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Idea Wall: A real-time collaboration tool to support and orchestrate knowledge construction across multiple social planes

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Abstract: The Idea Wall is a collaborative technology that aims to support collective knowledge construction and idea negotiation across multiple social configurations. Further, to support multiple entry points for student collaboration, the Idea Wall provides (and requires) multiple modalities for interaction through text, collaborative discourse, and spatial orientation of ideas. To support the teacher in implementing and orchestrating Idea Wall activities, we designed: 1) an authoring portal to enable teachers to quickly create Idea Wall instances; 2) a whole class view to support whole class discussions; and 3) a set of real-time agents that can alert the teacher when students may need teacher intervention or new groupings based on natural language processing of students' co-constructed ideas within the Idea Wall.

Introduction

To support students' engagement in collective knowledge construction, idea negotiation, and collaborative sensemaking, which are increasingly vital in the 21st century, we need to design learning environments that effectively scaffold these discursive processes. Far too often, teachers and researchers are forced to adapt their learning goals to fit off-the-shelf software that are not designed for these complex forms of social interactions. In response, we present Idea Wall, a tool that can flexibly support students as they move between individual, small group, and whole class inquiry and idea negotiation. As part of its design, the Idea Wall environment also provides the teacher with a suite of tools to allow them to adapt the orchestration of class activities based on emergent events in the class.

Goals

The Idea Wall was designed around three central learning goals: 1) support students to engage in collaborative knowledge construction across multiple social configurations (Slotta et al., 2018; Dillenbourg, 2013); 2) encourage students to collaboratively negotiate and refine their ideas across multiple modalities; and 3) provide the teacher with just-in-time information to support their classroom orchestration (Tissenbaum & Slotta, 2019a).

Collaborative Knowledge Construction Across Multiple Social Configurations

While ability for students to share ideas and build knowledge with peers is hardly novel on its own (Scardamalia & Bereiter, 1994; Slotta & Linn, 2009), there have been limited approaches to scaffolding these kinds of knowledge construction in ways that allow students to have their knowledge follow them across contexts and social configurations. Developing means for students to seamlessly integrate the outputs from earlier stages of their inquiry in new classroom configurations and connect those outputs to the work of their peers allows them to take ownership of collective knowledge in the classroom and connect it to border elements of the curriculum, creating new knowledge (Slotta et al., 2018). While there have been educational tools that focus on the long-term development and visualization of the knowledge community's growth (Yuan et al., 2022), we believe there is value in lightweight tools that embrace the potential ephemeral nature of these configurations, with students coming together, potentially in *ad hoc* configurations, to share ideas, new knowledge, or inquiry questions.

Encouraging Collaborative Negotiation Across Multiple Modalities

While platforms like Knowledge Forum (Scardamalia & Bereiter, 1994) and Idea Thread Mapper (Yuan et al., 2022) aim to support collaboration through text-based models that expand upon traditional discussion forum modalities, their focus on written text, while not explicitly designed as such, may limit opportunities for verbal discussion and idea negotiation. Verbal collaborative discourse has been shown to be an important means for students to establish intersubjectivity and mutual cognition (Dornfeld & Puntambekar, 2016; Miyake & Kirschner, 2014; Rowe, 2011). Further, by introducing other visual modalities, such as spatial organization of ideas in a shared space, popular educational approaches (e.g., mind maps) can provide students with differentiated and potentially more equitable ways to collaboratively exchange and discuss ideas, engage in argumentation, and visualize their collective knowledge (Sadler et al., 2015).

As such, there is significant potential for learning environments in which students are scaffolded, and potentially required, to collaborate across textual, verbal, and virtual spatial modalities as they develop their

collective understanding and build new knowledge. Enabling students to write their ideas on a shared screen; scaffold them to orally debate the merits, similarities, and differences of their individual contributions; collaboratively visually organize their ideas; and collectively agree on the final visual organization have the potential to provide a rich set of multimodal scaffolds for students to engage with their peers.

Just-in-Time Teacher Orchestration Support

As technology-mediated learning environments become increasingly complex, teacher's management - often termed orchestration (Dillenbourg, 2013) - of the flow of materials, students, and activities has become one of the grand challenges in the learning sciences (Wise & Schwarz, 2017). Within collaborative inquiry designs, it is difficult for teachers to know where and when they are needed (Tissenbaum & Slotta, 2019a). As a result, there is a need to develop supports for teachers that can reduce orchestrational load by offloading managerial and monitoring tasks, allowing them to act as a wandering facilitator who focuses on students who would most benefit from their immediate support (Hmelo-Silver, 2004).

By leveraging the real-time data generated by students' interactions within the learning environment, we can capture an array of rich student data (e.g., typed notes, mouse clicks, speech, and gaze) at the individual, small group, and whole class levels, then process it to gain insights about the state of the class that would otherwise be prohibitively complex and time consuming during live class sessions (Slotta & Acosta, 2017). The use of this data has been shown to effectively help teachers to engage with students in critical moments in their inquiry, resulting in more complete student reasoning (Tissenbaum & Slotta, 2019a). This information can also be used to group students based on their current state of understanding to complement collaborative activities (Yang et al., 2021). Additionally, as inquiry activities progress, there may be a desire for the teacher to leverage students' individual or small group knowledge in new configurations (e.g., new small groups or whole class discussions), adapting the overall learning script in response to emergent avenues of inquiry - what Tchounikine calls "orchestrable technologies" (2013). Providing flexible and easily scriptable means for teachers to design and implement ad hoc discussions opens new ways for the teacher to adaptively orchestrate class activities.

Design Principles

In response to our goals above, we wanted to design the Idea Wall as a flexible collaborative knowledge construction tool that had the following design principles:

Support students to engage in multiple social configurations. We wanted the Idea Wall to allow students to collaborative with peers and have their personal learning traces follow them across multiple configurations. As a result, as part of this design, we wanted a space specifically designed for idea negotiation and refinement that could sit outside of, and complement, their inquiry activities (e.g., conducting research or experiments). This allows the Idea Wall to plug into a range of knowledge community tools that focus on the long-term development of knowledge, which may not be as easily scriptable across multiple social planes.

Provide multiple modalities for collaborative interactions. We wanted to ensure that students not only had multiple means for engaging in collaborative sensemaking, but also that (on some level) these modalities would be required to reach consensus. To this end, as described below, the Idea Wall requires students to collaborate through text, verbal discussion, and spatial organization of ideas.

Provide the teacher with orchestration and orchestral supports. To enable the teacher to focus on acting as an informed wandering facilitator, we wanted to reduce the time they spent guessing on where to be in the room and setting up different class configurations. As part of this principle, we did not want to overwhelm the teacher with information, rather we wanted to only show them what was salient to their current orchestration needs.

What was designed

The Idea Wall consists of two core components that work together to support class discussion across multiple configurations: 1) a front-facing suite of tools for students and teachers, and 2) a real-time analytics engine to support emergent classroom orchestration. We outline each of these aspects below in more detail.

Front-Facing Tools

All of our front-facing tools and their corresponding real-time interactions are powered by the room manager which utilizes Socket.io, a library that opens a bidirectional channel between users and the front-facing suite. Socket.io allows for low-latency communication between clients, transporting data through a dedicated server

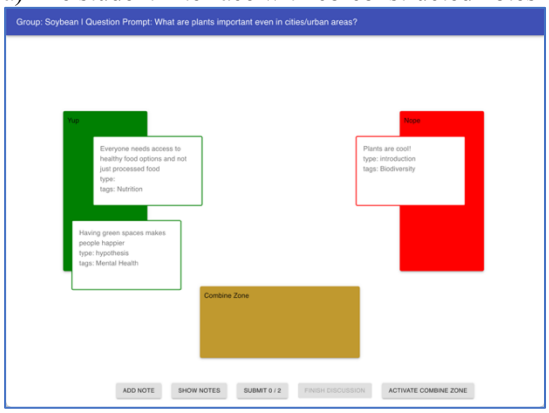
for idealized reliability bolstered by automatic connection detection (*How It Works | Socket.IO*, 2022) that frees up the suite's API to record contributions and interactions for future analysis.

Student Interface

The student interface for the Idea Wall is largely consistent across all the different scriptable configurations. The Idea Wall is presented to students as an open canvas with three areas represented by colored boxes (Figure 1a): **Yep**, in green, where students drag notes they collectively agree to keep; **Nope**, in red, where students drag notes they choose to discard; and **Combine Zone**, where students can drag two or more notes to combine them into a single higher-order note. Students can create a new note by pressing "New Note" or insert a text note from earlier individual work or Idea Wall sessions by pressing "Show Notes" (Figure 1b). All students in the group are free to sort the collaboratively generated ideas into or out of any of the boxes, with any changes represented on all students screen in real-time. Before submitting their final set, all students in the group must click on the "Submit" button (Figure 1a). Through this interface, students must collectively synthesize their contributions towards a final set of ideas before they can proceed. Based on our prior research, this approach successfully supports students' engagement in collective science reasoning and debate (Tissenbaum & Slotta, 2019a).

Figure 1

a) The student interface with co-constructed notes



b) The note side panel with notes from previous work

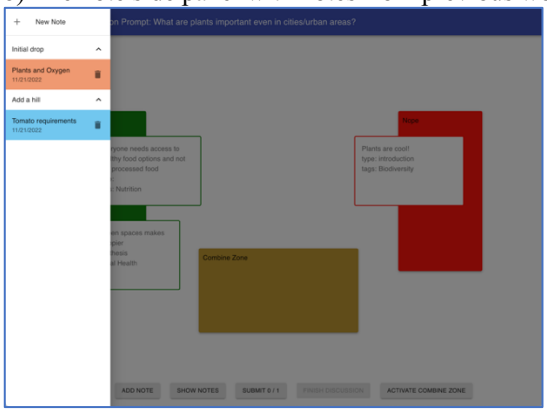
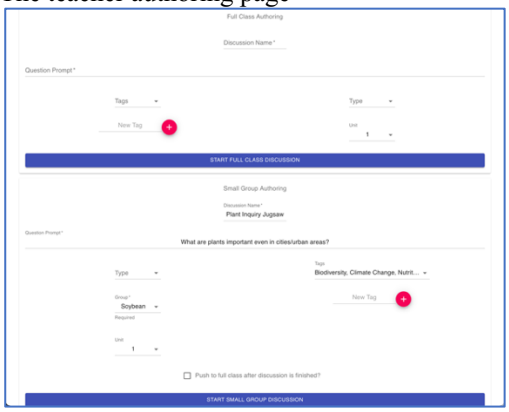
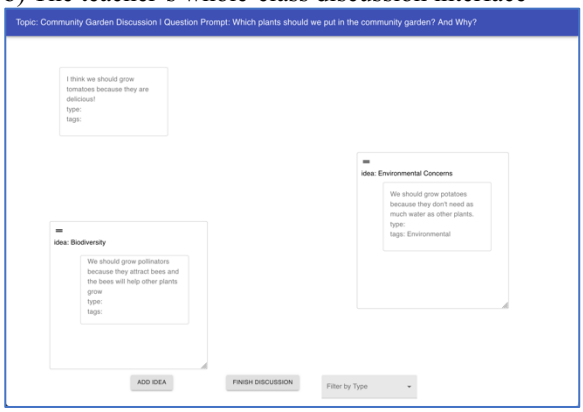


Figure 2

a) The teacher authoring page



b) The teacher's whole-class discussion interface



Teacher Interface

The teacher has several tools to support them in scripting and orchestrating class discussion. The first tool is an authoring portal that allows the teacher to create specific Idea Walls instances (small group or whole class), choose the question prompts that drive discussion, pre-seed any tags for students to choose, and decide where the outputs of the activity will be sent (e.g., to students' notebooks, another Idea Wall activity, or to a Whole Class Discussion Interface (Figure 2a). During whole class discussions, the teacher is provided with an interactive large-format display at the front of the class that shows all contributions of individual students (or small groups, depending on the configuration; Figure 2b). On this screen, the teacher can spatially organize students' notes and filter them by tags to support whole class discussion. The teacher can also create new "Topic

Ideas" based on emergent class discussions (Figure 2b). Topic ideas are boxes that "hold" student notes to create sub-topics, which are sent to each students' personal device for future individual or collaborative use.

Finally, to support the teacher during real-time orchestration of class sessions, we developed "check-in" and "student grouping" interfaces. The check-in interface alerts the teacher when a group has submitted their final Idea Wall note set. The teacher can approve the students' notes or send them back for refinement. This design builds on our prior work showing these timely interventions can significantly improve the completeness of students' inquiry reasoning (Tissenbaum & Slotta, 2019b), as well as data from an earlier pilot of the Idea Wall that showed that while the teacher was able to engage with students around their ideas, her decisions around which groups to visit were not necessarily in response to each group's progress in the activity. The student grouping interface allows the teacher to quickly designate which students are in each Idea Wall group (similar to how Zoom creates breakout rooms). This was also developed based on teacher feedback during our initial pilot, as they wanted to be able to reconfigure the class based on emergent and existing dynamics.

Real-Time Analytics Engine

Throughout all the Idea Wall activities, individual and group notes are logged in a real-time API along with their positions on the screen, the timestamps for when they are dragged (and where they are dragged to), and by whom. While this can be a useful tool for unpacking how ideas and collaboration unfolded *post hoc*, by placing all this data in our real-time API, we can also leverage it for real-time analytics using our custom instance of a Flask server (a cloud-based server implementation of Python). In our current implementation, as students are working, the real-time analytics engine captures and processes the digital notes of individual students which works to generate suggestions for new group configurations using a natural language processing bag-of-words algorithm designed to balance group dynamics. This is then sent to the teacher's room manager interface for them to accept for the next activity or adjust based on their personal understanding of the class's dynamics.

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