible confounders. At this time we cannot comment on what these correlations mean, as internship experience and GPA may each house a number of other factors, experiences, and influences. We do, however, believe this preliminary work suggests an interesting phenomena that merits further study.

Future Work

For the next phase of this work, we will conduct a larger-scale study of engineering intuition that will propel us towards developing classroom interventions for "teaching" intuition. In this phase, we seek to gather data from large sample sizes that provide strong evidence for possible trends.

We recognize that our current methodology is not feasible for a larger-scale study implemented by course instructors nationwide, as it requires work on the part of the instructor. We are developing standardized problems and an accompanying questionnaire that can be easily integrated as a homework problem in the appropriate course(s). We will use online data collection, and point-of-collection consent, to minimize any work for the course instructor.

To further support standardization, we will not be using previous simulation tools such as GMAT but rather are developing simulation tools that can be run on software commonly used by engineering students, such as Excel and MATLAB. Students will first take an online survey collecting information such as institution, gender, GPA, major, class year, career goals, internship experience, and interest in the subject matter. The students will then be prompted to complete simple calculations for the simulation problem and given the simulation file to download and run. After students input these values into the simulation, they will be prompted with a previously tested "stretch" problem for which they will be asked to provide an answer and justification. We will run similar data analyses as in our previous work, with the exception that we anticipate not needing to use Fisher's Exact Test as the sample size will be larger. We plan to test this simulation tool in the fall of 2018 with our own classes to ensure there are no user-interface issues, and then roll-it out to selected universities in Spring 2019.

We intend to use the results from this larger-scale study to more confidently identify experiences that are correlated with high engineering intuition. We recognize that experiences are non-standard across individuals, even individuals at the same institution, and thus "high overall GPA" may not hold the same meaning from one student to the next. However, we believe with a large sample size and careful attention to confounding and blocking variables we will develop valuable insight into engineering intuition development without intervention. We will then turn our attention to better understanding these experiences and factors that are shared among high intuitors, and what attributes within them contribute to development of engineering intuition. This information will propel us into the development of curricular and classroom interventions that provide opportunities to foster engineering intuition in all students.

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