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Work in Progress: Understanding Student Self-regulation During Engineering Problem Solving: A Preliminary Study

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After an undergraduate degree in Computer Information Systems, a Masters in Engineering Management coupled with 10 years of experience teaching design and problem solving to undergraduate level engineering students, I am currently pursuing my PhD in Engineering Education, at Utah State University, Logan, UT, USA. Currently, I am studying the course work as well as exploring existing literature with an initial focus on reading research and understanding Meta-cognitive processes and their interaction with the learners' self-regulation.

WIP: Understanding Student Self-Regulation during Engineering Problem Solving: A Preliminary Study

1. Introduction

Engineering students are trained to be effective problem solvers. Specifically, engineering students are expected to become skillful at synthesizing and applying information across multiple knowledge domains to generate optimal solutions to problems of varying levels of difficulty. Unfortunately, many engineering students graduate with discernible gaps in their problem solving skills. Research has attributed these gaps, in part, to specific cognitive processing challenges that students face during problem solving activities [1]-[10]. For example, Hadwin [4] and Lawanto et al. [6] [7] found that students exhibited incomplete or inaccurate task understanding during problem-solving activities. In fact, these researchers reported that many students did not realize that they lacked accurate task understanding, even after receiving feedback; and that students often failed to access a correct representation of knowledge required to solve problems [9]. moreover students did not always approach problem-solving activities as instructors intended [11, 12].

These findings suggest that students have difficulties (1) developing adequate and appropriate knowledge about problem-solving tasks and (2) linking that knowledge to the actions they take during problem-solving activities. For example, students often begin a problem-solving activity by generating thoughts and actions that are directed toward attaining the best solution to that problem. They may instantly consider application of a particular formula and then look for clues within the available information that matches the variables in the formula. To be effective problem-solvers, however, students must learn to construct accurate and appropriate understandings and knowledge about the relationships between task characteristics (i.e., purpose, structure, and components of tasks) and associated processing demands. This personal knowledge about the problem-solving task at hand is known as metacognitive knowledge about task (MKT) [13]. Ideally, the MKT helps students enact more effective self-regulation, particularly task interpretation processes. Students' engagement on a task as a whole, including their active and reflective coordination of cognitive processes in light of metacognitive knowledge, conceptions about problem-solving tasks and the context of academic work, is called self-regulation in action (SRA) [14].

2. Brief Relevant Literature Review

2.1. Problem Solving in Engineering Education

In the literature, problem solving is simply defined as an effort to bridge the problem space (i.e., the entire range of elements that exists in the process of finding a solution to a problem) to the solution space (i.e., all feasible solutions that satisfy a particular problem). Simon claimed that "solving a problem simply means representing it so as to make the solution transparent" (p. 153) [15]. This claim suggests that, as students engage in solving a problem they begin with thinking about what they know about the task, relevant concepts, knowledge, and strategies that are needed to solve the problem.

According to Jonassen and Hung [16], problem-solving tasks may be classified into a continuum based on the level of problem difficulty (i.e., from least to most difficult). Wood described difficulty as "a gauge of how likely the problem is going to be solved correctly or appropriately" (p. 46) [17]. Defining problem difficulty is a complex process [18]. Several internal factors, such as the level of students' domain knowledge, experience, and reasoning skills, and external factors (i.e., external to the student and endemic to the nature of the problem) contribute to problem difficulty. The level of difficulty of problems used in this study will be determined by three external factors: *structuredness*, *complexity*, and *dynamicit*y of problem [16].

There are three indicators used to assess problem structuredness: (1) the number of unknown aspects or elements in the problem [19]; (2) the number of possible methods or approaches to solve the problem [20]; and (3) the number of potential solutions for the problem [20]. Problem's complexity [21] is indicated by: (1) the number of issues, functions, or variables involved in the problem; and (2) the level of uncertainty about which concepts, rules, and principles that are necessary to solve the problem. Problems vary in their stability or dynamicity, which indicates the likeliness of needing continuous adaptability for understanding of the problem and searching for new solutions [22].

2.2. Metacognitive Knowledge about Task (MKT)

When students are engaged in academic tasks like problem solving, they naturally become involved in active and reflective coordination of learning processes (i.e., self-regulation) in light of their personally held metacognitive knowledge and motivational beliefs. Flavell [23] defined three types of metacognitive knowledge: person, task, and strategies. Metacognitive knowledge about person encompasses everything that learners might believe about the nature of themselves and other people as cognitive processors. Likewise, metacognitive knowledge about task and strategies refer to the information that leads to learners' understanding of the task demands (i.e., goals), and of strategies to achieve those goals, respectively. These three types of metacognitive knowledge influence students' approaches to academic work.

Tasks, which refers to "problems" in our research project, can be defined in terms of three interrelated characteristics: task purpose, task structure, and task components (Figure 1).

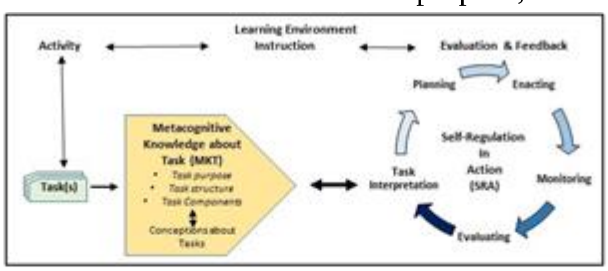

Figure 1. The interplay between MKT and SRA in a learning activity; adopted from Butler and Cartier (2004)

Metacognitive knowledge about task purpose refers to students' perception about the underlying reasons for solving the problem; Metacognitive knowledge about task structure refers to students' perception about categorization of information presented in the problem; Metacognitive knowledge about task components refers to students' perception about the required steps, sub-tasks, and processes that have to be undertaken in order to solve the problem. As problems vary in their nature and their presentation (or representation) from well- to ill-structured, simple to complex, and low to high-dynamicity problems, such challenges require different levels of productive metacognitive knowledge about tasks reflective of each of these three interrelated task characteristics (i.e., purpose, structure, and components).

Wong [24] argued that successful problem solvers are sensitive to task purpose. Skillful students draw on their metacognitive knowledge about task purpose when interpreting task requirements and then adapt learning activities responsively to match different purposes [12], [25]. Each task has its own underlying structure [13]. Problem task structure may (likewise) be described in terms of the solution detail, appropriateness (of assumptions and equations), logical flow (of problem solving steps), and accuracy (of mathematical procedures). Students' metacognitive knowledge about the structure of the problem influences how they interpret task demands. Besides task purpose and structure, effective students construct metacognitive knowledge about typical task components. Students' understanding of task components drives their selection of strategies. For example, when students are concerned about getting the best solution for a problem, they may select strategies for evaluating all the possible solutions.

2.3. Self-Regulation in Action (SRA) and Its Role in Problem Solving

While research shows that metacognitive knowledge about task is necessary for strategic task engagement, it is not sufficient. Strategic task engagement, rather, also requires the ability to self-regulate cognitive processes in light of the metacognitive knowledge about the task developed.

Self-Regulation in Action (SRA) also known as Strategic Action, is at the heart of models of self-regulated learning (SRL). SRA is comprised of iterative and recursive cycles of interpreting requirements, planning (e.g., resources, time, strategies), implementing cognitive processes, monitoring progress, evaluating progress against internal and external standards, and continually refining approaches so as to better achieve goals (see Figure 1) [26], [27]. Numerous studies have found that enhancement of SR abilities strengthens learning skills [28]-[36] and improves academic success [37]-[41].

From a metacognitive perspective, research describes SR as relying on both students' knowledge and beliefs about themselves and tasks (i.e., metacognitive knowledge), as well as their deliberate control over their engagement in activities (i.e., metacognitive control) [42], [43]. As students manage their activities in tasks, they engage in iterative cycles of strategic activity, including actively interpreting requirements, developing a plan of action, acting on developed plan, monitoring progress and results and adjusting approaches if necessary.

According to Butler and Cartier, the quality of students' self-regulation is influenced by multiple layers of context. Contextual influences are established by how activities are situated in a given country, state/province, school, or classroom, and linked to particular teachers, instructional approaches, curricula, and learning activities, including collaboration with peers. In engineering education, contexts include learning expectations in problem-solving courses, the nature of particular problems, and the expectations of the instructor. For example, studies reported that students adjust their problem-solving approaches based on the contexts surrounding the task [10], [44].

3. The Project

3.1. The Purpose and Anticipated Impacts

The purpose of this project is to (1) develop, field-test, and refine research protocols and tools to be used to study students' metacognitive knowledge about tasks (MKT) and their self-regulation in action (SRA) (i.e., Phase 1), and (2) develop a better grasp of collecting, analyzing, and interpreting a large amount of qualitative data associated with students' MKT, SRA, and students' learning contexts (i.e., Phase 2) during engineering problem-solving.

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

A case study approach was selected for this study because we are interested in looking for and describing detailed tracing of student's self-regulation processes in engineering problem solving (i.e., the "case") within context [45]. Students' self-regulation is iterative and influenced by details of their interaction with the contexts such as students' learning environment including faculty's instruction, and across courses and different level of problem difficulty (see Figure 1). We situate this study within the Fundamental Electronics for Engineers, one of several second-year engineering courses offered within the college of engineering at the western part of the United States. We will select 3 student volunteers for in-depth study. Purposeful sampling will be used in selecting the student participants for this research to include variability in terms of gender and major of engineering studies. Participation will be voluntary. Two research questions will guide the research: (1) How does students' metacognitive knowledge about engineering problem-solving tasks inform their self-regulation in action processes while engaged in problem-solving activities?; and (2) How do students' metacognitive knowledge about engineering problem-solving tasks and self-regulation in action dynamically evolve during problem-solving activities?

3.2. Data Collection and Analysis

Because this case study investigates a bounded system holistically, the research team needs to collect, assemble, and relate multiple kinds of evidence (i.e., contextual influences, conceptions about engineering problem-solving tasks, and students' MKT and engagement in SRA). We will gather evidence from variety of sources like self-reports (e.g., interview), students' thinking (i.e., Think aloud protocol or TAP) while solving problems, observations of classroom environment when class is in session, and documents/artifacts such as course syllabus, problem descriptions and solutions.

To answer the research questions, we will analyze the transcripts from the interviews and think aloud protocols using constant comparative analysis (CCA) methods [46], [47]. An approach for analyzing qualitative datasets through *coding*, CCA was initially developed in conjunction with well-known grounded theory methods [48], [49]. CCA was developed to provide systematic strategies for iteratively comparing qualitative data and constructing codes by defining and "actively naming the data" through careful interpretation of the participants' perspectives (p.115), [46]. At least two researchers will involve in this coding processes and achieve an acceptable interrater reliability (i.e., 90% or higher). We will conduct within group CCA (i.e., within each level of problem difficulty) by developing focused codes that define the relationships between participants' metacognitive knowledge about task and self-regulation in action (RQs 1 and 2) [50].

3.3. Current and Future Progress

Phase 1 of the project began with the development of research protocols and problem-solving tasks to be used to study students' MKT and SRA while solving engineering problems of varying levels of difficulty. In addition, we are recruiting three undergraduate students currently taking the Fundamental Electronics for Engineers course this spring semester. Near the sixth week of the semester (i.e., early March), students who are enrolled in Fundamental Electronics course will be invited to participate in the study in accordance with an approved protocol for research with human subjects. Phase 2 will be conducted in May and June.