Spatially Manipulable Interactive Note Taking Tool to Facilitate Collaborative Learning in Science Education

Litong Zeng*
University of Illinois at Urbana-Champaign
litongz2@illinois.edu

Shafagh Hadinezhad
University of Illinois at Urbana-Champaign
shafagh2@illinois.edu

Mike Tissenbaum
University of Illinois at Urbana-Champaign
miketiss@illinois.edu

ABSTRACT

We examined how Idea Wall, a collaboration spatially manipulable interactive note tool, supports collaborative scientific reasoning among students. Through a design-based research approach, the study also aims to identify potential improvements to the tool that can better support collaborative interactions. The Idea Wall has the ability to facilitate spatial manipulation and interactive note-taking supported student engagement and collaboration. This paper contributes to the growing body of research on the use of interactive tools to enhance scientific reasoning skills in collaborative learning environments. By researching the affordances and challenges of the tool, this study provides valuable insights into the design considerations and potential improvements of such tools in building new norms of collaborative discussion for a knowledge community.

KEYWORDS

Computer Supported Collaborative Learning, Design-Based Research, Science learning, Spatially Manipulable Interactive Note Taking tool, Knowledge building community

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1 INTRODUCTION

With policies such as the Next Generation Science Standards, schools are increasingly encouraged to integrate collaborative and inquiry skills into K-12 science education [3, 8]. To meet this goal, students should be involved in authentic scientific practices in the classroom that would provide them with the opportunity of exploring and developing their knowledge and understanding of scientific ideas. As part of this shift, there is a growing understanding of the role collaborative learning can play in supporting socially mediated learning and individual cognitive development [2, 10]. Further, the skills students need to develop in order to prepare them to thrive in the knowledge society of the future, are unlikely to be developed in isolation. In contrast, knowledge community approaches, where students work together to collectively advance the class's knowledge have been shown to effectively support students' development of these critical skills [9, 14].

There have been several approaches to supporting these kinds of knowledge building communities. For instance, Knowledge Forum (KF), a web-based discussion forum, provided a communal space for students to create, share, and build on the collective contributions (such as the ideas, or the results of experiments) of the entire class. Through KF's support for them to build on, question, refine, and synthesize each other's ideas, students were able to deepen their content knowledge [9]. Toward this goal, technology-enhanced environments are often used to support students to engage in classroom practices collectively and connect students with each other and with the work of their peers to build new knowledge [11, 13]. However, the design of these knowledge community environments does not happen overnight. Rather, they often take multiple rounds of iterative design, implementation, testing and revision to systematically understand and predict how they can support learning. This process of continual development and refinement is often referred to as design-based research (DBR) [1]. Unlike traditional lab experiments, DBR is situated in real-world contexts and emphasizes close collaboration among participants and researchers [4]. During the implementation process, researchers may use qualitative and quantitative methods to observe and analyze learners' interactions with the designed system and adjust the design in response to perceived issues with the design to improve the ongoing design in an interactive, flexible and iterative process [5]. As part of this, researchers should document the why and how they made the adjustments [1]. In response to the need to support students as a knowledge community and the tools required to make this happen, we are trying to build a new norm of collaborative discussion. Also, using a design-based lens to examine *in situ* interactions of students, this study aimed to answer the following research questions: **Q1: How does a spatially manipulable interactive note taking tool support students in their collaborative science reasoning? Q2: Using a design-based research approach, what improvements can be made to the tool to better support these collaborative interactions?** Below, we investigate the students' interactions across both lab and classroom implementations of a novel knowledge community tool, the Idea Wall, at both the individual and group levels.

2 METHODS

2.1 Idea wall

The Idea Wall is a spatial manipulative collaborative tool that can be used alone or as part of the SimSnap environment, a middle

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Table 1: Coding schemes

Code	Definition	Example	Reference
Idea Generation	Every time when students make a new note	[Student adds a note to the idea wall: note: "How lush the planet maybe"]	Adapted from [9] and [7]
Making Suggestions (Physically - moving notes)	Moving a note to yes/no/combine/ or neutral zone (either move their own notes or other's notes)	[Student moved a note to the No Zone note: "I think that too much water will drown the planet"]	Original from [7]
Rise above	Students generate a deeper formulation of their understanding of the topic such as synthesizing key ideas together", or assign tags etc. by using the combine zone	[Student combined note: "The abiotic factor" and note: "water soil sunlight"]	Original from [9]
Making suggestions (Verbally)	"Making verbal suggestions and giving opinions" verbally	Student: "let's combine this."	Original from [7]
Clarification	Asking for clarification of verbal or physical suggestions, also clarify other's ideas	Student: "Excuse me, who said how lush the planet maybe?"	Adapted from [14]
Negotiation verbally	Explanation of own ideas, Justification of own actions, Verbal blocking: telling others to 'stop' or 'put it back'	Student: "That's not relevant to making plants grow. I also have edible plants."	Original from [7]
Off-task talk and behavior	Verbal and nonverbal interactions not relevant to the prompt	Two students talk about a game they have played	Adapted from [12]
Maintaining joint attention and awareness	Narrate your actions to inform others or make your actions visible to others	Student: "That's not important? no wait, it's important to make plants grow, photosynthesis makes plants grow."	Adapted from [7]

school biology course created by a team from the University of Illinois Urbana Champaign, UW-Madison, and Toronto Metropolitan University. In small groups, students discuss assigned topics such as factors that influence plant growth using the Idea Wall. They can view and copy previous notes from the Sim Snap Notebook and add their own notes to the interactive Idea Wall. The tool has Yes, No, and Combine Zones, color-coded for easy manipulation and consensus-building (Green for Yes, Red for No, and Brown for Combine Zones). Notes become the color of the zone to which they are attached. After reaching a consensus, students move ideas to Yup or Nope boxes or combine them in the Combine Zone. All students must agree on the final set of notes before submitting, which becomes part of each student's digital notebook or facilitates whole-class discussion if sent to the main screen.

2.2 Activity

We developed a 5-day middle school biology unit on the role of plants in ecosystems and the impact of abiotic factors on their growth. The Idea Wall served as a collaboration tool for knowledge building during Days 1-3, accommodating various social configurations, from individual to whole class and small group discussions. Before class implementation, a lab experiment was conducted with 4 students to test the mechanics of the Idea Wall. The same instructions were given to a small group of 4 students in a larger classroom setting of 20 students, one teacher, and 4 researchers. Days 2 and 3 focused on factors influencing plant growth and hypotheses about plant growth, respectively. Students used the Idea Wall to discuss their ideas.

2.3 Participants

Participants were Twenty-four 8th grade students and one teacher from a STEAM magnet middle school in the Midwest with a diverse student population. We had the teacher, and the students use our collaboration tool, the 'Idea Wall' over three 45-minutes periods to examine how the Idea Wall could support the knowledge building of students during a mini-unit about the factors that influence plants' growth.

2.4 Data sources and analysis

We recorded student interactions and activities throughout the 5-day study in both class and lab settings using video and audio, including screen recordings of each student's Chromebook. We analyzed the lab study's video recordings to examine the various interactions and conversations between students and with the Idea Wall. Additionally, we analyzed the video recordings of Day 2 and Day 3, where the teacher and students utilized the Idea Wall to facilitate knowledge building on different levels. To allow us to capture different types of interactions including both on and off screen we adjusted the coding system from the CLM [7] and DCLM frameworks [14], the knowledge building coding scheme from [9] and collaboration coding scheme from [12] (See Table 1). Two researchers coded the lab study together, discussed the coding scheme and reconciled the differences, then independently continued coding the videos and audio of day 2 and day 3 of the class study based on the adapted coding system.

3 FINDINGS

In the lab experiment, students interacted for 9 minutes and 44 seconds within a 21 minute and 20 seconds session, with 12 turns of talk, there was no verbal Negotiation, off-task talk or Joint Awareness and Attention. During the Idea Wall interactions, there were 13 Idea Generation, 6 Rise Above, and 19 Making Suggestion Physically events. On Day 2 (in class), students interacted for 8 minutes and 3 seconds within the 9 minutes and 4 second activity. There were 19 turns of talk consisting of 3 Making Suggestion verbally, 1 Accepting Suggestion, 5 Clarification, 2 Negotiation, and 7 Joint Awareness and Attention events. For Idea Wall interactions, there were 6 Idea Generation, 2 Rise Above, and 28 Making Suggestion Physically. The Day 3 class activity was 7 minutes and 45 seconds long, in which students interacted for 4 minutes 23 seconds, conducting 29 interactions consisting of 3 Clarification, and 1 Joint Awareness and Attention, 4 Idea Generation and 13 Making Suggestion events. There were no instances of Making Suggestion, Off-task talk, Making Suggestion or Accepting Suggestion, or Rise Above events, (See Figure 2).

Despite similar instructions, the lab activity had less verbal communication than the class activity. Students talked first in the lab activity, and then talked less frequently while working on the Idea. The class activity had no clear separation between verbal communication and Idea Wall interactions, but still had less verbal communication while working on the Idea Wall. Clarification tended to happen after Idea Generation or physically Making Suggestions, and most occurred during the middle of the session. Neither the lab activity nor the Day 3 activity had any verbal negotiation. In both the lab and Day 2 activities, students stopped interacting with the Idea Wall while making verbal suggestions. Some interactions showed that students used the Idea Wall differently than intended, and some behaviors and intentions were not identified by existing coding schemes. These interactions provide insights for future collaboration tool development and frameworks. Each day had valuable interactions worth discussing in detail.

3.1 Interaction 1 Lab Setting Activity

In the lab setting, the students' collaborative effort resulted in one note in the Yes Zone with the tag "Solutions" titled "Renewable Resources," and two notes in the No Zone with the tags "Solution" and "Examples" titled "Removing Natural

Resources for Unnecessary Cost" and "Waste (Plastic Litter Etc.)," respectively (see Figure 3 screenshot on the right). We observed that the students during the lab experiment considered the Yes Zone and No Zone differently than what we originally designed it for. We designed the Yes Zone for notes that students would agree on, and No Zone for notes that students have disagreement about, the Combine Zone for notes that students see similarities or relations, that they would want to combine and make a new note. The group of students in the lab activity thought the Yes Zone was meant for notes you should do to improve pollution, and the No Zone for things you should not do and would cause more pollution (see Figure 3). They used the spatial orientation of the ideal wall to facilitate their discussion in ways we did not expect based on the affordances of the space. Despite their differing understanding of the functions of digital tools, the students were still able to have a productive discussion and collaboration about the pollution topic. Additionally, towards the end of the activity, the researchers reminded the students about the Combine Zone feature and were told that they had already combined their notes before typing them in, even though no conversation about synthesis had been observed. As a result of this conversation, the students began to use the Combine Zone and ended up with 3 notes out of 11, indicating that they had engaged in a complete inductive reasoning process (see Figure 3, from left to right).

3.2 Interaction 2 Class Activity in Day 2

For the Day 2 class activity, the collaborative topic was: What factor helps plants grow? The group's final results are four notes in the Yes Zone: "Photosynthesis: plant capture sunlight, energy of sun combines w/CO_2 and water to make carbs and oxygen"; "Abiotic factors: Temperature-air-soil-water, sunlight"; "(nutrients transported by water; keeps them standing straight by applying pressure)-soil"; "weather affects plant growth". We noticed that in this activity and group, students had verbal interactions during the collaborative process. We were not able to capture the verbal interactions in the coding, because they were neither content related nor Off-topic. The students were talking about the grouping and submission features while interacting with the Idea Wall. We also observed in this activity that some students are having a hard time fitting all the notes into the Yes Zone. Some of the notes were hiding behind their individual notes and not visible.

3.3 Interaction 3 Class Activity in Day 3

On Day 3, students worked together to generate hypotheses about plant growth. They recorded their final results in three neutral Zone notes, and one note in the No Zone. The neutral Zone notes included hypotheses about plant growth under different conditions, while the note in the No Zone suggested that too much water may harm the plant. See Figure 5 for details. During the activity, a student asked the group for clarification about a specific note by moving it out of the original zone and showing it to others. This action may have helped the group stay focused, but it's unclear whether the student intended to make suggestions by moving the note in and out of the zone. Although the yes and no zones are meant for sharing thoughts and ideas, this new use of the zones helped facilitate conversation. (See Table 2).

4 DISCUSSION

Our observations suggest that when students use the digital tool, they tend to avoid verbal communication. While typing notes to the Idea Wall, students frequently stopped talking, only occasionally making clarifications or suggestions verbally. We expected more verbal interactions, but the collaborative results and final notes students came up with did not allow us to conclude which form of communication resulted in better collaboration. In the next step of our research, we plan to collect more data to investigate the impact of verbal versus non-verbal communication on collaborative learning.

We identified three types of physical suggestion interactions that can indicate different situations in the collaborative process. The first involves students moving notes into the "yes" or "no" zones to

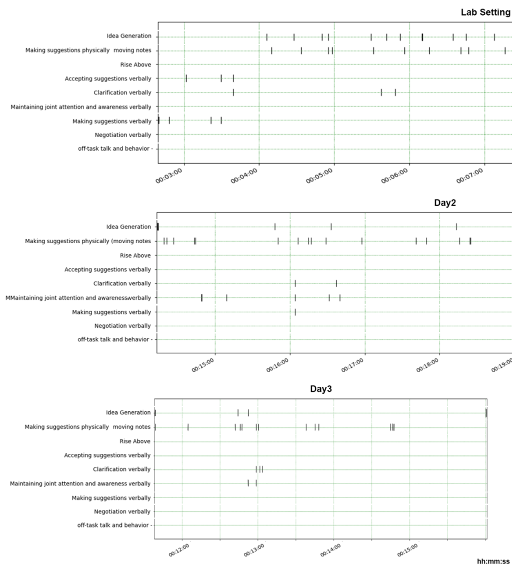

Figure 1: Temporal Analysis of the Three Activity Session

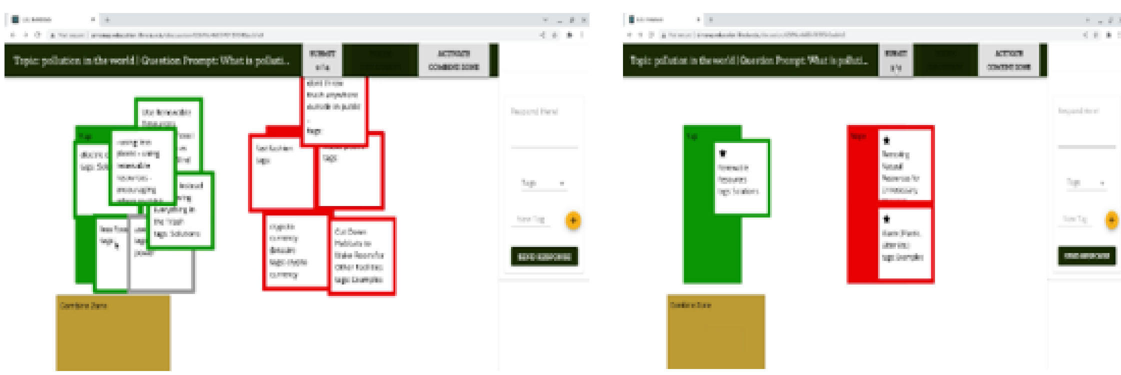

Figure 2: On the left: before the inductive process; on the right: after the inductive process final result from the lab activity

Table 2: Example of the Day 3 Interaction

Time	Interaction	Code
12:14	[Student adds note: "How lush the planet maybe, Type: hypothesis"]	Idea Generation
12:15	[Move note to Yup "How lush the planet maybe", Type: hypothesis]	Making Suggestion physically
. . .	. . .	. . .
12:23	Student: "Excuse me, who said how lush the planet maybe?"	Clarification; Joint Awareness and Attention
12:28	Move note to neutral zone "How lush the planet maybe", Type: hypothesis	Making Suggestion physically
12:32	Student: [Raise his hand in response to the other students] "I said"	Joint Awareness and Attention
12:33	Student: "What does that mean?"	Clarification
12:35	Student: "It means how well the plant grows."	Clarification
. . .	. . .	. . .
13:14	Move note to Yup "How lush the planet maybe", Type: hypothesis	Making Suggestion physically

indicate agreement or disagreement. The second involves students moving notes out of a zone without immediately placing them elsewhere, indicating a need for further consideration or clarification. The third involves students moving notes to the "combine" zone, indicating the identification of similarities and connections between multiple notes. These interactions can provide insight into the collaborative dynamic. For instance, in the lab study, no neutral zone interactions occurred, but on day 3, notes were moved from the "yes" zone to the neutral zone for clarification. We will develop coding schemes for a detailed analysis of these interactions in future studies.

We have three major reflections on the interface design of the Idea Wall. Firstly, Despite the unclear scaffolds in the interface design of the Idea Wall, our observations suggest that it still provides students with the affordances to communicate and facilitate their conversation. Although the students had different interpretations of the functions of the zones, they still had productive collaboration. This suggests that the design's affordances are being used productively, albeit in an unintended way, and may lead to important insights for future design improvements [6]. In future versions of the tool, we need to be clearer in our instructions to students and ensure that the interface design is less prone to multiple interpretations. Secondly, the "combine" zone could be made more visually prominent to help students recognize its function. Finally, the Yes and No zone area might be too small and unstable, making it difficult for some students to work with. Additionally, some students used the tag feature for notes while others did not, which could be a potential area for improvement in the tool's organization.

We recently modified the instruction for using the Idea Wall to improve clarity and used it to facilitate teaching physics and geology via a prompt-based collaboration. The students began the activity outside of the Idea Wall, conducting experiments related to the prompt, and subsequently engaged in a discussion on the Idea Wall to arrive at a joint response to the prompt. We have been conducting these sessions in two classes, recording the students' interactions via video. We recorded the entire class, screen recorded two groups of four students in each class, and tracked each student's involvement in the conversation to further examine how they collaborate to solve problems using the Idea Wall. Our goal is to delve deeper into the physical aspect of making suggestions on the Idea Wall and verbal versus nonverbal communication during the collaboration process. In the next cycle of the Idea Wall, we will address the key reflections on the interface design and the follow up research questions.

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