

Board 50: WIP: Evidence-based analysis of the design of collaborative problem-solving engineering tasks

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Taylor Tucker graduated from the University of Illinois at Urbana-Champaign with a Bachelor's degree in engineering mechanics. She is now pursuing a master's degree at UIUC and will begin in the Digital Environments for Learning, Teaching, and Agency program in the department of Curriculum and Instruction in the fall of 2019. She is interested in design thinking as it applies to engineering settings and lends her technical background to her research with the Collaborative Learning Lab, exploring how to assess and improve ill-structured tasks for students in order to promote collaborative problem solving and provide experience relevant to authentic work in industry.

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WIP: Evidence-based analysis of the design of collaborative engineering tasks

Introduction

Ill-structured tasks are important in engineering courses because they are similar to the problems that students will encounter in their future work. These tasks are motivating and require collaboration because they stimulate problem-centered interactional activity [1]. The collaboration aspect is significant for engineering students because engineers typically do not work alone, and rely on input from other engineers and experts in various fields to arrive at an informed solution [2]. Research has examined how scaffolding tools in ill-structured problems affect student group work, but it is not clear how these tools or other aspects of the task design promote effective problem-solving processes, or how to ensure students engage effectively in those processes [3]. In this work-in-progress paper, we will describe a method to assess the effectiveness of the design of ill-structured tasks for collaborative problem solving.

The design and implementation of collaborative tasks in face-to-face engineering classrooms is challenging. Our ongoing design-based research project, Collaborative Support Tools for Engineering Problem Solving (CSTEPS) [4], [5] involves the design and implementation of collaborative ill-structured tasks using a research-based framework that outlines the necessary elements of such tasks: an introduction to the problem that provides context, a description of the problem itself, the specific task(s) students are expected to achieve as a group, supplementary material that provides information useful for solving the task, and scaffolding tools that students can use to develop plans, draw diagrams, and generate solutions [6]. This paper presents a method to evaluate the design of ill-structured tasks in relation to the interaction processes that students used in their groups. The paper showcases the use of our method by evaluating the design of one ill-structured task, and provides suggestions for improving its design.

Jonassen [7], building on work by Schön [8], notes that well-structured tasks require a search for a pre-determined solution, whereas ill-structured tasks can be thought of as a design process. Thus, solving an ill-structured task requires more than simply attempting to solve for a single correct answer. Ge's research [9] has shown that when working with peers, students must implement four interaction processes to effectively solve an ill-structured task: representing the problem (through exploration), planning and proposing solutions, attempting to solve (iterating plans and making justifications), and monitoring and evaluation (evaluating the solution and considering alternatives). To assess the design of ill-structured engineering tasks for collaborative problem solving, we have developed a method that is based on the presence and proportion of Ge's four processes. This paper identifies the processes implemented by groups of students as they solved an ill-structured task, and determines which aspects of the task design promoted those processes. Based on the findings, we will make suggestions to further improve the design of the task and comment on the overall takeaways for the design of any collaborative, ill-structured task. This study seeks to answer the following research questions:

- 1) What aspects of the task enabled students to effectively implement the processes necessary for solving ill-structured problems?
- 2) How can the task be improved to further promote the effective implementation of the interaction processes when solving ill-structured problems in groups?

Methods

Participants were 21 undergraduate students (6 females) from two 50-minute discussion sections that met weekly as part of an introductory engineering course at a large, public university. Groups of 3-4 students were assigned during the first week via software that minimized the isolation of any student minority. Skill levels of individual students were not controlled. Both sections took place in a laboratory classroom and were taught by the same graduate teaching assistant and two undergraduate course assistants. In both sections, groups solved the same ill-structured task. All task work was done within each section, and the task was not revealed prior to the discussion. The task was installed on 11" tablets. Tablets of students in the same group were synchronized. Data was collected from six groups (three from each section). These groups were chosen because they had each worked together on other ill-structured tasks without any changes to the group members in five previous discussion sections in the same classroom. Video and audio data were collected from ceiling-mounted cameras and table microphones.

The Task

The task was presented to students as a digital worksheet comprised of five sections: an introduction that defines beam deflection; a description of the problem (to design a pair of salad tongs that can lift one cherry using the cheapest wood); supplementary material that shows the model and dimensions of the tongs and information about three types of wood; a scaffolding tool that asked students to determine which wood would be the cheapest per unit for manufacturing the tongs and verify that their choice still allowed the tongs to function as specified; and a second scaffolding tool that required students to implement design changes that further lowered the unit cost of the tongs and then prompted them to evaluate the performance of their altered design.

Data Analysis

Based on literature, a framework was developed to define the four interaction processes in the context of our ill-structured task. From this framework, we developed a coding scheme (Table 1) that identified each process in verbal interaction, including both talk between at least two group members and interaction that takes place through the shared tablet space during one member's narration. For inter-rater reliability, two researchers coded 2 of the 6 videos; Cohen's kappa was .87.

Code	Definition	Example
Process 1 (P1): Problem Representation	Interactive turns in which students verbally explore the scope of the task. This can include communicating their understanding of the task (or lack thereof), elaborating on the task, identifying a plan for solving the task, and creating a joint representation of the task.	<i>Student 1: "I assume we don't have to take into account the weight of the wood or anything." Student 2: "No, we don't."</i>
Process 2 (P2): Proposing Solutions	Interactive turns in which students select a method or plan for solving by discussing choices and reasoning. This can include representing the problem in multiple ways.	<i>Student 1: "We should find the moment equation." Student 2: "Yeah, that makes sense because we need the moments to do the deflection."</i>
Process 3 (P3): Making Justifications	Interactive turns in which students make attempts to solve the task, alternative solution, or correction to the solution. This can include discussing or arguing about their chosen solution method and how to advance along the path to reach the final answer.	<i>Student 1: "Oh, this one should be plus C, and then this turns into PX plus C." Student 2: "Yeah, but those should be zero 'cause of the boundary conditions, right?" Student 1: "No, C1 was equal to something." Student 2: "But this has to equal zero because Y prime of zero is always zero."</i>

Process 4 (P4): Monitoring and Evaluation	Interactive turns in which students evaluate their solution and assess alternatives. This includes identifying errors in their solution and suggesting a method for correcting the errors, but does not include attempts to solve the corrections or alternatives.	<i>Student 1: "There are way too many variables in our answer." Student 2: "We can change P over H to 100."</i>
No Process (NP)	On-task, interactive turns that do not fit one of the four processes.	<i>Student 1: "It should be 6 Y prime...so then we will need to change this." Student 2: "That's a big equation."</i>

Codes were applied at the turn level first, then grouped into episodes; the majority of turn-level codes determined themes of episodes. A change in episode was indicated by a transition in the group's conversation from one type of talk to another, a pause in the conversation that lasted at least twenty seconds, or an interruption by a TA or other outside influence.

Results

As a result of our coding process, we achieved quantifiable turns for and measurable episodes of each of the four processes as they occurred in each group's collaboration. Fig. 1a shows the average number of turns for each process; Fig. 1b shows the average duration of each process. Both figures show that students' interactions included processes of representing the problem (P1), planning and proposing solutions (P2), and monitoring and evaluation (P4); however, the dominating interactions consisted of attempts to solve the task (P3).

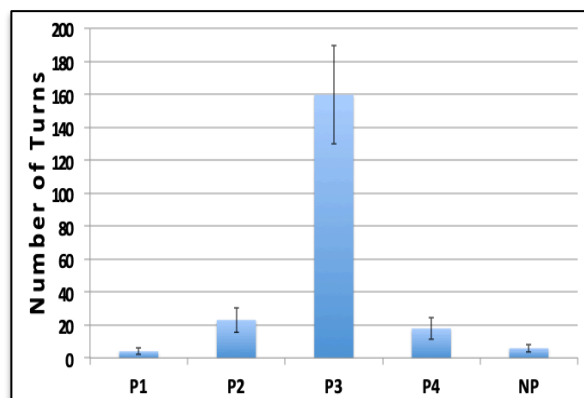


Figure 1a: Average Process Turn Codes

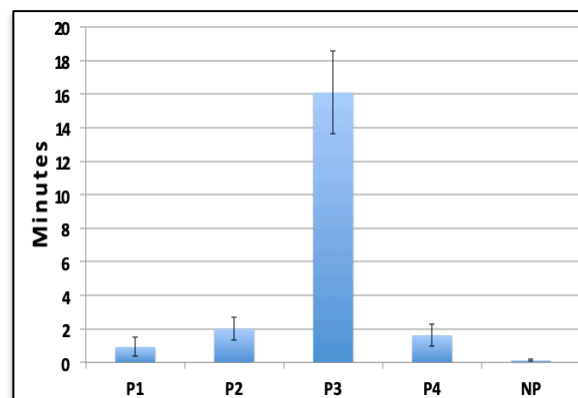


Figure 1b: Average Process Episode Durations

Discussion

The occurrence of representing the problem (P1) turns and episodes, as shown in Figs. 1a and 1b, suggests that the presence of the introduction, description of the problem, and supplementary material may have prompted the exploration of the task as showcased by one of the groups in excerpt 1, below. Nevertheless, the presence of these sections did not prompt students to explicitly discuss drawing a free body diagram (FBD), which we know from our framework is a characteristic of P1 [10]. To promote this, we suggest that the task contain an explicit prompt in the worksheet for groups to draw a FBD before proceeding. This can help students develop a joint representation of the problem, which can improve the quality of their interactions.

Excerpt 1 – P1:

Student 1: "I think we can just take the- no, we can't take the derivative of that, never mind."

Student 2: "Um, we can move to A."

Student 1: "I don't know where that's from."

Student 3: "It says E."

The occurrence of planning and proposing solutions (P2) turns and episodes (Figs. 1a and b) suggests that the groups discussed plans and solutions to solve the task as shown in excerpt 2. Research emphasizes the importance of planning by discussing relevant existing knowledge when solving an ill-structured task [7]. To further promote this process, we suggest modifying the design of the task so that it explicitly prompts the students to articulate the knowledge they have drawn upon by writing a summary of their plan and the reasoning behind it.

Excerpt 2 – P2:

Student 1: *“Isn’t the moment equation different? Before P and after P? Or we only need the second one, right? ‘Cause that’s where the cherry is?”*

Student 2: *“Yeah, there’s nothing happening after P.”*

Student 1: *“And I mean, like, don’t we need to solve for the moment equation after P but not before P- we don’t need it before P, I don’t think. Where’s the cherry being put?”*

Student 3: *“At P.”*

The first and second scaffolding tools asked students explicitly to evaluate the performance of the design they had generated, which prompted monitoring and evaluation (P4) as showcased in excerpt 3. However, the average number of monitoring and evaluation turns and the average duration of the corresponding episodes were very low compared to those of attempting to solve the task (P3). This suggests that prompts from the actual worksheet alone are not enough to ensure successful responses from students; teacher’s instruction is necessary to reinforce and incentivize the prompts.

Excerpt 3 – P4:

Student 1: *“We definitely made some assumptions.”*

Student 2: *“Yeah.”*

Student 1: *“But they’re not, like, outlandish.”*

Student 2: *“Yeah, and they’re based on logic, too.”*

Conclusions and Implications

This paper presented a method that can be used to evaluate the design of ill-structured tasks in relation to the interaction processes that students use in their groups as they solve the task. This method was used to evaluate the design of one ill-structured engineering task for collaborative problem solving, which was created following a research-based framework [6]. While design changes specific to the chosen task were suggested, the findings demonstrate scaffolding tools necessary for the design of any collaborative ill-structured task: for exploring the problem, a prompt for students to represent the problem in a joint diagram; for proposing solutions, a prompt for students to explicitly state the reasoning behind their planning; and for all prompts, teacher reinforcement is a necessary element. The four interaction processes necessary to effectively solve an ill-structured task are not normally achieved naturally in an engineering classroom setting; implementing these design changes will foster their increased occurrence. This study did not account for the effects of support provided by the teaching assistants to individual groups during the discussion. Future work should use this method to evaluate and improve the design of other tasks.

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