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Designing and Implementing Web-based Scaffolding Tools for Technology-Enhanced Socioscientific Inquiry

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ABSTRACT

This study explores how web-based scaffolding tools provide instructional support while implementing a socio-scientific inquiry (SSI) unit in a science classroom. This case study focused on how students used web-based scaffolding tools during SSI activities, and how students perceived the SSI unit and the scaffolding tools embedded in the SSI activities. A web-based SSI unit was developed and utilized in a technology-enhanced science classroom, and included three types of embedded annotations (definition, background information, thinking questions). The findings of this study suggest that students benefitted from web-based annotated scaffoldings in their individual reading and group discussions. The effective use of hard scaffolding may have contributed positively to students' engagement in the SSI activities and allowed students to easily explore a variety of context-related hyperlinked resources. In addition, the hard scaffolding tools allowed the teacher greater flexibility to effectively monitor students' learning progress, evaluate students' understanding of the topic, and provide guidance as needed through questioning. A holistic and dynamic approach is recommended when teachers and instructional designers consider how web-based hard scaffolding tools might function to assist students' learning in SSI.

Keywords

Inquiry-based learning, Socioscientific inquiry, Scaffolding, Annotations, Technology-enhanced environments

Introduction

Inquiry-based learning (IBL) has long been considered important for promoting the understanding and retention of concepts, skills and attitudes that are required for solving ill-structured problems. Recently, socioscientific inquiry (SSI) has been emphasized as a curricular model that engages students in scientific topics while considering associated ethical or social issues. In SSI, students develop their understanding of fundamental aspects of science through a question-driven and open-ended process, which includes inquiry activities, planning and managing investigations, and analyzing results (Edelson, Gordin, & Pea, 1999). Specifically, SSI processes include authentic activities designed to motivate learners to acquire and apply new knowledge. Despite the learning benefits of SSI, students often feel frustrated due to a lack of certain assets, such as (1) domain specific knowledge (Bell, Blair, Crawford, & Lederman, 2003), (2) analysis and argumentation skills (Krajcik et al., 1998), (3) the ability to manage information and determine relevance (Hogan, 2002), and (4) the ability to monitor and reflect on their own learning processes (Quintana et al., 2004).

Many researchers have argued that scaffolding provides the framework for assisting students with these challenges. Scaffolds are tools, strategies, and guides that help individual learners to accomplish tasks that are beyond their ability to complete alone (Vygotsky, 1980). Scaffolding can appear in multiple forms depending on the various types of support provided to engage students in an inquiry-based learning activity. Saye and Brush (2002) conceptualized two forms of support: hard and soft. Hard scaffolds are static supports that can be planned in advance in anticipation of potential difficulties with a task. These support structures can be embedded within learning environments to provide students with support while they are actively engaged with a problem (Krajcik et al., 1998; Simons & Klein, 2007). For instance, prompts designed to give definitions or background information for concepts can help students better understand a specific issue during the problem-solving process (Simons & Klein, 2007). In contrast, soft scaffolds are dynamic, situation-specific supports provided by a teacher to help with the learning process. This includes teachers' clarification of tasks or monitoring of students' progress (Kim & Hannafin, 2011a), which requires teachers to continuously diagnose learners and provide timely support based on student responses. This type of assistance is generally provided "on-the-fly," where the teacher monitors students' progress while engaged in a learning activity and intervenes when support is needed (Saye & Brush, 2002).

Given that hard and soft scaffolds interact in dynamic ways in a classroom context (Kim & Hannafin, 2011a), it is essential to investigate what supports can be provided by scaffolding tools and what supports can be offered by the teacher to optimally facilitate problem-solving among students. For example, as students generate problem solutions, opportunities to assist students with integrating discrete fragments of evidence into a broader problem context may be incorporated into an inquiry-based unit via additional small-group discussion sessions with the teacher (Saye & Brush, 2004), which would be difficult to provide as a “hard” scaffold.

Scaffolding research typically has focused on certain features and affordances of technology in various settings rather than on the holistic use of scaffolds to support the overall learning experience (Kim & Hannafin, 2011a). Little is known regarding how students experience different types of scaffolding in SSI classrooms. Furthermore, as a relatively new curricular model, few studies have documented the roles of soft and hard scaffolding during SSI activities in classroom practice. Therefore, investigating different types of scaffolding and how they function in different contexts may expand our understanding of how to support and facilitate learning during SSI instruction.

Literature review

Web-based scaffolding tools for inquiry-based learning

Web-based resources have been widely developed and utilized to support students during IBL activities (Lee & Calandra, 2004; Oliver & Hannafin, 2000). For instance, web-based multimedia resources in multiple formats (i.e., audio, text, visual) can represent various perspectives and enable the presentation of authentic examples, thus promoting learners’ cognitive flexibility (Jacobsen & Spiro, 1995). Despite these potential benefits, it has been reported that learners sometimes feel confused and overwhelmed when utilizing web-based multimedia (Jonassen, 1989; Romiszowki, 1990). In order to relieve learners’ cognitive burden without excluding the potential advantages of web-based learning environments, researchers have highlighted the importance of scaffolding and the benefits of web-based scaffolding tools incorporated into IBL activities (Lee & Calandra, 2004).

Some researchers have reported that web-based scaffolding tools are effective in promoting students’ scientific reasoning skills (Lee & Calandra, 2004; Walker & Zeidler, 2007). For example, Lee and Calandra (2004) reported that annotations embedded in web-based resources encouraged students to access prior knowledge which is essential in understanding contextual information and generating their own explanations during problem-solving. Walker and Zeidler (2007) studied SSI instruction which utilized the Web-based Science Environment (WISE) and found that the environment facilitated students’ exploration of multiple perspectives with various resources. Findings also suggested that engaging in SSI instruction using WISE was not sufficient to promote their understanding of topics as well as acquire scientific skills. Without any guidance in SSI, students produced hasty conclusions or generalizations, or did not make explicit references to a conceptual understanding of the nature of science during classroom debate. However, researchers did find that guiding questions embedded within the WISE environment may have assisted students in recognizing potential bias in information presented to them on-line. This suggests that hard scaffolding tools embedded in web-based instruction may facilitate learner’s scientific inquiry skills in SSI.

As a result of the increased use of IBL, researchers have expanded the classifications of hard scaffolding and guidance about how to integrate hard scaffolds into IBL activities to support students’ learning (Linn, Clark, & Slotta, 2003; Raes, Schellens, Wever, & Vanderhoven, 2012; Williams & Linn, 2002). Hard scaffolding tools include conceptual scaffolds that provide definitions of new terms or web-based resources (Hannafin, Land, & Oliver, 1999), strategic scaffolds that embed expert advice as text-based responses (Simons & Klein, 2007) or video clips to assist students in evaluating alternative approaches to address problems (Pedersen & Liu, 2002), and metacognitive scaffolds that provide evaluation criteria or thinking questions to help students in monitoring and evaluating their progress in completing specific learning activities (Davis & Linn, 2000; Shin & Song, 2015; Wesiak et al., 2014).

Researchers have investigated how learners use web-based scaffolding tools and resources through IBL activities (Belland, 2010; Kim & Hannafin, 2011b). For example, Kim and Hannafin (2011b) explored how 6th graders use peer-, teacher-, and technology-enhanced scaffolds in their classroom during their scientific inquiry activity on WISE, which was used to promote students’ knowledge integration of science topics. Embedded scaffolding, including inquiry maps, hints, and prompts helped learners monitor and reflect on their progress while engaged in inquiry activities. The researchers found that students perceived the embedded scaffolds as useful in helping them focus on important resources to organize evidence needed to support their argumentation. In Belland’s (2010) study, the Connection Log was utilized in a web-based environment, allowing students to respond to prompts and collaborate with peers. Students used the Connection Log to organize information, share their work, and manage group work throughout the problem-solving process. Results found that scaffolds may assist students in articulating their thoughts and facilitate their thinking processes during problem-solving activities.

Purpose of the current study

Although some studies have investigated how scaffolding tools are utilized through IBL, most research has emphasized the effectiveness of hard scaffolding tools in increasing student performance (Kim & Hannafin, 2011a). While measuring students' achievement has value, there has been relatively little research on how those scaffolds are utilized to support inquiry-based learning strategies such as SSI in a typical classroom. Thus, the purpose of this study was to explore how scaffolding tools can be implemented to support students' SSI activities in a science classroom. Specifically, this study addressed the following questions:

- How do students use hard scaffolding tools during their SSI activities?
- How do students perceive hard scaffoldings embedded in the SSI unit?
- How do hard scaffolding tools support teacher's soft scaffolding during SSI activities?

Method

Research design

This study examined how students utilized and experienced scaffolds integrated into instructional activities, rather than how they evaluated the technology-enhanced classroom itself, by way of an instrumental case study with multiple forms of data (Yin, 2003). Such case studies are used to discover new understandings toward an event, possibly leading toward re-thinking a trend, design, or approach (Marshall & Rossman, 1995).

Participants

A 9th grade biology teacher and his 71 students were involved in the present study. Sixty-two students, including 32 males (51.6%) and 30 females (48.4%), completed the reflection survey, and 12 students participated in focus group interviews. The teacher had nine years of experience teaching science and math, and was recruited from among the recipients of a nationwide award program that recognizes expert teachers of inquiry-based approaches with technology.

Research context

The context for this study was a high school biology course, comprised of four classes taught by the same teacher, offered in a high school in a rural community in the Midwestern United States. The classes met daily for 50 minutes. This course was selected because this case allows for an in-depth examination of teacher-led development of a science inquiry unit that embedded scaffolding in a technology-enhanced classroom. The course aimed to offer students a unique opportunity to advance their inquiry skills through addressing socioscientific issues.

Scaffolding sesign: Socio-Scientific Inquiry Network System

The teacher developed a unit in a web-based learning environment, the Socio-Scientific Inquiry Network (SSINet), in which students explored authentic socioscientific issues in the classroom. SSINet supports science teachers in their design and implementation of SSI curriculum with web-based curriculum design tools that easily allow them to link to and sequence a wide variety of web-based resources for delivery to students. Teachers can use the "Activity Creator" tool to organize resources and hard scaffolds via a web-based "viewer."

In this activity, the teacher embedded color-coded hard scaffolding to provide students with guidance. Using the SSINet tools, the teacher was able to embed "definitions (green)" and "background information (blue)" for difficult concepts and "thinking questions (red)" to focus attention on important concepts and issues relevant to the unit (see Figure 1). Students were able to access this information via the activity viewer (see Figure 2).

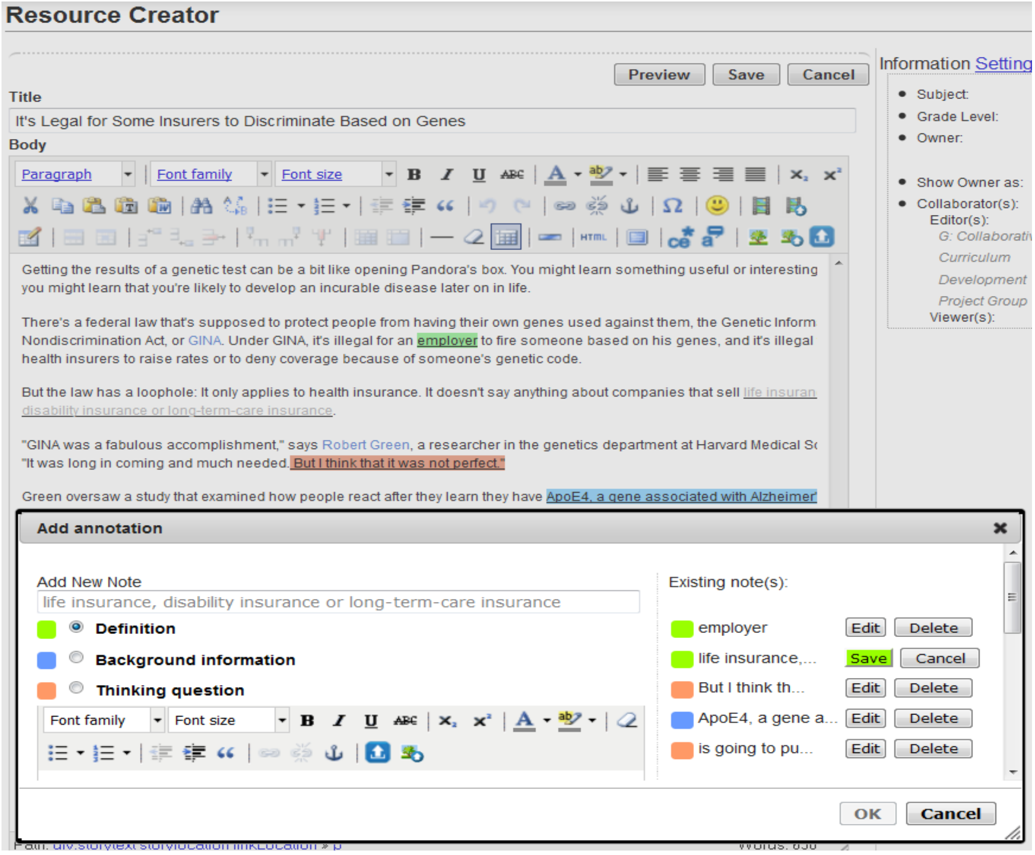

Figure 1. Annotation tool in SSINet

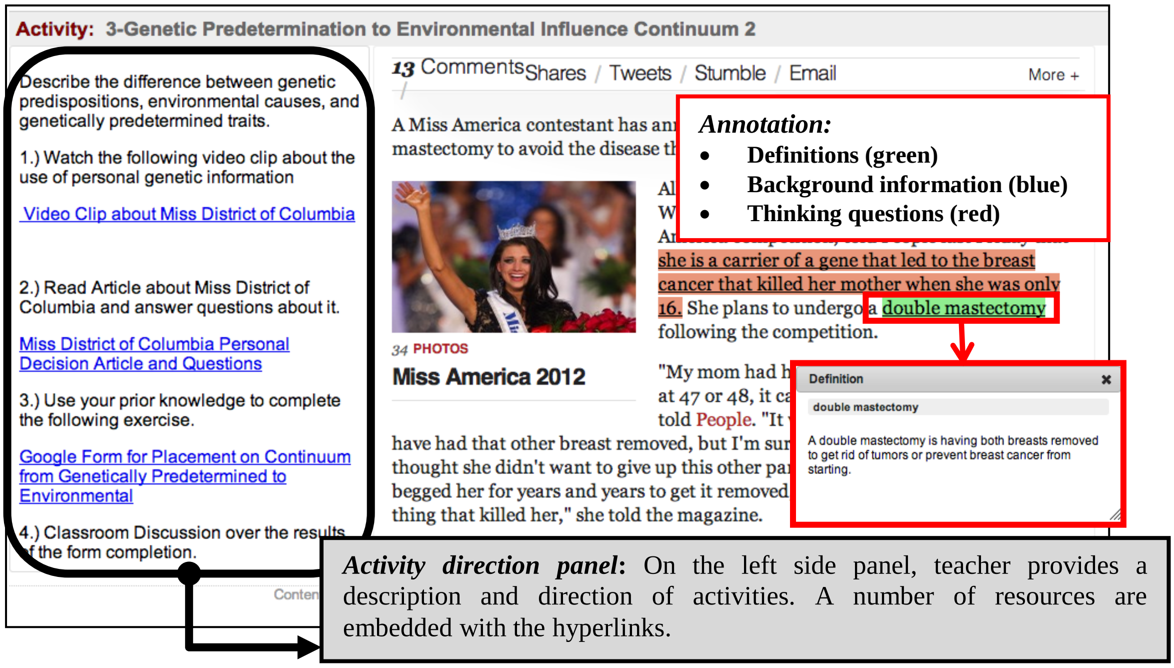

Figure 2. Activity viewer as it appears on students' mobile devices

Teacher-developed inquiry activity

The teacher collaborated with the researchers in developing the SSI unit, which was guided by the following driving question: "When should we use personal genetic information to make decisions?" Students completed a sequence of four SSI activities: Entry event, Jigsaw, Whiteboard, and Culminating activity (see Figure 3).

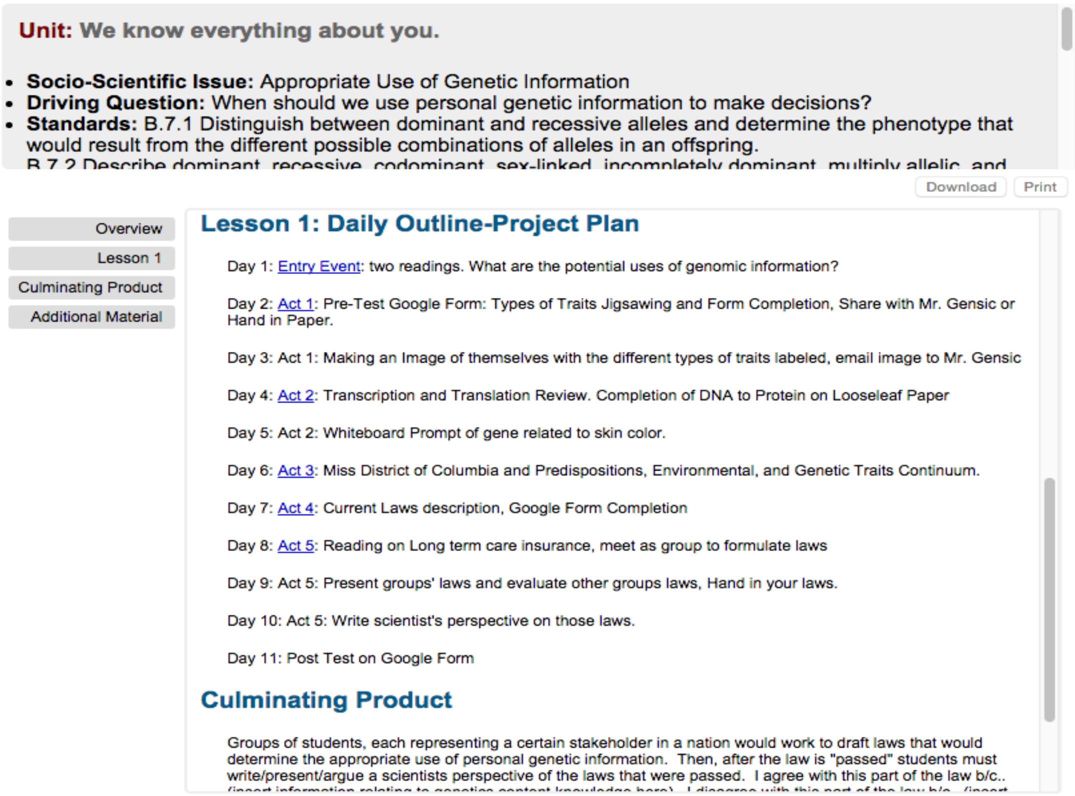

Figure 3. The SSI Unit activity

Data collection

Classroom observations

Two researchers observed classes and recorded field notes during each day of the unit to examine how the teacher used scaffolding to support student progress and how students interacted with resources and tools. Video recordings of the entire classroom and student group activities were also collected.

Screencasts of student screens

Eight students' laptop screens were recorded using QuickTime Player to determine which resources were viewed and used during hands-on activities.

Focus group interviews

The authors followed a purposive sampling strategy to select 12 students for focus group interviews (Creswell, 2012). Four groups of students participated focus group interviews. Each group had three students selected by the teacher to maximize diversity of gender, ability, and motivation in the subject area. The interviews explored students' perceptions of resources and tools that were embedded in the activities. The interviews took place in a classroom, and were audiotaped and transcribed.

Reflection survey

A student reflection survey was administered at the end of the unit and examined students' perceptions about the tools, resources, and inquiry activities. The questionnaire included 10 close-ended and seven open-ended questions. Cronbach's alpha was used to test the attitude items of the survey and the reliability coefficient was 0.75.

Teacher's post-unit interview and debriefings

During the unit, daily debriefings were conducted with the teacher, as well as a post-unit interview. Interview/debriefing questions were related to impressions of the class, including the use of resources and tools in his teaching, perceptions about the strengths and weaknesses of this unit, students' issues or problems, and an assessment of his management of the unit activities.

Procedure

The unit was implemented for eight class sessions. At the beginning of each session, the teacher explained the purpose of the SSI unit and how to access it on the laptops and iPads.

The overarching issue of the unit was introduced with an entry event activity through a case about a woman who had cancer genes. The next six class sessions focused on inquiry activities including: (1) learning about the potential uses of genomic information, (2) examining genetic predetermination and its relation to the environmental influence continuum, (3) investigating when it is legal and illegal to use genetic information, (4) building student opinions, and (5) discussing what laws should govern the use of genetic information.

On the last day of instruction, a reflection survey was administered to students and focus group interviews were conducted. While the class was completing the survey and posttest, students participating in focus group interviews were asked move to another classroom for their interview. Two researchers conducted the focus group interviews based on a semi-structured protocol and asked six to ten questions based on in-class activities. Students were asked to reflect on unit activities (e.g., How do you think that these activities for the unit were different from other activities you have done in this class?), and provide their perceptions of the web-based tools and resources embedded into the SSI unit (e.g., Do you think the tools and resources which are embedded in the activities were useful to you?). Once they completed the interview, students returned their classroom to complete the remaining group activities and reflection survey. Each group interview lasted 10 to 15 minutes, totalling 50 minutes to complete all four group interviews.

Data analysis

Quantitative and qualitative data were collected from multiple data sources to confirm and interpret conclusions (Creswell, 2012). Screencast data were used as a primary data source in order to measure the frequency of usage of color-coded annotations. The total number of visits and amount of time spent using annotations were calculated. Forty-eight annotations were embedded into the SSI unit: 18 as *Definitions*, 12 as *Background Information*, and 18 as *Thinking Questions*. To investigate students' perception of the SSI unit, the reflection survey was analyzed with descriptive statistics. Data from students' and teacher's interviews, screencasts, and observations were coded by researchers and grouped into conceptual categories related to possible factors affecting student inquiry learning. For the third research question, the teacher's post-unit interview and observations were analysed and triangulated using comparative analysis to identify reliable themes (Creswell, 2012).

Results

Students' use of the SSI unit and scaffolding tools

Students frequently used embedded color-coded annotations to explore, find and solve problems using resources that were embedded in the SSI unit. Table 1 summarizes the number of visits to annotations and time spent on each while students interactive the resources that embedded into the SSI unit. The analysis of screen-cast data demonstrated that students accessed annotations that provided thinking questions more often and for longer periods of time than definitions or background information.

Screen-casting data showed that students first skimmed an article by clicking most annotations then later focused on specific annotations when revisiting the resources, particularly the "thinking questions" designed to focus students' attention on key aspects of a resource. In focus group interviews, four students highlighted benefits of using color-coded annotations, particularly as a starting point for understanding the genetic issues. Most groups mentioned that they skimmed through resources, went back to annotations and tried to focus on the important aspects of the content, as the following comment suggests:

> "…that's where I really started skimming through it and picking out key points which helped because I could figure out where the key points were by what he highlighted…" (Focus group 1)

Overall, the findings suggested that students perceived annotations as important and used thinking questions to direct their focus.

Table 1. Usage of color-coded annotations (n = 8)

	Definitions		Background information		Thinking questions	
	M	Total	*M*	Total	*M*	Total
Number of visits	20	180	30	270	45	315
Time spent[a]	29.94	152.46	43.66	212.96	60.28	452.54
(Per annotation)	(1.76)		(2.46)		(3.35)	

Note. [a] = Measured in seconds.

The annotations were also useful when facilitating group discussion. The use of embedded thinking questions helped students to deepen their understanding and analysis during the group activity. In student interviews, one student stated, "…sometimes you click on the red highlighter that gives you questions and when you give it to your partners you discuss them. So, it was kind of interesting, the different questions that they had and how we are giving our opinion on them (Focus group 2)." In addition, data from observations revealed that the activity directions embedded within the activity viewer such as what procedure to follow, what topics to deal with, and what aspects to consider, may have provided strategic scaffolding to assist students as they progressed through the SSI activities. During group activities, the students checked the procedure and key points of group activities by following the prompts with limited guidance from the teacher. In sum, the findings suggested that students perceived the technology-enhanced environments, which facilitated the use of hard scaffolding, as beneficial for helping them focus on the SSI task.

Students' perceptions of the scaffolding tools and resources

Quantitative findings

Students perceived that scaffolding tools helped engage them with the SSI unit by allowing them to learn more about the presented problem and facilitating group work. Table 2 summarizes the descriptive statistics for the students' reflection survey. Results showed that students perceived that the activities helped them learn more about genetics (M = 4.03, SD = .97) and that their experience with group work promoted greater learning (M = 4.21, SD = 1.04). Specifically, students indicated that using mobile devices, such as iPads and laptops, was a positive component in their access to the resources for the unit (M = 4.47, SD = .78).

Qualitative findings

Two themes emerged from analysis of qualitative data: (1) authentic resources facilitated student engagement with IBL and may have helped increase their understanding of content, and (2) students struggled with understanding multiple perspectives and providing evidence to support their positions.

The students believed that the resources and materials embedded in the SSI unit were useful and helpful in terms of increasing their understanding and strengthening their grasp of concepts. Specifically, four groups mentioned in the focus group interviews that various materials, such as video clips, annotated articles, and other media, were authentic and context-based resources related to their real life, which helped them connect with and understand the material:

> "My favorite thing was reading the articles. I liked learning about other people's lives, how genome sequencing affected them…" (Focus group 3)
>
> "I just liked like reading the articles, and watching some of the videos. It helped me understand it better." (Focus group 2)

However, observation and interview data indicated that some students found it difficult to support their position using evidence provided in the culminating activity. Specifically, when asked to identify the most difficult activity in the SSI unit, most of the students mentioned the challenges involved in developing their group presentations. During the focus group interview, one student discussed the challenges associated with this activity, particularly with respect to supporting her opinion with evidence: “Sometimes just agreeing with the rest of the group because you know somebody would put down something and you would be you didn’t all really decide on that. And sometimes coming with the reasons, it's like you know what you want to say but you don’t know how to back it up.” (Focus group 4)

In addition, observation data revealed that some of the groups failed to provide evidence to support their position on the use of personal genetic information. The groups were able to discuss their chosen position on the issue, but the evidence they used to support their position was weak or missing altogether.

Table 2. Students’ reflection survey (*n* = 62)

Item	*M*	*SD*
I enjoy science class.	3.90	1.04
I do well in science class.	4.19	.90
I would like to learn more about how genetic information is used to make decisions.	3.23	1.16
I enjoyed using the iPad/laptop to access the resources for this unit.	4.47	.78
The activities I completed in this unit helped me learn more about genetics.	4.03	.87
I enjoyed the group work I completed in this unit.	4.30	.98
I think working in a group helped me do better on the activities for this unit.	4.21	1.04
I enjoyed completing the final project for the unit.	3.82	.97
I wish the teacher had provided more guidance to my group and myself during the unit.	2.22	1.00
I would like to study other science topics the same way we studied genetics in this unit.	4.14	1.07

Note. 1 = strongly disagree, 5 = strongly agree.

The Role of hard scaffolding tools and soft scaffolding

Supporting self-directed learning

Analysis of student data obtained from focus group interviews and open-ended survey questions revealed that scaffolding tools and resources may have enabled students to conduct their own research more independently. For example, comments made by students during focus group interviews suggested that by clicking the hyperlinks, the students easily accessed necessary information and resources to successfully complete specific activities. One student stated, “it was really organized, and you could easily find things with simple instructions, you can find stuff, it was all set up for you, so you didn’t have to spend half the class finding it (Focus group 1).”

In addition, interview data suggested that hard scaffolds embedded in the activities may have provided more opportunities for independent individual learning. Six students (50%) mentioned in the interviews that utilizing the hard scaffolding allowed them to better manage their learning. For instance, one student explained:

> “Something that I like personally was you have a lot more freedom …and you can work on your own pace as long as you got it done. You didn’t have to try rushing through it or miss things but you also didn’t have to get through, stop, and wait for half an hour until the rest of the class catches up (Focus group 4)”.

The teacher also mentioned in the post-unit interview that hard scaffolds (such as embedded annotations) were useful for his students in terms of exploring the learning content without his direct support: “…. They (students) were able to click on certain words, find out the definitions of the words without me having to explain them, or using a cumbersome dictionary tool. I thought it was useful for that.”

Although hard scaffolding was provided while students were in the process of discussing and developing their presentations, observation of the class suggested that some students still struggled with solving problems. In such cases, soft scaffolding by the teacher may have supported the students by providing modeling and questioning. While conducting the culminating activity, the students experienced challenges to developing their presentation, and the teacher provided specific examples and asked questions to shape their thinking and guide them through the activities. Specifically, survey data showed that the teacher provided sufficient soft scaffolding, which might influence students’ satisfaction with their learning experience (see Table 1). In response to the question “I wish the teacher had provided more guidance to myself and my group during the unit,” only 10% of students indicated that they felt they needed more guidance. In response to the question, “I would like to study other science topics the same way we studied genetics in this unit,” over 75% of students indicated that they enjoyed the experience.

Enabling the provision of timely soft scaffolding

Providing hard scaffolding may have allowed the teacher to assist other students who needed help. In a focus group interview, one student noted: "If he thinks you understand it, then he'll just let you do it by yourself, he spends more time with kids that need help with…things (Focus group 3)." The data from observations, and the teacher's debriefings and interview support this student's assertion. While observing the class, researchers found that the teacher was able to monitor students' progress through the activities, and assess their level of understanding of the content. The teacher moved through the classroom and periodically asked questions of students to both facilitate their understanding and to determine which students may be having difficulty with the content.

The teacher's comments in debriefings and interviews also suggested that hard scaffolding enabled him to secure time for providing soft scaffolding. As he stated, "… [the annotations] allowed me to go around and ask questions as they are reading, because I could kind of see where a student was at, and ask a pertinent question based on that." The teacher also noted that he was able to have more interaction with his students and assess their progress, which in turn allowed him to both adjust the support he provided to some students while in turn giving other students greater independence.

Discussion

The purpose of this study was to examine how learners used the resources and scaffolding tools embedded in an SSI unit to support their learning, and how hard scaffolding tools could support teacher soft scaffolding. The first research question examined students' use of resources and hard scaffolding during their SSI activities. In this study, students benefitted from color-coded annotated scaffoldings in their individual reading and group discussion, specifically as they were identifying SSI issues, exploring background information, and researching evidence. We found that students considered the annotations as supports that the teacher intentionally provided for additional information on reading materials. Analysis of data suggested that students used the annotations as a starting point for helping them better understanding the content and assisting them with their reading comprehension. In addition, based on students' interviews and observations, we identified three benefits of web-based color-coded annotations that may play an important role in promoting greater student engagement in inquiry activities: (1) directing attention to important information, (2) providing structured guidance that enhances learners' interpretation and analysis of problems, and (3) facilitating questions that highlights critical aspects of the problem. As previous studies have suggested, different hard scaffoldings, which were provided in this study as conceptual, strategic and metacognitive scaffolds, can be utilized to alleviate learners' difficulties and facilitate the problem solving process (Shin & Song, 2015; Simons & Klein, 2007). However, the present findings attempt to address the limitations of past studies that investigated the effects of scaffolding on student achievement by identifying how students recognize and use scaffolds to acquire content knowledge or background information during IBL activities.

Another important finding was that students preferred to use strategic scaffolds (e.g., thinking questions, activity guides) while investigating content and participating in activities and group discussion. As a strategic scaffold, thinking questions may help students develop and refine their reflective thinking because question prompts may serve as a cue or guide to focus their attention and continually monitor their learning as they explore the content (Davis & Linn, 2000; Ge & Land, 2003). In SSI, learners deal with problems that accommodate multiple perspectives and incorporate theory or principles in evaluating and supporting their arguments. Research suggests that learners struggle to conduct disciplined SSI with substantial learning loads when simultaneously managing the necessary reasoning skills and new content, and strategic scaffolding may relieve their cognitive burden and promote their problem-solving processes (Walker & Zeidler, 2007).

The second research question investigated learners' perceptions of the SSI unit and scaffolding tools. The findings suggest that the effective use of hard scaffolding may have contributed positively to students' engagement in the SSI activities, especially through the activity viewer which allowed students to easily explore a variety of context-related hyperlinked resources. In SSINet, the activity viewer presented resources with embedded hyperlinks on the left side, which enabled students to explore the resources on the right side of panel by clicking the hyperlinks. This structure also facilitates the navigation of other resources (i.e., review the guidelines of activities, revisit resources from the left panel). This SSINet tool feature may promote learners' cognitive abilities to investigate essential information without eliminating the benefits of non-liner features found in hypermedia learning environments. In addition, in this study, the students indicated that the resources related to their own life experience were helpful for understanding multiple perspectives and increasing their understanding of actual social problems. These different interactive scaffolds may positively impact students' satisfaction with the SSI unit and acquisition of content knowledge. While the rich and numerous resources seemed to play a positive role in the students' initial engagement, these resources and scaffolds may also have sustained effects as students build and contextualize new knowledge in meaningful ways (Schank, 1999).

However, students encountered challenges while conducting the culminating group activities, suggesting that additional hard scaffolds may be needed to support their learning throughout the entire process. Specifically, student feedback indicated that learners sought additional annotations, including examples or expert explanations, for help with representing the central issue from multiple perspectives and modelling problem-solving processes such as developing claims and evidence. Students' difficulties with linking evidence to specific problem contexts might be due to their lack of experience in making arguments and limited opportunities to develop and support knowledge claims with evidence (Kim & Hannafin, 2011b; Krajcik et al., 1998; Zeidler, Walker, Ackett, & Simmons, 2002). For example, Kim and Hannafin (2011b) found that 6th grade students failed to examine evidence during a science inquiry activity. They reported that learners' difficulty in generating their arguments with supporting evidence was influenced by their limited inquiry strategies and understanding. The results of this study suggest that additional hard scaffolding, such as strategic scaffolds that guide students while building arguments, might be needed to facilitate more effective decision- making processes among student groups while developing their group presentations.

The third research question focused on the role of soft and hard scaffolding. The findings suggest that hard scaffolding may play a significant role in increasing teachers' ability to provide timely soft scaffolding to students. While interacting with the resources and scaffolding tools embedded in the SSI unit, some students were able to independently identify problems, investigate resources and content, and construct their own arguments. This in turn allowed the teacher greater flexibility to effectively monitor students' learning progress, evaluate their level of the understanding, and provide guidance as needed through questioning.

Since individual learners frame their arguments around their own experiences and prior knowledge (Kim & Hannafin, 2011b; von Aufschnaiter, Erduran, Osborne & Simons, 2008), they may need specific and differential support to complete various tasks required of them during an SSI unit. However, a teacher may not be able to provide appropriate guidance to facilitate problem solving processes to individual students in K-12 classroom environments because of limited time and resources (Hmelo-Silver, 2004). Similar to previous studies on hard scaffolding in classroom environments (Saye & Brush, 2001; Simons & Klein, 2007), the results of this study suggest that providing differential hard scaffolds can create more time for teachers to provide soft scaffolds when necessary. In this study, hard scaffolds helped guide some students through the process of solving socioscientific problems by themselves, which allowed the teacher to prioritize other students' needs for additional support. The teacher was able to provide timely soft scaffolding by questioning and modelling while monitoring and evaluating all of his students' progress through the SSI activities.

Implications and suggestions for future research

Although this study has allowed us to explore the role of hard and soft scaffoldings in a typical science classroom environment, the findings cannot be generalized, and should be articulated and expanded with further research in different settings. Nonetheless, the results of this study do contribute a clearer and more nuanced perspective of teachers' and students' experiences with scaffolding in technology-enhanced classroom environments, and help to refine conceptions of hard and soft scaffolding related to inquiry-based learning activities. First, hard scaffolds embedded into the SSI unit might support learners in overcoming barriers to dealing with ill-structured problems, which are central to SSI activities. Given that students focused more on the annotated elements, instructional designers should consider carefully how students perceive scaffolding tools and how and what condition they used it. Practically, utilizing scaffolding tools interacted with complexed and dynamic situations in an actual classroom. Considering that students' prior knowledge and experiences may affect their use of scaffolding tools, further research is needed to investigate learners who experienced challenges during the inquiry processes in order to gain additional insight regarding improved scaffolding design to support those learners.

Secondly, providing authentic and relevant resources that directly link the problem to authentic situations may have been helpful in terms of building students' background knowledge and provoking their initial motivation. Most students reported that the resources and scaffolding embedded in the SSI unit were interesting and meaningful due to their realistic relationship to real-world problems. In order to enhance the impact that scaffolding has on learners' engagement, it is crucial to provide authentic resources and tasks that students can meaningfully relate to their own experiences.

Finally, it is important to understand and clarify the teacher's role during disciplined inquiry in technology-enhanced classroom environments. Although the hard scaffolds embedded in the unit activities did assist leaners' inquiry activities, the teachers' soft scaffolding, in the form of questioning or modelling, remains essential for monitoring student progress and promoting greater understanding. However, results of this study did suggest that the hard scaffolds (particularly the annotations and the linked resources) assisted the teacher with targeting additional soft scaffolding to students who were struggling with specific SSI activities. To better support IBL activities in technology-enhanced environments, researchers should further explore the relationship between hard and soft scaffolding, and consider how to best align scaffolding supports with different elements of the learning environment. To accomplish this, further research is needed to investigate in more depth the relationships and outcomes of employing different types of soft scaffolding in tandem with hard scaffolding in classroom environments.

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