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Designing a Teacher Guidance Tool for Collaborative Inquiry Play

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Abstract: The current design paper presents a theory-driven framework for the design of a real-time teacher guidance tool that assists teachers in providing timely and appropriate scaffolding contingent on students' progress. Grounded in problem-based learning and distributed scaffolding theories, we discuss how the design of the tool can help teachers make decisions and provide appropriate scaffolding in collaborative inquiry play.

Introduction

Providing timely and appropriate scaffolding plays a key role in student learning, especially in collaborative inquiry play, an approach that utilizes problem-based learning (PBL) in a game-based learning environment (Saleh et al., 2019). Contingency is a critical characteristic of scaffolding (Puntambekar, 2021), especially for classroom orchestration, which refers to multifaceted management of workflow consisting of monitoring progress and coordination of learning activities across various social levels (Dillenbourg et al., 2018). Contingent scaffolding involves first determining if scaffolding is needed and then providing appropriate forms of support that respond to student needs in a timely manner. However, implementing such scaffolding requires the teacher's acute awareness of student and group needs along with strategies for appropriately addressing them. Such scaffolding can be distributed across the teacher and technology tools including a teacher guidance tool as part of a CSCL environment that can provide real-time classroom information and actionable recommendations in response to progress. However, prior research has shown that a poorly designed teacher guidance tool can actually increase demands on a teacher due to excessive information that is challenging to interpret and act on (Martinez-Maldonado, 2019). Thus, it is valuable to explore how we can design a real-time teacher guidance tool that can provide effective contingent and actionable guidance by suggesting who should, when to, and how to intervene in the learning process (Matuk et al., 2019).

We present a theory-driven framework for designing a teacher guidance tool that offers real-time recommendations. The tool enables teachers to extend their instructional capacity to provide contingent and adaptive scaffolds by easing the managerial burden (also known as orchestration load; Dillenbourg et al., 2018) in such complex learning contexts. We draw on PBL and distributed scaffolding theories to design real-time or concurrent teacher guidance that could help educators make *appropriate* and *timely* decisions (Martinez-Maldonado, 2019). We aim to address the following design questions for a teacher guidance tool: 1) what forms of scaffolding to provide; 2) who receives the scaffolding; 3) when the scaffolding is to be provided; and 4) how to provide appropriate scaffolding in collaborative inquiry play and discuss detailed prompts in the form of guidance for teachers. Throughout this paper, we use "guidance" to refer to prompts delivered to teachers and "scaffolding" to refer to prompts given by either a teacher or a technology to students.

Theoretical Background

PBL is a student-centered instructional approach that centers around collaboratively solving ill-structured problems (Hmelo-Silver & Barrows, 2006). In PBL, a teacher takes the role of a facilitator to guide students' learning and promote group collaboration. For successful PBL instruction, teachers should provide scaffolding contingent on understanding of individuals' or groups' needs. However, it is challenging for teachers to quickly grasp students' specific needs, which constantly change during the learning process, while managing the entire class. To assist teachers in diagnosing what type of scaffolding might be beneficial for students, we draw on five types of students' needs as guiding principles to develop teacher guidance based on the types of scaffolding needed in PBL identified by Kim et al. (2018). The five types of needs are 1) *conceptual*, 2) *strategic*, 3) *metacognitive*, 4) *motivational*, and 5) *collaborative*. Learners who have conceptual needs are likely to have incorrect disciplinary ideas or revisit content multiple times. They can usually benefit from hints and other content-related resources. Students' strategic needs increase when they struggle with navigating problem-solving processes as well as the learning environment. These needs could be met with strategies that guide how to sustain problem solving while navigating the process. Students with metacognitive needs might be encouraged to monitor their learning and inquiry processes by recognizing what they know and should know. Such students' recognition of these needs enables them to establish proper plans and strategies for how to engage in problem solving. For motivational needs, individual students are invited to enhance their participation and interest in learning through facilitation of their behavioral, emotional, and cognitive engagement. Lastly, when participation patterns that disrupt students' collaboration are identified (e.g., bullying or violations of group norms), collaborative needs should be met immediately.

Furthermore, appropriate scaffolding is presented contingent on social levels. Puntambekar (2021) describes how scaffolding is distributed across multiple social levels and provides learners assistance at different levels at specific moments in the learning process in CSCL. She also suggests that teacher guidance be purposefully designed to offer scaffolding across different social levels of learning: individual, group, and whole class. Thus, real-time guidance could expand teachers' capabilities in monitoring multiple groups, advance their decision-making processes, and help prioritize their instructional actions depending on social levels in complex learning environments. While teachers often provide scaffolding for individuals, this study focuses on designing guidance about small groups to assist educators to manage multiple small PBL groups and support collaborative inquiry processes in a game-based collaborative learning environment.

Designing teacher guidance for orchestration

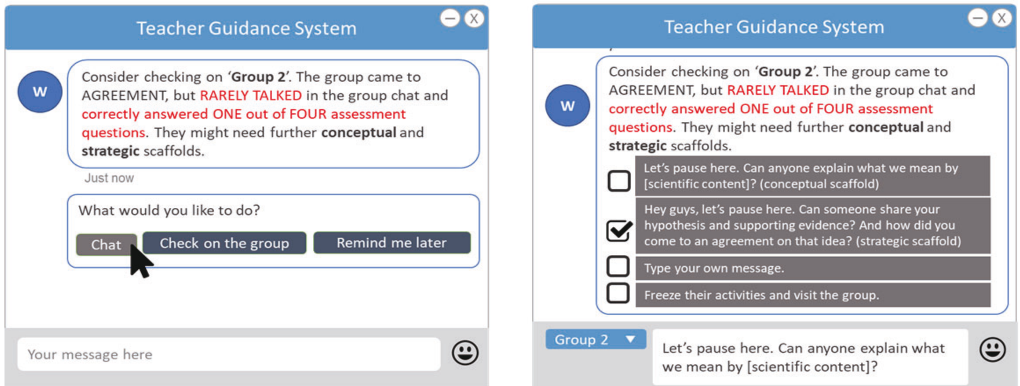
The context for this study is the design of a real-time teacher guidance tool to support classroom orchestration in 6th grade life science classrooms. The teacher guidance tool can support orchestration within a game-based learning environment, CRYSTAL ISLAND: ECOJOURNEYS, which focuses on an ecosystem problem to try to determine why tilapia at a local farm are sick. The game is implemented in the classroom with multiple small groups working together in teams of three to four students. To solve the problem, students learn concepts related to ecosystems and collect data and evidence as they explore the game environment in their scientific inquiry. They also engage in collaborative inquiry such as generating hypotheses and reasoning about evidence. The students as a group participate in group chats, engage in argumentation, and negotiate agreement on potential causes of the fish's sickness using tools such as a brainstorming board, an in-game chat thread, and a voting feature used to support consensus building (Saleh et al., 2020).

Table 1
Structure of Teacher Guidance for Group Level

Types of Needs	Example Situation	Example Indicative Behaviors	Recommended prompts or teacher actions
Conceptual	Only a few students understand the scientific content. Most students appear to agree with a leader without engaging in deep scientific discussion.	Less use of scientific words, incorrect responses, limited justification, or evidence to support claims, etc.	"Let's pause here. Can anyone explain what we mean by [scientific content]? How does it relate to the problem that we are trying to solve?" (Pushing for explanations)
Strategic	There are competing opinions, and students do not want to change their opinions. The group is at a standstill and cannot move forward.	Extended duration of time on a collaborative task relative to peers, disagreements with no change in votes, etc.	"Can someone share your group's hypothesis and supporting evidence?" "How might we come to a consensus?" (Generating hypotheses)
Metacognitive	The group does not know what to do or is not sure about plans for the next steps.	Extended duration of time on steps in the inquiry process relative to peers.	"It seems that we are still in this phase, what do you think we need to do next? Why do you think that?" (Open-ended metacognitive questions)
Motivational	Students in a group seem to lose interest in the game, and only a few students are engaging in game activities.	Not looking at a screen, extended number of off-topic lines in chat, no in-game actions, etc.	"What are you working on? Is everything going, okay?"
Collaborative	One student is constantly spamming in a group chat.	Using the same words repeatedly, etc.	Freeze their activities and visit the group.

In this design, we draw on event trace logs and multimodal data to design a real-time teacher guidance tool. Available event logs from the trace data include numbers of correct answers and lines in chat, the amount of time looking at in-game materials, and so forth (Saleh et al., 2020). Multimodal data streams such as facial expressions, gestures, and gaze data will be used to determine benchmarks (e.g., group reasoning and inquiry strategies) that may signal heterogeneous and homogeneous patterns of participation. Based on these patterns, we describe potential situations under each type of students' needs in the context (see Table 1). Then, the teacher guidance tool will generate appropriately contingent prompts (see Figure 1).

Figure 1
An Example of Teacher Guidance



Design for *What* scaffolding to provide and *Who* receives scaffolding

Determining what scaffolding to provide in response to students' specific difficulties and needs is critical (Puntambekar, 2021). As the tool detects learners' different participation patterns that might need the teacher's attention, the teacher guidance tool identifies a specific group with a need at that moment (Figure 1). Sometimes, the tool may note that students require more than one type of scaffolding to address the current issues they encounter, which enables teachers to offer fine-tuned scaffolding. The teacher guidance tool describes not only students' needs but also a specific situation that represents their difficulties in the game. It supports teachers' judgment and decision making as well as enables sophisticated scaffolding. For example, two different groups may have similar strategic needs but may show different participation patterns. The first group may use few words related to scientific concepts compared to the total number of words the group uses in the group chat. Some students have not accessed any of the in-game collaborative tools and are leaning back in their chairs, possibly indicating a lack of engagement (Baker et al., 2010). This could mean that students are disengaged and are instead exploring aspects of the environment that are not related to the collaborative tasks. The second group may be actively engaged in chat but cannot move forward because no one changes their vote, and an agreement is not reached. With the information about groups' specific situations, teachers are positioned to interpret situations accurately and infer appropriate scaffolds in accordance with groups' various needs and difficulties (Puntambekar, 2021). Teachers can also infer the overall tendency of the class and plan a whole-class intervention based on priorities in that situation. As such, teachers can more effectively handle their classroom, and are less likely to be distracted from myriad information when making decisions.

Along with identifying what scaffolding to provide, teachers should decide who will receive scaffolding contingent on a social level, which are 1) individuals, 2) groups, and 3) the whole class. Teacher guidance specifically identifies outliers (i.e., a student's name, what percentage of students in which group, or what percentage of a whole class) and advises the teacher that the designated individuals, groups, or a class as whole need support during the scientific inquiry. The tool could provide information about progress at multiple granularities at a glance and allows the teacher to select the granularity of support. For instance, when more than 80 percent of the students show inactive participation in group discussion, the teacher guidance tool recommends that the teacher pause classroom activities in favor of a whole-class level intervention. As such, teacher guidance will empower teachers to make critical decisions on who needs scaffoldings, what scaffoldings would be appropriate for certain group sizes, and whether it is the right time to move forward.

Design for *When* and *How* to provide scaffolding

Teacher guidance should appear at a critical moment to offer timely interventions, while ensuring students have enough time to engage with a problem before the teacher or system intervenes. To determine the appropriate timing, facilitators' goals proposed in PBL (i.e., engage students in collaborative learning, monitor the group learning process, help students reflect on their thoughts, and facilitate knowledge construction) are applied (Hmelo-Silver & Barrows, 2006). A situation that needs timely intervention is a moment when a student or a group's participation patterns stray from the facilitator's goals in PBL. We specify potential situations which need the teacher's attention corresponding to each type of group needs. Regarding "monitor and maintain group progress", even if students are having an off-topic conversation during the game, the teacher guidance tool does not need to inform the teacher. If students are progressing in scientific inquiry discussions, it is not a situation that is flagged. In this way, the teacher guidance supports teachers to make accurate and timely decisions on when to provide scaffolding and alleviate their orchestration load by suggesting a proper timing for providing scaffolds.

Once situations, problems, and proper timing to present interventions are identified, teachers should decide how to provide scaffolding, corresponding to given conditions. We used facilitation strategies frequently used in PBL to devise messages in teacher guidance (see the right column in Table 1) (Hmelo-Silver & Barrows, 2006). These strategies have been aligned with each type of need and timeline of the unit. For instance, generating/evaluating hypotheses is employed as one of the strategic and/or metacognitive scaffoldings. One of the prompts for the strategy displayed in teacher guidance would be, "Can someone share your group's hypothesis and supporting evidence? And how did you come to an agreement on that idea?" This could help students focus on their inquiry process, have an opportunity to substantiate an argument with supporting evidence, and check if the hypothesis sounds correct. The group can also realize what should be investigated further and regulate their inquiry process (Hmelo-Silver & Barrows, 2006). Furthermore, facilitating strategies interplays with group size and unit timeline; Teacher guidance generates several prompts for scaffolding at a time with consideration of specifics. The information given in teacher guidance, including a subject, types of needs, a specific situation, and a goal of the facilitators allows teachers to use their judgment to select among options without excessive orchestration load.

Conclusion

This paper provides a principled design for how PBL and scaffolding theories could support real-time teacher guidance to provide information about students, situations, timing, and facilitating strategies. This can help teachers make informed decisions on what, when, whom, and how to provide scaffoldings and offer timely and appropriate support contingent on students' current status. For the future work, we are planning to evaluate the efficacy of the design of the real-time teacher guidance proposed in the paper.

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