Using the Gini Coefficient to Characterize the Distribution of Group Problem-Solving Processes in Collaborative Tasks

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Abstract: Existing literature has outlined the processes necessary for problem solving of ill-structured tasks. These processes have been identified in groups' verbal interactions in the context of collaborative engineering tasks. In this paper, we present analysis using the Gini coefficient as a group-level measure of the distribution of the four processes as characterized by groups' verbal interactions. We use this coefficient to evaluate the design of two ill-structured tasks.

Introduction

Ill-structured tasks are important in engineering courses because they are similar to the problems that students will encounter in their future workplaces (Jonassen & Hung, 2008). Research on how to design ill-structured tasks for problem-solving exists (e.g. Hung, 2019); however, less is known about how to evaluate the design of these tasks as implemented in actual classrooms (Tucker et al., 2019). In the context of collaborative problem solving, one measure for evaluating ill-structured task design is to quantify the problem-solving processes through which students work to solve the task. These processes can be characterized by students' verbal interactions. Research has established that the quality of interactions is important for group work (e.g. Barron, 2003). Four problem-solving processes have been identified in the literature as necessary for effective collaborative ill-structured problem solving: exploring the problem (P1), planning how to solve (P2), attempting to solve (P3), and evaluating the solution and considering alternatives (P4) (Ge & Land, 2004). In this paper, we present a method to evaluate task design by comparing the distribution of these processes in students' verbal interactions to an idealized distribution.

The Gini coefficient is a group-level measure that sums the deviation of an experimental distribution of scores from a theoretical distribution. In an analysis of students' collaborative interactions, the Gini coefficient was established as an effective measure for evaluating quality of collaboration at the group level (Martinez-Maldonado et al., 2013). This paper proposes using the Gini coefficient as a group-level measure of the deviation of the distribution of the four problem-solving processes from an ideal distribution. This method is showcased through the evaluation of two ill-structured engineering tasks; one task included explicit scaffolds for all four processes, and one did not.

Methods

Data collection

Following a framework developed in our earlier work (Shehab et al., 2017), both tasks included an introduction that provides context, a description of the task, supplementary material that provides information useful for solving the task, and scaffolding prompts to develop plans, draw diagrams, and generate solutions. Data collection took place during one semester in a large, required undergraduate engineering course. Four 50-minute discussion sections took place in a laboratory classroom; each section was taught by three teaching assistants. Each week, groups solved the same ill-structured tasks in all sections. The task was installed as a digital worksheet on 11-inch tablets. Tablets of students in the same group were synchronized to allow for the creation of joint representations. Video and audio data were collected over two weeks; video was transcribed using a playscript format.

Data coding

We analyzed 22 total video recordings from 11 groups with consistent members across both tasks (i.e. no student was absent for a week of data collection). Following a previously-developed framework, we developed a coding scheme to identify the turns associated with each of the four processes in each group's video (Tucker et al., 2019). For inter-rater reliability, two researchers coded 3 of the videos for each task. Cohen's kappa was .82 for the first task and .87 for the second. For each group, the proportion of each of the four processes was calculated by dividing the number of turns associated with each process by the total number of turns that were associated with any of the four processes.

Data analysis

To measure the groups' employment of the four processes, Gini coefficients by process were calculated for each group in each task. Because ill-structured tasks emphasize problem solving, it is realistic to expect that students will spend the majority of time attempting to solve the task (P3); however, it is equally important that they spend some amount of time in each of the other three processes. Based on our previous classroom observations of students' verbal interactions while working collaboratively on problem-solving tasks, we devised a distribution of the four processes that realistically represents student problem solving. This equated to ratios of 0.5 for P3, 0.25 for P4, and 0.125 each for P1 and P2. The Gini coefficient is attained by dividing each of these values by the maximum possible deviation, giving a measure of how far each group deviated from this ideal.

Results

The groups had lower average Gini coefficients in the scaffolded task (M = 0.191, SD = 0.072) than in the non-scaffolded task (M = 0.337, SD = 0.085). A repeated measures analysis of variance was conducted, which indicated a main effect of task, $F(1,10) = 24.94$, $p = .001$, $\eta^2 = .715$. The Gini scores were significantly lower in the scaffolded task than the non-scaffolded task, indicating that the groups' participation in the four processes deviated less from the ideal distribution in the task that included explicit scaffolding prompts. The task that included explicit prompts more effectively engaged students in desirable, realistic participation in each process.

Significance of the results

This study contributes to ill-structured task design for collaborative problem solving by showcasing a method for analysis of the groups' verbal interactions using the Gini coefficient. Findings indicated that the inclusion of explicit scaffolding prompts in ill-structured tasks improved the efficacy of the task in promoting groups' implementation of the four processes necessary for effective collaborative problem solving. While the study did not measure students' individual collaboration proficiencies, the explicit prompts present in the scaffolded task successfully moved groups' problem-solving interactions toward an idealized distribution of the four processes. Future research should focus on understanding how task prompts matter for students with different levels of expertise in collaboration.

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