Assessing Students' Knowledge Co-construction Behaviors in a Collaborative Computational Modeling Environment

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Abstract. Successful knowledge co-construction during collaborative learning requires students to develop a shared conceptual understanding of the domain through effective social interactions [1]. Developing and applying shared understanding of concepts and practices is directly impacted by the prior knowledge that students bring to their interactions. We present a systematic approach to analyze students' knowledge co-construction processes as they work through a physics curriculum that includes inquiry activities, instructional tasks, and computational model building activities. Utilizing a combination of students' activity logs and discourse analysis, we assess how students' knowledge impacts their knowledge co-construction processes. We hope a better understanding of how students' co-construction processes develop and the difficulties they face will lead to better adaptive scaffolding of students' learning and better support for collaborative learning.

Keywords: Knowledge co-construction · Prior knowledge · Collaborative learning · Computational model building

1 Introduction

Knowledge co-construction processes during collaborative learning are known to be impacted by the prior knowledge each student brings to the group and externalize through discussion, explanation, and argumentation [1]. In this work, we adopt a learning-by-modeling approach, where students have to simultaneously develop and apply their domain knowledge and computational thinking (CT) processes to develop models of scientific phenomena. We extend current research by analyzing how the distribution of prior knowledge in a group, particularly when students are learning two domains simultaneously, impacts students' domain knowledge and social co-construction processes. Using students' discourse and activity logs, we assess students' co-construction processes by analyzing the strategies they apply in their inquiry and problem-solving tasks, their conversations as they work in pairs, and their model building performance. By understanding the impact of students' prior knowledge on their domain-specific and social co-construction processes, especially when they face difficulties, we hope to develop better adaptive supports to facilitate effective collaborative model building.

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2 Study Description and Data Analysis Methods

During a 9-week-long study, consisting of a two-hour class once a week, students worked together in pairs, assigned based on their pre-test performance. The student with the highest pretest score was grouped with the student who had the lowest pretest score, and so on. We collected (1) screen-capture video that recorded students' conversations; (2) action log data from both the CoSci [4] and C2STEM [2] environments; and (3) students' final computational models developed for the three challenge tasks. In this paper, we analyzed one of the three kinematic modules, 1D motion with acceleration module. After initial instruction, students completed inquiry tasks with CoSci to explore the relationships between position, velocity and acceleration through parameter manipulation in a scenario where Mario, moving at constant velocity from a pre-specified position, had to catch a mushroom falling from a height. In their final task in the module, students transitioned to a modeling challenge where they built a computational model of the motion of a truck that sped up from rest to a speed limit, then cruised at the speed limit, and then had to slow down and stop at a designated STOP sign.

We identified three types of groups based on each student's prior knowledge distribution relative to the median: (1) Balanced prior knowledge in 2 domains: one student had high prior knowledge in one domain and their partner had high prior knowledge in the other (e.g., S1: high-physics, low-CT; S2: low-physics, high-CT); (2) Unbalanced prior knowledge: one group member had high prior knowledge in both domains while the other had low prior knowledge in both (e.g., S1: high-physics, high-CT; S2: low-physics, low-CT); and (3) Deficit in one domain, where neither group member had high prior knowledge in one of the domains (e.g., S1: low-physics, high-CT; S2: low-physics, low-CT).

For the CoSci inquiry task, we used the log data to infer three strategies, previously identified in [3], that students applied to explore the relation between position, velocity, and acceleration: (1) ***Systematic (SYS)***, i.e., they systematically designed their experiments by changing one variable at a time; (2) ***Trial and Error (T&E)***, where they changed variable values randomly to find answers; and (3) ***Calculation (Calc)***, where they used the equations of motion to calculate the two parameters by selecting one and calculating the other. We also identified the following strategies that students used while modeling the three phases of the truck's motion in C2STEM: (1) ***Data Tool Usage (DT)***, identified as students opening the data tools and making edits (DATA → ADJUST), where ADJUST refers to adjusting the existing model; (2) ***Trial and Error (T&E)***, identified by sequences of ADJUST → PLAY actions, where PLAY refers to running the simulation; (3) ***Depth-first (DF)***, identified by multiple code construction actions without PLAY actions. By extracting the student discourse during behavior changes, we also analyzed students' use of the kinematic calculations (*Calc*) to compute the conditions for the truck's behavior transitions, especially if they computed the correct lookahead distance (*Suc/Unsuc*). In addition, we identified their use of the ***HELP*** strategy, where another group was asked to help with model construction steps. To evaluate overall performance, the groups' final truck models were scored using a rubric that evaluated their conditional (*COND*) and relationship expressions (*REL*) in the model.

3 Results

Table 1 shows the different inquiry (*INQ*) and model building (*MB*) strategies as well as the model scores groups obtained in their truck modeling task. Our results show that the use of the systematic inquiry strategy (*SYS*) was linked to effective knowledge co-construction of the physics relations for the truck model. The exception was group G5, which did not have high scores for the relationship expressions in model building. The other *SYS* groups, G2, G3, G6, G9, G11, and G12 had high prior knowledge in both domains, and this helped them with the relationship expression component. The same cannot be said for their conditional construct implementations, where varying results are observed. This suggests that while the groups' prior knowledge in both domains led to their using the systematic (*SYS*) strategy during inquiry, it did not translate to success in the model construction components. While the use of *SYS* inquiry strategies positively impacted knowledge co-construction of the physics-based relationship expressions, this strategy did not help students with their conditional constructs, which required students to combine their Physics and CT knowledge to establish the correct conditional expressions and constructs.

Table 1. Students' strategies and model scores

Type	Group	INQ Strat.	MB Strat.	COND	REL	Total
Balanced	G2	SYS	Calc (Unsuc) → HELP	4.5	6	10.5
	G3	SYS	Calc (Semi-suc) → T&E	4.5	6	10.5
	G6	SYS	DT	3.5	6	9.5
Deficit in one domain	G4	T&E	Calc (Unsuc) → DF	3.5	5	8.5
	G5	SYS	Calc (Unsuc) → DF	1	3.5	4.5
	G7	T&E	DT	2	2	4
Unbalanced	G8	T&E + Calc	Calc (Suc)	3	6	9
	G9	SYS	Calc (Suc)	6	5	11
	G11	SYS	Calc (Suc)	4.5	6	10.5
	G12	SYS	Calc (Suc)	4.5	6	10.5
	G13	T&E + Calc	Calc (Suc)	5.5	5.5	11

4 Discussion and Conclusions

In this paper, we leveraged the combination of activity logs and discourse to study the relationships between students' prior knowledge in Physics and CT, an inquiry task, and a model building task that required students to build a correct computational model of a truck that sped up, cruised, and then slowed down to a stop. The systematic inquiry strategy in CoSci promotes students' understanding of the domain knowledge, which then facilitates their co-construction processes during computational modeling. Our results also show that students who did not use systematic strategies for their inquiry tasks (primarily because of their low prior knowledge) may need additional scaffolding or instruction to help them develop basic domain knowledge to help them benefit from the inquiry tasks. A good understanding of the domain knowledge is a stepping-stone to using effective co-construction processes to support model building tasks.

While both unbalanced and balanced groups had relatively equivalent performance in the modeling task, only those with unbalanced prior knowledge were fully successful in using the kinematic calculations (*Calc*) strategy. Through the discourse, we see the high prior knowledge student leading all discussions. We hypothesize the one-way interactions of the unbalanced groups imply they may not have to come to a shared understanding during the inquiry task but their success during model building implies they acquired sufficient knowledge for successful construction. In contrast, the balanced groups had to truly co-construct knowledge with CT prior knowledge group members working to understand the physics concepts, and the physics prior knowledge students working to understand the CT concepts, like the conditional expressions. Our results show that although these groups attempted to co-construct knowledge, they had difficulties with calculating the correct lookahead value (lack of physics knowledge) or a difficulty operationalizing the correct value into the conditional expressions (lack of CT knowledge). Groups with a deficit of physics prior knowledge had similar difficulties but succeeded in the modeling task. We hypothesize that groups with a deficit of physis prior knowledge had difficulties because neither group member could leverage physics' prior knowledge, causing them to be least successful in the modeling task.

While this study is limited in the number of groups, we believe this provides a starting point for understanding students' knowledge co-construction and the impact prior knowledge has on the social and domain components of these co-construction processes. While the unbalanced and balanced group performance is relatively equivalent when looking at this one task, the average learning gains after the completion of the three modules were -0.06 and 0.24, for students in the unbalanced and balanced groups respectively. This suggests that groups with balanced prior knowledge may be able to better synergistically co-construct knowledge after completion of all three modules.

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