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Board 383: Self-Regulation of Cognition and Self-Regulation of Motivation in Problem Solving

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Self-Regulation of Cognition and Motivation in Problem Solving

Abstract

This work-in-progress paper shares findings of the early stage of a 3-year research funded by the National Science Foundation. The major aim of the project is to advance engineering and mathematics (EM) education theory and practice related to students' self-regulation of cognition and motivation skills during problem-solving activities. The self-regulation includes students' metacognitive knowledge about task (MKT) and self-regulation of cognition (SRC). The motivational component of self-regulation (SRM) includes self-control of the motivation needed to maintain the level of engagement and deliberate practice necessary for scientific thinking and reasoning. To be effective problem-solvers, students must understand the relationship between the MKT, SRC and SRM throughout the problem-solving activities.

Four research questions will guide the research: (1) How do students perceive their self-regulation of cognition (SRC) and motivation (SRM) skills for generic problem-solving activities in EM courses; (2) How does students' metacognitive knowledge about problem-solving tasks (MKT) inform their Task interpretation?; (3) How do students' SRC and SRM dynamically evolve?; and (4) How do students' SRC and SRM reflect their perceptions of self-regulation of cognition and motivation for generic EM problem-solving activities?

A sequential mixed-methods research design involving quantitative and qualitative methods are used to develop complementary coarse- and fine-grained understandings of undergraduate students' SRC and SRM during academic problem-solving activities. Two 2nd year EM courses: Engineering Statics, and Ordinary Differential Equations were purposefully selected for the contexts of the study. One hundred forty two students from both courses were invited and participated in quantitative data collection using two validated surveys during spring 2022 semester. Later in the semester, qualitative data will be generated with twenty students in both courses through one-on-one interviews with students and course instructors, think-aloud protocols with students, and classroom observations.

Coarse-grained understandings of students' SRC and SRM are currently developed through analysis of quantitative data collected using self-report surveys (i.e., BRoMS and PMI). Fine-grained understandings of students' SRC and SRM will be developed through analysis of qualitative data gathered via one-on-one interviews, think-aloud protocols, classroom observations, and course artifacts gathered as students engage in EM problem-solving activities.

I. Introduction

Understanding the problem-solving process has implications for Science Technology Engineering Mathematics (STEM) education. Research has shown that many STEM students graduate with discernible gaps in problem-solving skills. These gaps are caused, in parts, by specific cognitive processing (e.g., [1]) and motivational regulation (e.g., [2]) challenges that students face during problem-solving activities. In In our preliminary study, we found that reviewing the solution after engaging in problem-solving activities did not significantly improve students' understanding of the problem-solving tasks, especially when they were solving problems that were considered to be difficult (e.g., [3]).

Much still remains to be investigated, particularly in 2nd year EM education, related to how and why students initiate cognitive processes in task interpretation and regulation of motivation. In mathematics education, for example, researchers have reported that students struggle with the concepts of ratios and proportions [4] and functions (e.g., [5]). Researchers do not clearly grasp the type of conceptual difficulties students encounter in mathematics courses such as Ordinary Differential Equations (ODE), or how their motivations contribute to those difficulties. In engineering education, researchers have reported that students often fail to access the knowledge required to solve engineering problems (e.g., [6]) and to enhance motivation during problem-solving activities [7].

This three-year project aims to advance engineering and mathematics (EM) education theory and practice related to students' self-regulation of cognition and motivation skills during problem-solving activities. The self-regulation includes students' metacognitive knowledge about task (MKT) and self-regulation of cognition (SRC). The motivational component of self-regulation (SRM) includes self-control of the motivation needed to maintain the level of engagement and deliberate practice necessary for scientific thinking and reasoning.

II. Brief Relevant Literature Review

In the literature, problem solving is simply defined as an effort to bridge the problem space to the solution space (i.e., all feasible solutions that satisfy a particular problem). To be effective problem-solvers, students must understand the relationship between task characteristics and associated processing demands, and maintain positive motivation throughout the problem-solving activities. First, personal knowledge about the problem-solving task is known as metacognitive knowledge about task (MKT) [8]. The MKT that students develop helps them interpret tasks, and to bridge the gap between mental representations of the problem and effective solution strategies. Second, the ability to control motivation, thoughts and actions to effect accurate problem solving is also an essential component of SRL (e.g., [9]) and serves to increase student persistence during problem-solving activities [10]. Low motivation during problem-solving tasks influences students' affective states (e.g., frustration, disappointment) [11] and may eventually lead to poor academic performance [12]. Consistency in students' use of self-regulatory processes, both cognitively and motivationally, is highly correlated with student achievement during problem solving [13].

When students engage in problem-solving tasks, they are influenced by their personally held metacognitive knowledge and motivational beliefs. Flavell [14] defined three types of metacognitive knowledge: person, task, and strategies. "Person" encompasses everything that learners believe about the nature of themselves and other people as cognitive processors. "Task" and "strategies" refer to the information that leads to learners' understanding of the task demands (i.e., goals), and strategies to achieve those goals, respectively. The three types of metacognitive knowledge influence students' approaches to academic work. Tasks, which refer to "problems" in our research project, can be defined in terms of three interrelated characteristics: task purpose, task structure, and task components. Task purpose refers to students' perceptions about the underlying reasons for solving the problem; task structure refers to students' perception about categorization of information presented in the problem; task components refers to students' perception about the required steps, subtasks, and processes to be undertaken in order to solve the problem. As problems vary in nature and in the way they are presented (i.e., from well- to ill-structured, simple to complex, and low- to high-dynamicity), such challenges require different levels of productive metacognitive knowledge about tasks reflective of purpose, structure, and components.

Students' active and reflective coordination of cognitive processes in light of metacognitive knowledge and metacognitive regulation strategies, is called self-regulation of cognition (SRC) [8]. In this study, self-regulation of motivation (SRM) is defined as students' conscious control over their motivations. Because problems vary in content, composition, and representation, (i.e., simple to complex, well- to ill-structured, and/or low to high problem dynamicity) [15], the challenges that students encounter as they develop and link MKT to SRC and SRM represent critical obstacles to their development as effective problem solvers.

III. Purpose, Goals, and Significance

A. Purpose

The purpose of this project is to understand (1) how students' self-regulate their cognition and motivation, and how those regulation processes dynamically evolve over time during EM problem-solving activities; (2) how students' MKT informs their self-regulation of cognition (i.e., interpreting tasks, planning, enacting, monitoring, and evaluating processes) while solving EM problems of varying levels of difficulty; and (3) how students' SRC and SRM may be enhanced in the context of EM problem-solving activities through developing SR-infused problem-solving practice.

B. Objectives

The objectives of this project are to: (1) advance the knowledge of students' use of self-regulation during problem-solving activities in EM academic settings; (2) assist EM educational practitioners in structuring problem-solving activities and learning environments that support students' self-regulation habits; and (3) bring together content experts and curriculum developers from EM disciplines to discuss and initiate improvement of students' problem-solving skills through the practice of self-regulation.

C. Significance

This project is expected to make three significant intellectual contributions. First, findings will broaden the limited knowledge about how students' metacognitive knowledge about task informs their cognitive and motivation self-regulatory processes in EM problem-solving activities. Second, because this research will develop, test, and implement new protocols to assess students' metacognitive knowledge about task and the strategies they use, lessons gleaned will contribute positively to future SRL-related studies in EM as well as in other fields such as the arts. Third, by working directly with EM faculty to derive implications of our findings and develop new SRL-promoting practices and tools, this project will simultaneously enable further research and advance problem solving.

IV. The Study

The innovations used in this study embody specific theoretical claims about teaching and learning, and help us understand the relationships among educational theory, designed artifacts, and actual practice. The value of using this approach will be measured by its ability to improve educational practice. This project comprises of three components.

1. Component 1: Development, Field-Testing, and Refinement of Data Collection instruments for Qualitative Research

The expected outcome of component 1 is a well- developed and tested suite of data collection instruments to be used during qualitative research. It consists of two major activities: (1) development, field-testing, and refinement of all instruments for qualitative data collection; and (2) development, field-testing, and refinement of the problems to be solved by student participants during think-aloud protocols. These instruments and problems will be used in Component 2.

2. Component 2: Mixed-method Research Data Collection and Analysis

The expected outcome of Component 2 is the advancement of the knowledge base related to students' use of self-regulation during problem-solving activities in two EM academic settings: engineering statics and ordinary differential and linear algebra courses. A mixed-method sequential triangulation design [16] was used to "confirm, cross-validate, or corroborate findings within a single study" [p. 215]. In this research design, quantitative data will be collected at the beginning of the semester, and qualitative data will be collected starting a few weeks after that. Thus, data in this study will be collected during a single semester for each EM course. Coarse-grained understandings of students' SRC and SRM will be developed through analysis of quantitative data collected using self-report surveys (i.e., Brief Regulation of Motivation Scale, BRoMS and the Physics Metacognitive Inventory, PMI). Although PMI was initially designed for Physics, it can be used to assess students' metacognition for problem solving in other knowledge domains by simply revising the word "physics" to other domain knowledge [17]. Fine-grained understandings of students' SRC and SRM will be developed through analysis of qualitative data gathered via one-on-one interviews, think-aloud protocols (TAP), classroom observations, and course artifacts gathered as students engage in EM problem-solving activities.

Four research questions will guide the research:

1. How do students perceive their self-regulation of cognition (SRC) and motivation (SRM) skills for generic problem-solving activities in EM courses?
2. How does students' metacognitive knowledge about problem-solving tasks (MKT) inform their SRC processes (i.e., task interpretation)?
3. How do students' SRC and SRM dynamically evolve?
4. How do students' SRC and SRM reflect their perceptions of self-regulation of cognition and motivation for generic EM problem-solving activities?

While the first research question develop coarse-grained understandings of students' SRC and SRM during academic problem-solving activities, the second and third research questions is intended to develop fine-grained knowledge of students' SRC and SRM while engaged in specific problem-solving activities. The fourth research question compare the results of coarse (quantitative) and fine-grained (qualitative) SRC and SRM data analyses.

One hundred forty-two students were recruited to participate in the quantitative data collection and 20 students among them were recruited to participate in the qualitative data collection. Participants for the qualitative research were purposefully selected from pool of students with high SRM (i.e., at least M+1SD) and low SRM (i.e., not more than M-1SD) identified during the quantitative research. Quantitative data collected from both instruments will be analyzed through descriptive and ANOVA tests. The qualitative data collected from the interview and TAP, and written notes, and the participant artifacts will be analyzed through constant comparative analysis (CCA) methods [18]. Data analysis is currently in progress.

5. Component 3: Integration of Self-Regulation within STEM Courses

The expected outcome of Component 3 is students' effective problem-solving experiences through SR infusion. Integration efforts are divided into three kinds of activities (i.e., SR integration, workshop, and dissemination) with three distinct objectives.

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