Scaffolding Peer Facilitation in Computer-Supported Problem-Based Learning Environments

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Abstract: In this study, we explore the forms of expert-like facilitation that are adopted by students in the context of a collaborative game-based learning environment centered on an ecological problem. Utilizing a case study approach, we examined four focus group discussions with middle school students (N=10) to explore the nature of peer facilitation in CSCL group processes to better inform our design iterations. Peer mediated feedback (Walker, Rummel, & Koedinger, 2009) can be supported by including simple prompts and further supported by attending to an activity system (Kaptelinin & Nardi, 2012), which includes the software system and classroom context to support student facilitation. Put differently, the ontology of CSCL group processes must consider different group formations to scaffold student facilitation and learning.

Background

Problem-Based Learning (PBL) is an instructional method that engages groups of students in collaborative problem solving and reflection of this process (Barrows, 2000). A critical element of PBL is the role that scaffolds, or supports that students receive in their learning process, which is often delivered by expert facilitators. While research in artificial intelligence and computer supported collaborative learning have successfully designed adaptive or intelligence-based scaffolds that explore how to support CSCL interactions and learning (for a review, see Magnisalis, Demetriadis, & Karakostas, 2011), most modeling techniques and software technologies focus on delivering explicit scaffolds to students (e.g., suggesting the next course of action). The research presented here represents an integration between the learning sciences and artificial intelligence focusing on how to scaffold group inquiry learning by attending to peer mediated feedback (Walker et al., 2009). Specifically, we focus on a facilitating a design space where the adaptive collaborative learning support (ACLS) system provide hints to students so that they can better support their peer's self-regulated learning, in addition to the direct feedback that students receive. We consider how this unfolds in the context of the collaborative game-based learning environment centered on an ecological problem. A primary goal of this work is to answer the following questions; 1) what forms of expert-like facilitation are undertaken by students in group inquiry and 2) what are the implications for designing adaptive scaffolds that support this process?

Theoretical framework

We adopt activity theory (Engeström, 1987; Kaptelinin & Nardi, 2012) as our primary theoretical lens in considering the forms of facilitation that students engage in as part of the PBL process. Activity theory considers learning as a collective activity, which consist of persons in activity (e.g., students and teachers, etc.) interacting with social others and material objects as they work towards individual and collective goals (known as the object). Additionally, participants' actions are mediated by tools, rules, and division of labor In a PBL scenario, students may take on roles (i.e., division of labor) to organize their work toward finding a solution to the problem at hand (i.e., the goal). These roles are often structured and defined by rules for action and interaction. Attending to these expectations in a group task as students use technology-rich learning environments will inform how to design the ACLS system.

Methods

The data sources are drawn from a larger study, which aimed to get feedback from students about design of a collaborative game-based learning environment centered on an ecological problem. In 45-minute activities, groups of middle school students (N=10) worked together to create a scientific model explaining on a whiteboard tool. Students used a Phenomenon-Mechanisms-Component (PMC) conceptual framework (Hmelo-Silver, Jordan, Eberbach, & Sinha, 2017) and explained how components (C) interact, giving rise to mechanisms (M) and/or ecological phenomenon (P).

There were four focus group sessions in two after-school clubs (three in one club; fourth in another). Due to the nature of the after-school club, there were a few returning participants in the multiple focus group sessions in the first club. In each activity, students generated a model explaining the decrease in fish population in a pond. Students were provided information about the problem in their journal, categorized according to Phenomenon (yellow), Explanations/Mechanisms (green) or Evidence (blue, Figure 1). To build their model, students moved information from their journal to a whiteboard. To facilitate the construction of the model, only Components of the statements (e.g., underlined concepts), and arrows that demonstrated the relationships among the Components, Evidence and Explanations could be manipulated by the students.

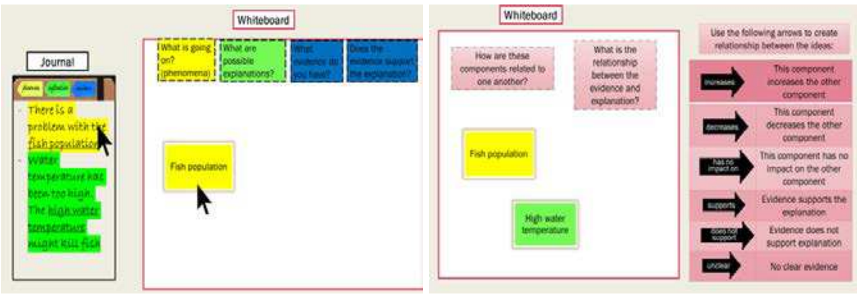

Figure 1. Information provided to students.

Two groups of students worked with physical pen and paper models that approximated ACLS interactions whereas another two worked used an online whiteboard tool to generate their models. These sessions were videotaped and transcribed. A case study approach was utilized to facilitate preliminary explorations of the nature of peer facilitation in group processes to better inform our design iterations. To answer our research questions, we adopted a fine-grained analysis of how students collaborated with one another to generate their models.

Results

Due to space constraints, we present key findings and present two excerpts that illustrate them. A key takeaway from the four sessions is the rich discussion that occur alongside students' physical and digital interactions when gathering information and using the whiteboarding tool. When using the whiteboard tool, students were oriented towards a shared goal of explaining the phenomenon, sharing their explanations and defending these explanations based on the information that they have. This pattern of discussion and negotiation was observed across all groups, even with limited expert facilitation. This suggests that students were able to manage the inquiry process by using the materials provided to them and adopted facilitation roles even when unassigned (see excerpt 1). In the following segment of discussion, students were provided with the physical model and provided with the prompts in the whiteboard (see figure 1). Students were tasked to generate a hypothesis as to why the fish is dying by explaining the relationship between temperature, algae, and dissolved oxygen.

Excerpt 1. Debating the mechanisms behind the fish kill phenomenon

1	Steve	Guys, my idea is this look it says that the fish um- ((*looks at background information*))
2	Neal	Are dying
3	Steve	((*reads information*)) Temperature, the temperature data shows that it has been an average of 90 degrees for this month
4	Neal	Which means the algae will grow
5	Steve	((*reads information*)) High water temperature does not kill this type of fish according to the vet
6	Neal	And also-
7	Steve	The fish are used to the high temperature-
8	Neal	Yeah
9	Steve	And so- the high temperature would make more algae and the more algae
10	Henry	Gets rid of
11	Steve	Some of them die and that makes more dissolved oxygen
12	Neal	No, the dissolved oxygen is good-
13*	Henry:	Is it?
14	Neal	Yeah, dissolved oxygen is good for fish

15	Steve	And then it doesn't give them very much sunlight [...] and they would die because they are used to the sunlight
16	Neal	I just want to say something
17	Steve	And they would die because of all the green muck on the pond
18	Jack	Let Neal say something
19	Neal	So so the sunlight is helping the algae live which means that the algae is um getting rid of um dissolved oxygen and dissolved oxygen is if there is not (.) it if there is low dissolved oxygen the fish die
20	Steve	Oh yeah
21*	Neal	And you’re saying the opposite

The discussion highlights how students articulate, contest and/or build on each other’s ideas (e.g., lines 2, 4, and 13). The students have a shared goal of developing a model that meets the rules of the PMC framework. We see a variety of moments where different mediators shape the groups collaborative inquiry (e.g., the information provided, student prompts). A mediating factor in this productive discussion is the facilitator role that these students take on as they work with one another (lines 13 and 18). Jack adopts a facilitator role, asking his peers to cede the floor for other voices (line 18). Steve, on the other hand, generates discussion by explicitly sharing the information to the group. The students in the discussion also make inferences based on the data provided (line 3 and 9). These actions mirror the processes that Quintana et al. (2004) suggest should be attended to when designing software scaffolds (e.g., sense making, process management, and articulation and reflection. A key takeaway is the context within which the discussion occurs. Given that students were creating the physical model, the discussion occurred as they were working with the model. We see similar productive group inquiry when students were using the digital tool to generate their model (excerpt 2).

Excerpt 2. Student and facilitator scaffolds in group inquiry when using a digital model

1*	Natalie	Algae doesn't increase the green muck. That doesn't make sense.
2	Evan	Yes it does because algae- dead algae is green muck.
3	Kate	Yeah. But then-
4	Natalie	So then the water temperature (5 second pause) the water temperature-
5	Kate	((*reading information from the screen*)) Yeah it says the green muck is actually dead algae.
6	Natalie	Yes, we know. Ok. So the water temperature also-
7	Evan	((*mutters*)) Ok it decrease-
8*	Natalie	So hold on. We have the sunlight that increases the algae, the algae which increases the green muck, even though they're the same thing, which makes zero sense. But, then it decreases the fish population so then -
9	Evan	((*working on the model as Natalie is speaking*)) The algae. Ok. The green muck also decreases algae. Er, has no impact on algae.
10	Natalie	Yeah
11	Evan	No- green muck decreases it because it is dead algae. Or something like that.
12	Natalie	The green muck is the same thing as the algae. So the algae cannot increase by green muck. And the green muck cannot decrease by algae.
13	Evan	But algae can decrease by green muck.
14*	Natalie	No, it cannot. Because they're the same thing!
15*	Kate	((*to Evan*)) What are you saying? I am so confused.
16	Evan	Ok ok, well then in that case. Green muck has no impact on algae.
17	Natalie	Yes.
18	Evan	Ok.
19	Natalie	So you need to take away the increases arrow
20	Evan	I already did that
21	Natalie	Flip around that has no impact arrow.

The group of students in excerpt 2 utilized the roles that were introduced; the timekeeper, facilitator and the modeler. Like their peers in excerpt 2, the students in this group also negotiated their ideas, specifically debating how to represent green muck or algae in the model. Students again drew on provided information (line

5) but also engaged in sense making processes (lines 8-14). Moreover, Natalie engaged in overt process management, directing Evan on how to manipulate the model.

Implications and future directions

In both excerpts, peer mediated feedback came in the form of questioning, often accompanying explanations that could be debated or were unclear (see asterisked lines in excerpts). While we did not provide explicit hints for students, the constraints provided to students in the form of the modeling tool helped students with this sensemaking practice. From a design perspective, embedding scaffolds that signal students to question the relationships in the model is a next logical step. Simple prompts such as "does this make sense" similar to how students voice their questions will likely support and facilitate group inquiry. However, this alone is not sufficient to ensure productive discussions. Students must also be aware of the kinds of roles that they need to adopt as part of the group inquiry process, especially since these roles are not always necessarily defined by students themselves.

Another implication of the rich group interaction that students have as they engage in the modeling process, whether digitally or physically is that such interaction might not be accounted for by the system. For example, behaviors and actions in a digital environment are often captured by user input (e.g., movement in the physical space). Often, non-actions are construed as inactive or disengagement from group inquiry and interactions. The results from the focus groups however suggest that students engage in productive actions outside of the digital space.

Based on these findings, we generate two design take-aways. We suggest two group formations that will support student facilitation and learning. First, students can be assigned to PBL groups and solve the problem presented to them. In the PBL groups, the ill-defined problem in the game-based learning environment will be introduced by various stakeholders who will present different facets of the information provided to student at each given stage. For instance, the stakeholders might all discuss algae as a contributing factor to the fishkill problem, but these ideas will be presented in various ways (e.g., graphs, simulations, pictures). Scaffolding the PBL group could take the form of process management, such as making sure that students engage in hypothesis generation and reflecting on their group in-game learning actions and processes.

Secondly, given that students naturally engage in discourse outside of the technology, this means that the classroom configuration must support this form of discourse. For instance, students could be physically arranged in the classroom to sit with peers who are assigned the same stakeholder, thereby generating groups of expert peers. Scaffolding provide to the expert peer group can take the form of facilitation prompts meant to trigger discussions and sense making processes. In this way, the spatial configuration will support students group inquiry process and ensure that these ideas are then communicated to their in-game members in chat. We believe that this is a productive approach since research has also suggested that timing student interactions around successfully completing tasks and reporting them in chat will support students group inquiry (Van Eaton, Clark, & Smith, 2015).

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