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CAREER: Students' Perceptions of Problem Solving Driven by Motivations Across Time Scales

Dr. Lisa Benson, Clemson University

Lisa Benson is an Associate Professor of Engineering and Science Education at Clemson University, with a joint appointment in Bioengineering. Her research focuses on the interactions between student motivation and their learning experiences. Her projects involve the study of student perceptions, beliefs and attitudes towards becoming engineers and scientists, and their problem solving processes. Other projects in the Benson group include effects of student-centered active learning, self-regulated learning, and incorporating engineering into secondary science and mathematics classrooms. Her education includes a B.S. in Bioengineering from the University of Vermont, and M.S. and Ph.D. in Bioengineering from Clemson University.

Adam Kirn, University of Nevada, Reno

Adam Kirn is an Assistant Professor of Engineering Education at University of Nevada, Reno. His research focuses on the interactions between engineering cultures, student motivation, and their learning experiences. His projects involve the study of student perceptions, beliefs and attitudes towards becoming engineers, their problem solving processes, and cultural fit. His education includes a B.S. in Biomedical Engineering from Rose-Hulman Institute of Technology, a M.S. in Bioengineering and Ph.D. in Engineering and Science Education from Clemson University.

Ms. Catherine D. McGough, Clemson University

Catherine McGough is currently a graduate research assistant in Engineering and Science Education at Clemson University. She obtained her B.S. in Electrical Engineering from Clemson University in 2014. Her research interests are in undergraduate engineering student motivations and undergraduate engineering problem solving skill development and strategies.

Courtney June Faber, Clemson University

Courtney Faber is a graduate student in the Department of Engineering and Science Education at Clemson University and a National Science Foundation Graduate Research Fellow. She holds a B.S. in Bioengineering from Clemson University and a M.S. in Biomedical Engineering from Cornell University.

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Abstract

This research seeks to help educators understand factors that contribute to engineering students' motivation and the relationship between those factors and their problem solving processes. Understanding these relationships will address the challenge of preparing students for a future of complex problem solving in the face of rapid technological change and globalization. This project addresses these research questions: What motivational attributes that characterize engineering students are relevant to their problem-solving skills and knowledge transfer? How do these relationships differ between engineering disciplines?

The focus of this paper is on the second phase of a three-phase project, which provides a detailed analysis of the relationship between students' future time perspectives (FTP) and knowledge transfer when solving an open-ended engineering problem. Interviews (n=9) were conducted with second year engineering students about their FTP characteristics (perceptions of the present, the future, and the interaction between the two). Interviews also explored students' perceptions of engineering problems and their approaches to solving them. Directed content analysis was applied, and data revealed distinct types of FTP characteristics. In general, students with well-developed future perceptions and who see connections between their future and present seek relevance and structure in problems they solve. Students with vague or broad future perceptions seek to create, explore, and help others.

Relationships between student motivation towards their future careers and the actions they take in the present can be used by educators to increase interest in engineering and prepare students to become effective engineers. We are in the process of further developing our quantitative assessment of engineering student motivation factors that are relevant to problem solving skill development. This assessment would allow educators to document outcomes of innovative approaches that present students with open-ended problems like those they will encounter in the future. The third and final phase of the study comprises a longitudinal study of changes in student motivation and problem solving practices over time.

Introduction

Student motivation is a major factor in the development of metacognitive and problem solving skills. A key factor in student motivation is their perceptions of their future possible selves, which are also linked to cognition and perceptions of themselves in the present.[1-2] Understanding factors that contribute to students' Future Time Perspectives (FTP), such as expectations, values, and goals, as well as their metacognitive and cognitive attributes, will help engineering educators prepare students for solving complex, open-ended problems such as those they will face in a future of rapid technological change and globalization.

The study presented here is part of a larger, multi-phase mixed methods study, the goals of which are to answer the following research questions:

- RQ1: What factors contribute to students' motivation to pursue engineering?
- RQ2: How do motivational attributes correlate to learning and cognition in engineering, especially problem-solving and knowledge transfer?
- RQ3: How do motivational attributes change over time as knowledge, experience and skills in one's field develop?

- RQ4: What relationship, if any, do the particular aspects of bioengineering (BioE) and mechanical engineering (ME) have to motivation, learning and cognition in those disciplines? How do these relationships compare between the two disciplines?

The focus of this paper is on the qualitative study that addresses RQ2: the interactions between student motivation and students' perceptions of problem solving.

The theoretical framework of FTP served as the basis for the study of factors contributing to students' motivations towards their futures, their perceptions of their present tasks in their engineering studies, and the interactions between the two.[1-2] To explore how students conceptualized problem solving, Rebello's theoretical framework on dynamic transfer was applied.[3] This framework takes into account four elements of dynamic transfer: external inputs, tools, answers, and workbench. "External inputs" refer to information from another person, text, pictures, or video, and facilitate students accessing their own resources, or "tools". "Tools" are what the student uses to understand the problem, and include a wide variety of objects or ideas (e.g. diagram or equation), and can be fabricated, target, or source tools. Fabricated tools are aspects of the student's own work, even in a previous part of the same problem, that are used later during the problem solving process. Target tools are aspects of the problem statement being utilized by the student, and since they are presented from an external source, every target tool is also an external input. Source tools come from pre-existing knowledge or experience. "Answer" refers to a stopping point which can be either decisive or indecisive. "Workbench" is where external inputs and tools are utilized together, and includes mental processes such as metacognition, decision making, mathematical operations, or inductive and deductive reasoning.[4] Workbench is characterized by metacognitive activities, which can be characterized as metacognitive knowledge and metacognitive regulation.[5] Metacognitive knowledge includes knowledge of persons, tasks, and strategies. Metacognitive regulation includes planning, monitoring, control and evaluation.

Methods

Interviews were conducted with second year students in bioengineering (BIOE) and mechanical engineering (ME) at a southeastern land grant institution. The first part of the interview revealed themes that allowed us to construct motivational profiles of students' future goals in terms of their possible selves and Future Time Perspectives.[6] In the second part of the interview, students were asked about their perceptions about solving problems in terms of their objectives and perceived instrumentality (i.e. how useful problem solving is to their future career).

Coding of the second part of the interviews was completed by one of the authors using directed content analysis. This method allows for initial a priori coding followed by emergent coding to identify codes and themes that were not represented in the initial coding. [7] A priori codes were developed based on existing theories on problem solving.

Results and Discussion

Through our interviews with second year engineering students, we are visualizing students' future perceptions as different shapes of ice cream cones, with the wide end representing the present and the tip representing the future.[4] These interviews also explored students' perceptions of engineering problems and their approaches to solving them. Students with highly defined goals and specific career plans beyond graduation are visualized as "sugar cones": relatively narrow and coming to a well-defined point. They value working on well-defined problems, and approach those problems in a linear, sequential fashion. The "waffle cone" student – wide at one end and narrowing at the tip - has a defined but broad range of possible future selves, and perceives many different current experiences as being instrumental to his future. The student with vague or unclear notions of her future is visualized as a "cake cone", truncated to represent the lack of definition beyond graduation. "Cake cone" students describe engineering problems as being "anything", tend to focus on concepts rather than a step-by-step approach to solving them, and do not see connections between their future selves and what they are doing in the present.

Students' perceptions of problem solving may actually be driven by their motivations across time scales. But not all students see the connections between their futures and the work they are doing in their courses. This work suggests that engineering educators should incorporate students' perceptions of the future into their teaching. As students' future perceptions become well-developed, they need context and relevance to value tasks and problems. Students with vague or broad perceptions of their futures describe their desire to create, explore, and help others. Developing problems and projects that allow room for exploring different fields of engineering may help these students focus on important concepts within those assignments.

Future Work

We have conducted a second interview with all of our participants in which they were asked to solve a complex, open-ended problem in a context that was new to them, which required them to transfer knowledge gained in previous learning environments to new situations. Students had unlimited time to complete the problem, which applied statics concepts in a cell biomechanics context took, and took between 25 and 45 minutes to solve it. The interview took place immediately thereafter, and lasted about 30 minutes. The interview was structured as a teaching interview, beginning with general questions about the problem, followed by prompts to walk the interviewer through their solutions, explaining their thought processes and working through any stopping points or questions. Students were prompted to think about new information that they may not have previously considered. These problem solutions and interviews have been coded using an a priori coding scheme previously developed by the author to identify problem solving processes and strategies.[8] While no connections were found between students' FTP characteristics and their problem solving processes and strategies,[9] our future work includes examining students' problem solutions for evidence of knowledge transfer.[3]

We will continue to conduct similar interviews with second year students to further explore and verify our current findings. We will continue testing and broadening the implementation of the motivation survey developed in the first phase of this study to answer RQ1, namely identifying factors of engineering student motivation that are relevant to their problem solving practices.[10] We are implementing the survey to different engineering student populations to broaden our findings to populations of under-represented minorities and other groups defined as diverse in different, non-normative ways. We are expanding our mixed methods study to further test the theories we are developing, and explore how engineering students' epistemic beliefs (i.e., what does it mean to know something in engineering?) affect their problem solving practices. In the next year, we will focus on completing a large portion of the longitudinal study by doing follow up surveys and interviews with students who took the motivation survey as first year students 1 and 2 years ago.

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