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The Role of Knowledge Structure, Knowledge Retention, and Misconceptions in Open-ended Biomedical Engineering Design Problems (Work in Progress)

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Hannah Yssels is a third year biomedical engineering student at UC Davis, specializing in medical devices. She is currently a research assistant to Jennifer Choi, PhD, investigating problem solving performance and thedevelopment ofdesign thinkingskills in biomedical engineering. She has also assisted in the Heinrich Lab, researching the characterization of monocyte membrane protein populations. Hannah is a two-time finalist in the UC Davis Biomedical Engineering Society's Make-a-Thon medical device design and prototyping competition.

Dr. Marina Crowder, University of California, Davis

Marina Crowder is currently Teaching Faculty in the Department of Molecular and Cellular Biology at UC Davis. In addition to teaching core undergraduate courses, Marina is aimed at understanding how to better support the development students' problem-solving skills. She has interests in graduate student teaching professional development, effective supplemental instruction models at the upper-division level, and improving the success of transfer students in STEM. Prior to joining UC Davis, Marina taught at Laney Community College and was a postdoctoral fellow in the laboratory of Dr. Rebecca Heald in the Molecular and Cellular Biology Department at UC Berkeley. She received her doctoral degree in Biochemistry, Molecular, Cellular and Developmental Biology and B.S. degree in Genetics, both from UC Davis.

Dr. Ozcan Gulacar, University of California, Davis

Dr. Gulacar has a Master's degree in Physical Chemistry and a Ph.D. in Science Education. In the last 15 years, he has worked in settings including international high schools and doctorate granting institutions. He has designed and taught undergraduate/graduate chemistry and science education courses for a wide range of audiences. Due to his interest in investigating the effectiveness of different teaching methods and tools, he has received grants and established collaborations with colleagues from different fields and countries. Dr. Gulacar has developed and organized workshops about implementation of social constructivist methods and effective use of technological tools in science classrooms.

Dr. Jennifer H. Choi, University of California, Davis

Jennifer Choi is currently a Lecturer with potential for security of employment (LPSOE) in the Department of Biomedical Engineering (BME) at UC Davis. In addition to teaching core undergraduate courses, Jennifer is aimed at integrating engineering design principles and hands-on experiences throughout the curriculum, and playing an active role in the senior design course. She has interests in engineering education, curricular innovation, as well as impacting the community through increased K-12 STEM awareness and education. Prior to joining UC Davis, Jennifer taught in the BME Department at Rutgers University, and was a postdoctoral fellow at Advanced Technologies and Regenerative Medicine, LLC. She received her doctoral degree in Biomedical Engineering from Tufts University, M.S. degree from Syracuse University, and B.S. degree from Cornell University.

Works in Progress: The role of knowledge structure, knowledge retention and misconceptions in open-ended biomedical engineering design problems

Introduction

The need to build problem solving skills in STEM undergraduates has been widely reported[1]. In biomedical engineering specifically, the application of problem solving skills to engineering design problems is especially desired. This is due to both the increasing demand from industry as well as the growing expectation that biomedical engineers will continue to play a significant role in the growth and innovation of new biomedical technologies[2]. Significant curricular efforts have been made to strengthen these skills throughout our department's undergraduate experience, which includes both paper-based and prototype-based design activities centered on the engineering design process[3]. The impact of these efforts however on the development and use of problem solving in the context of design, or design thinking skills, has yet to be determined.

This Works in Progress paper seeks to provide additional insight into the role of knowledge structure, knowledge retention, and misconceptions in solving open-ended biomedical engineering design problems. Correlations in problem solving performance to level of metacognitive awareness will also be assessed. As part of a larger multidisciplinary study, we seek to develop a model for undergraduates' STEM problem solving performance that will serve as a tool to guide support of students' problem solving skill development.

Goals and Research Questions

The overall goals of this study are to (1) analyze students' problem solving work in detail to develop a model that accurately reflects why and how students have difficulty with problem solving in biomedical engineering design and (2) determine correlations between knowledge retention and metacognitive awareness with problem solving success.

The following research questions will be addressed:

1. How are problem solving schemas developed and used by students in biomedical engineering? How do these schemas differ for high and low performing students?
2. How do students' problem solving abilities change during and throughout STEM courses?
3. How are students' misconceptions related to knowledge retention and their mistakes with connecting different parts in problem schemas?
4. How is a students' metacognitive awareness related to success in biomedical engineering design problem solving?

Methods

Study participants were enrolled in a first year introductory biomedical engineering (BME) course that introduced the field through BME specialization introductory lectures, prospective

BME career guest lectures, and team-based hands-on design challenges. This two unit course consists of one 50 minute lecture and a 3 hour discussion session focused on engineering design each week of a 10-week quarter. There were 142 students enrolled in this introductory course.

Study data collection occurred during two subsequent quarters, as illustrated in Figure 1. All study participants were enrolled in the same lecture, however may have attended different discussion sections (led by a teaching assistant) during the first quarter. To gather a baseline of students' design knowledge, the Comprehensive Assessment of Design Engineering Knowledge (CADEK) diagnostic test[4] was administered to students in the first and last week of class. Students were also asked to complete an online Metacognitive Awareness Inventory (MAI)[5] during week 2. In addition to the CADEK and MAI, students answered an open ended design problem on their first quiz (in Week 5), from which ten high performing and ten low performing students were identified and asked to participate in one hour think aloud interviews (TAInt). TAInt were conducted between weeks 7 and 10 of the quarter and participants were encouraged to speak through their thought processes while asked to solve three open ended BME design problems. To assess levels of design knowledge retention, participants were also asked to participate in a second round of TAInt in the following quarter utilizing the same open ended design problems. Participants may or may not have been enrolled in classes containing engineering design principles during the second quarter.

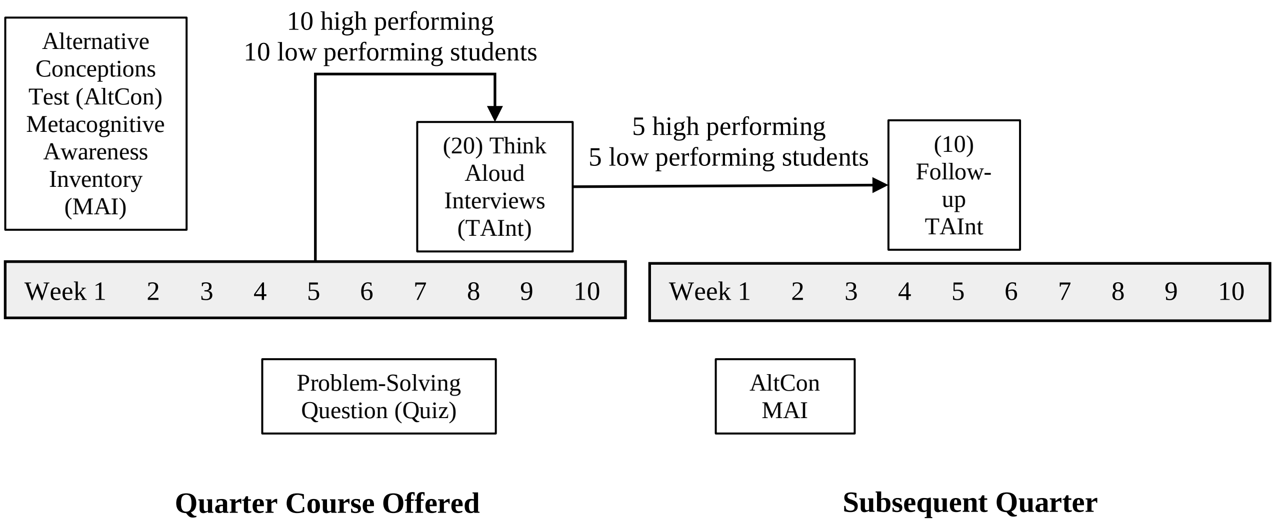

Figure 1. Timeline for study data collection.

Analysis

A thorough analysis will be conducted to provide insight into students' problem solving abilities in biomedical engineering design (Figure 2). Several developed instruments will be utilized to analyze the open ended design problems from quiz 1 and transcribed TAInt. The COSINE (Coding System for Investigating Sub-problems and the Network) method in particular, is an in-depth analysis of the difficulties students have during the problem solving process[6]. This method has previously been shown to reveal difficulties that students encountered in stoichiometry problems that might have been missed had an analysis focused on end results only been conducted[6]. In order to utilize the COSINE method, sub-problems that correlate with specific steps of the engineering design process will be identified, and will form the basis for a problem solving schema. For each transcribed TAInt, identified sub-problems will be assigned a code based on how the student performed in a particular step of the design process. Quantitative metrics such as the overall attempt success rate and total success rate will be developed based on resulting codes to gain insight into where and why students are unsuccessful. Statistical analyses will be performed to further understand how students performed on each design task, or sub-problem, how students moved from one sub-problem to the next, and common difficulties among all study participants. Additionally, as previous studies report students' improved problem solving skills when metacognitive analysis is performed[7], the MAI and CADEK results will be assessed in conjunction with the quantitative metrics generated to further assess the role of metacognitive awareness and design knowledge on problem solving performance. This will further expand our understanding of the problem solving process from both knowledge and metacognitive perspectives. Follow-up TAInt will also be analyzed using the COSINE method to assess level of design knowledge retention.

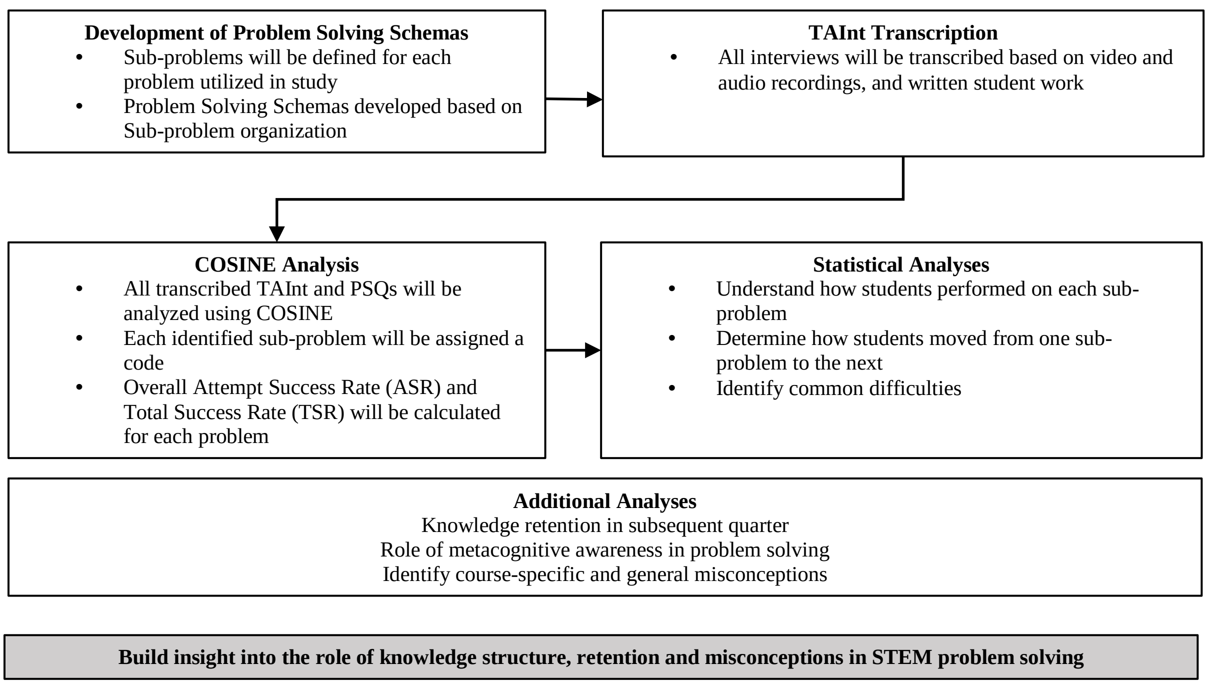

Figure 2. Summary of analysis methods.

Implications

Assessing study participants over the course of the BME undergraduate curriculum will also provide insight into strengths and areas for improvement of design instruction across the curriculum. Ultimately, the data collected from this study will be used to better understand current knowledge structure and retention in students to guide development of current and new curricular and co-curricular practices. Quantitative data generated from this project will also serve as a seed for developing a long-term collaborative study to identify common barriers in problem-solving abilities across undergraduates in STEM, improve our understanding of the processes students experience in problem solving, and determine, develop, and analyze effective approaches for building problem solving abilities and improving understanding in STEM.

Literature Cited

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