Designing Engineering Tasks for Collaborative Problem Solving

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Abstract: Research indicates that engaging students in authentic collaborative problem solving activities can lead to increased learning and persistence in STEM. A major piece of these activities is the task. This paper describes the process of creating guidelines and using them to design three engineering tasks that support collaboration between undergraduate students. This process led to a four-step framework that can be used to design future tasks.

Introduction

Research shows that engaging students in authentic, collaborative problem solving can lead to increased learning and persistence in STEM fields (e.g. Barron & Darling-Hammond, 2008). However, although there has been an increase in the use of collaborative activities in STEM less attention has been paid to the development of tasks for those students. In our work (Mercier, et al., 2015), we found little change in collaborative practices during four weeks of collaborative problem solving in an introductory engineering course on statics. One issue we identified was that the tasks were highly structured, algorithmic, and did not provide many opportunities for students to collaborate; interactions were often limited to checking answers. To address this issue, the research team worked with faculty, teaching assistants, and students to create guidelines for designing new tasks that are ill-structured and authentic. The process of designing these tasks is described in this paper. The process consisted of five stages that led to a four-step framework that can be used to create future tasks.

Stage 1: Reviewing relevant research

Relevant research areas were reviewed to account for what is known about collaborative problem-based learning. The first was collaborative problem solving in engineering. Successful engineers are those who are prepared to solve workplace problems. Jonassen et al. (2006) conducted interviews with 106 engineers; the responses showed that workplace engineering problems are ill-structured, can be solved in different ways, and require extensive collaboration. This research, along with work in problem-based learning (Hmelo-Silver, 2004), indicates that tasks used in engineering courses should reflect the workplace problems by having multiple solutions with multiple solution paths. This characteristic makes these tasks challenging and appropriate for collaborative problem solving.

The second ares reviewed was dimensions that may influence the difficulty level of a problem-solving task. One important factor to consider when designing these tasks is the difficulty level. Jonassen and Hung (2008) identified complexity and structuredness as dimensions that determine the difficulty level of a problem-solving task. Parameters of the complexity dimension include the amount of domain knowledge needed to solve a problem, the difficulty level of comprehending or applying a concept, the number and complexity of the steps that constitute a solution path, and the number of the relations that need to be simultaneously processed (Hung, 2016). Parameters of the structuredness dimension includes the unknown portion of a problem space, the number of possible interpretations for understanding and solving a problem, interdisciplinarity, instability of the variables throughout the problem solving process, and legitimacy of competing solutions that exist within the problem space (Hung, 2016). The researchers used the parameters of complexity and structuredness dimensions to make decisions associated with setting the objectives and content of the tasks and to evaluate difficulty level.

Stage 2: Meeting with faculty and teaching assistants

The researchers met with engineering faculty to set the goals and objectives of the tasks in relation to the learning goals for the course. Discussing the goals and objectives helped in identifying the key concepts that were used to determine the content of the tasks. Then, the researchers met with the teaching assistants to write the tasks. These meetings focused on finding real-life applications of the key concepts to contextualize the content of the tasks so that they are similar to a workplace problem, with multiple solutions and multiple solution paths

Stage 3: Iterative design of one task with stakeholders

An iterative design method was used to create the first task. After selecting the content of the task and finding real-life applications of the key concepts, the researchers wrote the task with a teaching assistant. Multiple iterations of the task were worked through by the teaching and research team.

Stage 4: Testing the task with teaching assistants and student informants

To evaluate the task, one teaching assistant solved the task and provided feedback on its length, content, clarity, difficulty, and ability to engage students' in collaborative interactions. Another engineering graduate student worked through the task, using a think aloud protocol to provide the researchers with insight into difficulties encountered in both the language and framing of the task. Finally, two engineering undergrads, who had recently completed the engineering course, worked together on the task, while being observed by the research team. Alterations were made between each pilot test.

Stage 5: Creating a four-steps framework for future task creation

Finally, a four-step framework was developed and tested while creating two additional tasks. The final framework can be used to design tasks in other disciplines. The four steps are:

1) Setting goals and objectives of the task,
2) Finding real-life applications of the key concepts associated with the task,
3) Completing the task template presented in Table 1
4) Evaluating the designed task through pilot testing.

Table 1: Sections in the task template

Section 1	Introduction	A short story that contextualizes the problem in an authentic situation. It is based on the real-life application of the key concepts. It is usually supported by figures.
Section 2	The problem	A short description of the problem.
Section 3	Your task	A description of task(s) that students are expected to achieve in their groups in order to solve the problem in a specific time.
Section 4	Supplementary material	Numbers, figures, tables, and/or any other information that the group members may need to solve the problem.
Section 5	Tools	Scaffolding tools that the group members can use to write a plan and/or sketch any diagrams to solve the problem.

Conclusions and implications

One major piece of implementing collaborative activities is the task. Descriptions of the nature of these tasks and how they should look exist in the literature; however, a description of a detailed process for designing these tasks is rare. This paper described a process that was implemented to design engineering design tasks and create a framework for future use. The three tasks that were designed were used in a recent course; after using these tasks the teaching assistants decided to use the framework to create similar tasks for later weeks of the course, providing students with more opportunities for authentic collaborative problem solving and indicating a desire to use these types of tasks in future iterations of the course.

Acknowledgments

This work was supported by a the National Science Foundation (1441149).

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