

Scaffolding peer facilitation in computer-supported problem-based learning environments

Asmalina Saleh, Katherine Shanahan, Yuxin Chen, Cindy Hmelo-Silver, Indiana University
Jonathan Rowe, James Lester, North Carolina State University

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. We posit that the notion of a design space (Walker, Rummel, & Koedinger, 2009) can be expanded 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 the 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 CSCL 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 design of a 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) subsequently, what are the implications for designing 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. Examining the expectations that underpin roles that students adopt in a group task as they use technology-rich learning environments will thus inform how to structure such a design space.

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.

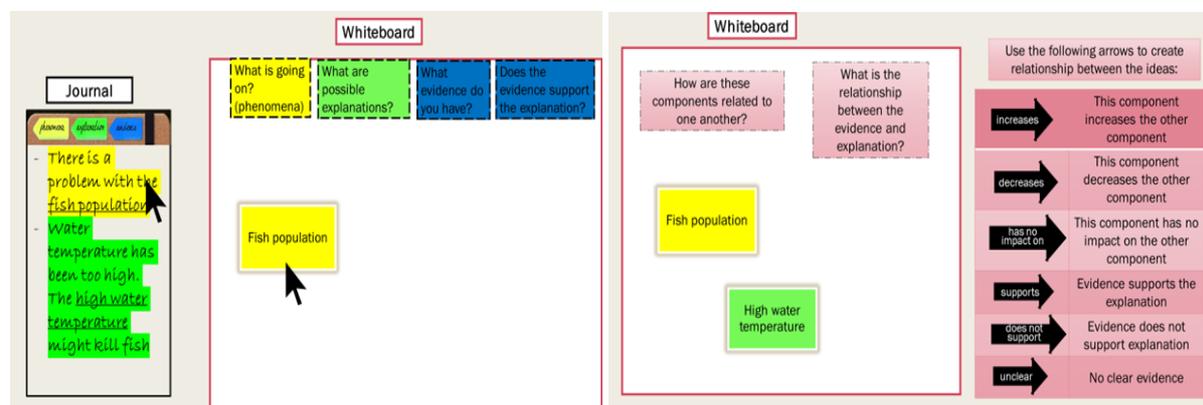


Figure 1. Information provided to students.

Two groups of students worked with physical pen and paper models that approximated CSCL 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 CSCL 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. 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 even adopted facilitation roles even when unassigned (see excerpt 1). In the following segment of discussion, the students continue to debate the relationship between the mechanisms of temperature, algae, and dissolved oxygen to further explain the phenomenon of fish dying in a local pond.

Excerpt 1. Debating the mechanisms behind the fishkill 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 (.) 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. In this example, 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. The students in the discussion demonstrate a variety of communicative strategies that would typically be employed by expert facilitators such as questioning (line 13). Although Neal does not warrant his claim that dissolved oxygen is good for the fish in this instance, he had earlier noted that he had learned from the previous focus group that oxygen is necessary for fish survival. Similarly, 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. These student 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 from this example 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. Even though the students were assigned specific roles, students ended taking on roles naturally. Natalie was the timekeeper but ended up facilitating, whereas both Evan and Kate engaged in creating the model. Kate was originally assigned the role of creating the model in the digital whiteboard, but Evan, who

was the facilitator, assisted her and ended up co-creating the model with Kate. Like their peers using the pen and paper whiteboard, 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. In this scenario, students drew on their own strengths, Evan used the technology effectively, whereas Natalie led the group discussion.

Implications and future directions

Given students' propensity to adopt roles that they are familiar with, this suggests that the design of an adaptive scaffold system that provides hints to peer experts to facilitate group inquiry is a fruitful direction. 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. The notion of a design space can be expanded by utilizing the concept of an activity system, which includes the software system and classroom context to support student facilitation. Put differently, we posit that the ontology of the classroom activity system must be considered. To facilitate this, we suggest two group formations to 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 fish kill problem, but these ideas will be presented in different 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 provided 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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