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DEVELOPMENT ARTICLE

Examining the hard, peer, and teacher scaffolding framework in inquiry-based technology-enhanced learning environments: impact on academic achievement and group performance

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Abstract
The purpose of this study was to examine how students' academic achievement and group performance related to their perceptions of the usefulness of hard, peer, and teacher scaffolds. A single instrumental case approach that integrated quantitative and qualitative analysis was employed for this study, which involved data gathered from 163 students in a ninth-grade biology course. Statistical results suggest that the students' perceived usefulness of hard scaffolding, followed by peer scaffolding, was the most significant variable to predict individual academic achievement. However, only the perceived usefulness of peer scaffolding was found to be a significant predictor of group performance. This finding empirically points to the positive impact that student perceptions of the usefulness of hard, peer, and teacher scaffolds may have on students' individual academic achievement and group performance in IBL (inquiry-based learning) activities.

Keywords Inquiry-based learning · Hard scaffolding · Teacher scaffolding · Peer scaffolding · Technology-enhanced classroom

Introduction

Inquiry-based learning (IBL) is a form of active learning that starts with students posing questions about a particular topic. By engaging in inquiry activities, students pursue the answers to their questions and come to understand they can take responsibility for their learning. IBL has been considered an effective instructional model to promote critical

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thinking, reasoning, and problem-solving (Kim and Hannafin 2004; Savery and Duffy 1996; Singer et al. 2000). In IBL, students have responsibility for setting learning goals, and managing and monitoring their activities to meet those goals (Hannafin et al. 1999; Palincsar and Brown 1984; Palincsar et al. 1987). However, due to the characteristics of the student-oriented, open-ended inquiry process, students may experience difficulties with limited guidance from a teacher, especially when they do not have sufficient prior knowledge and experience (Kirschner et al. 2006; Sweller 2010), and require significant scaffolding to work through problem-solving processes (Kim and Hannafin 2011a).

Scaffolding can be defined as assistance from adults or experts that enables students to achieve what is beyond their ability to accomplish independently (Wood et al. 1976). From a social constructivists perspective, scaffolding comprises all those student–teacher interactions that help students develop important knolwedge, skills, and dispositions deemed useful for students (Vygotsky 1980; Wertsch et al. 1980). The concept of scaffolding has expanded to include aid provided not only by teachers but also by peers who are more knowledgeable, such as peers who can help others complete tasks beyond their capability in a classroom environment (Kim and Hannafin 2011b). In addition to peer and teacher scaffolding, recently, alternative resources and tools are also seen as scaffolding, such as designing and using technologies to support learning. These types of scaffolding are considered to be hard scaffolding. Hard scaffolding refers to static supports (fixed, stable, preset) that can be planned in advance in anticipation of potential difficulties with a task (Saye and Brush 2002), and it has been widely developed and used to assist students during IBL activities (Lee and Calandra 2004; Oliver and Hannafin 2000). For instance, hard scaffolding can represent different perspectives through expert videos that provide problem-solving strategies as hints, or provide authentic examples in video or text format to aid understanding of specific situations or concepts that may be required to solve problems (Lee and Calandra 2004). In addition to studying hard scaffolding in learning activities, researchers have investigated the effectiveness of hard scaffolding on students' learning outcomes (Linn et al. 2003; Williams and Linn 2003). Some have reported that hard scaffolding is effective in promoting students' understanding of domain knowledge as well as scientific reasoning skills (Lee and Calandra 2004; Walker and Zeidler 2007).

Although some research has reported a positive impact of scaffolds on students' knowledge retention and inquiry skills, other research has identified several deficiencies in approaches that only use hard scaffolding. For instance, limitations may emerge when scaffolding excludes interactions between students and more advanced learners or teachers. Students who use hard scaffolds without such interactions might not adequately internalize information presented to them (Krajcik et al. 1998; Lakkala et al. 2005; Li and Lim 2008). Recent scaffolding studies have suggested that inquiry frameworks emphasize peer and teacher facilitation to engage students in inquiry learning while learners interact with scaffolding tools (Choi et al. 2005; Crawford 2000; Kim and Hannafin 2011a; Shin et al. 2017; Wu and Pedersen 2011). Previous studies have demonstrated that both peer and teacher scaffolding support learners' disciplinary ways of thinking and facilitate collaborative group work in IBL, and that students benefit from these scaffolds with respect to modeling the inquiry process and co-constructing knowledge on a given topic (Hovardas et al. 2014; Van de Pol et al. 2010). As such, scaffolding frameworks have demonstrated that hard, peer, and teacher scaffolding are of key importance in assisting students' learning in IBL.

Students' perceptions of the usefulness of scaffolding may be a critical component to how or why they utilize scaffolds in their learning. In IBL, students draw on their own experiences and prior knowledge during classroom activities, which may impact their use of scaffolding and their evaluations of the utility of different forms of scaffolding

(Bransford et al. 1999; Prince and Felder 2006). Accordingly, while carrying out learning tasks, students interpret activities through their different perspectives and selectively use scaffolds in ways that fit their individual needs and goals (Lepper et al. 1997; Sharma and Hannafin 2005). Within this context, teachers design IBL activities and provide scaffolding based on their own understanding of the learners' thinking processes during the activities (Hwang et al. 2015; Lin et al. 1999; Sharma and Hannafin 2005). Thus, even though teachers provide scaffolding with instructional goals aimed at all of their students, such as facilitating thinking processes or reducing difficulties, learners' individual interpretations and perceptions of scaffolding may be an important factor related to how they actually utilize and interact with different types of scaffolds. By extension, this could impact students' learning outcomes in IBL. Given that different types of scaffolding interact with each other within technology-enhanced classroom settings, it is important to better understand what forms of scaffolding learners perceive to be useful and appropriate for their learning in order to design and provide effective contextual scaffolding in IBL.

While integrating multiple scaffolding resources from technology tools, peers, and teachers may be a critical strategy for facilitating learning, this scaffolding framework has not yet been empirically tested in K–12 classroom settings. Considering this framework involves students seeking help from their teachers and peers while utilizing multiple scaffolds in order to obtain their learning goals in an actual classroom (Kim and Hannafin 2011a, b), it is important to test whether students' perceptions of the usefulness of hard, peer, and teacher scaffolds impact their learning outcomes with respect to individual achievement (e.g., posttest on domain-specific knowledge) and group performance (e.g., argumentation skills, problem-solving skills). The current study addresses this research gap and aims to empirically test whether students' individual academic achievement and group performance are related to the perceived usefulness of three different types of scaffolding.

Theoretical framework

Hard, peer, and teacher scaffolding in technology-enhanced classroom environments

Scaffolding can be defined as a cognitive and social support in which a more knowledgeable person, such as teacher or adult, guides an individual learner and provides a basis needed to solve a task (Wood et al. 1976). The concept of scaffolding, which emerged from sociocultural theory, assumes that learning occurs in the context of social interactions (Vygotsky 1980; Wertsch et al. 1980). One crucial aspect of successful scaffolding is that students work within their zone of proximal development (ZPD), which is defined as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky 1980, p. 86).

In practice, however, it is difficult to accommodate the ZPD of individual students in an actual classroom context; having a single teacher provide scaffolding for an entire class does not allow for personalized exchanges that more fully address the ZPDs of different students (Puntambekar and Hubscher 2005). In order to fill this gap, the notion of scaffolding has expanded to include interactions beyond those limited to individual teacher–student exchanges. Scaffolding now encompasses peer interactions (Ge and Land

2004), instructional strategies (e.g., formal/informal assessments, guided activity, modeling; Kim and Hannafin 2011a), and hard tools and resources (Puntambekar and Hubscher 2005).

Various types of scaffolds can be used and designed in multiple forms to engage students in inquiry learning activities. Saye and Brush (2002) categorized scaffolding as hard and soft. Hard scaffolds are pre-planned static forms of support that are designed to help students through anticipated difficulties with a particular task. These can be formatted as question prompts, check lists, or concept maps to support learners' problem-solving processes or to provide certain concepts or knowledge while they are actively engaged with a problem (Belland 2010; Krajcik et al. 1998; Shin and Song 2016). In contrast, soft scaffolds are dynamic forms of support that are provided by a teacher or peer to help with the learning process. This type of assistance is generally provided on the fly when, for example, a teacher monitors the progress students make while engaged in a learning activity and intervenes when support or guidance is needed (Pea 2009; Saye and Brush 2004). In addition, Kim et al. (2007) proposed the "microcontext" framework, which describes particular classroom environments in which students build their knowledge with more capable others by interacting with inquiry tools, teachers, and peers. In this framework, three different scaffolds interact with each other: (1) students engage in problem-solving processes using Web-based inquiry tools (student–tool interaction), (2) teachers design and develop hard scaffolding to support their students' activities (teacher–tool interaction), and (3) teachers facilitate and assist students' IBL activities through different types of scaffolding strategies (teacher–student interaction).

When considering technology-enhanced classroom environments, the three different types of scaffolds interact with each other and play a pivotal role in the IBL classroom context (see Fig. 1). Hard scaffolds are designed by teachers in advance to support students' inquiry learning activities. Students engage in a number of different IBL activities such as identifying and defining issues, developing arguments, and reflecting on and evaluating learning processes. These IBL processes are facilitated by peer scaffolding while also utilizing hard scaffolding. In addition, student groups may seek further help from their

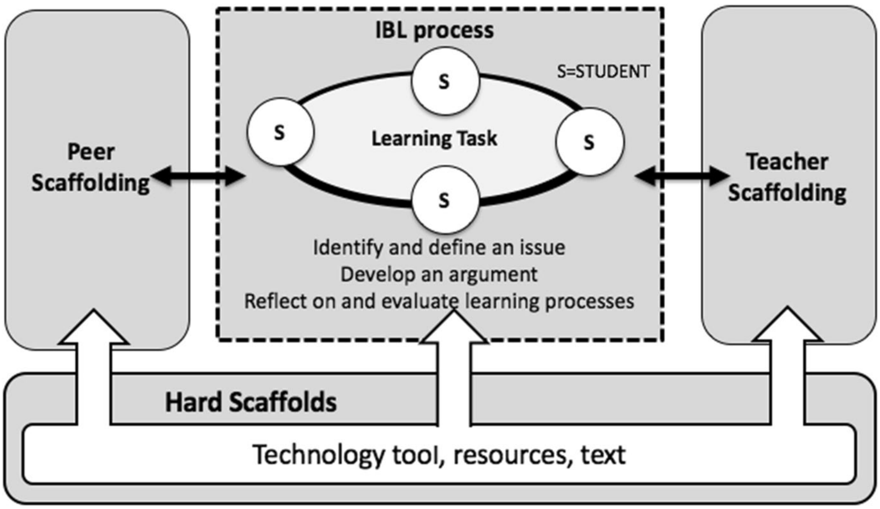

Fig. 1 Hard-, peer-, and teacher scaffolding in technology-enhanced classroom environments

teacher. In this way, hard, peer, and teacher scaffolding interact with one another dynamically in the classroom environment. Hard scaffolding may promote students' understanding of content and activities, as well as engage them in group discussion (Shin et al. 2017). At the same time, a teacher monitors the progress of individual students or groups to see if they are using their instruction time effectively, and students engage in their activities and receive help from hard and peer scaffolding. Taken together, this scaffolding framework shows that diverse forms of hard, peer, and teacher scaffolding interact in dynamic ways to help learners during their activities in a classroom context, and this process needs to be understood and considered from a broad perspective.

Students' perceptions of the usefulness of hard, peer, and teacher scaffolds in technology-enhanced classroom environments

Previous literature highlights the positive influence that scaffolding tools have on students' individual achievement, such as their understanding of domain knowledge and underlying scientific concepts (Demetriadis et al. 2008; Demetriadis and Pombortsis 1999; Jacobson and Archodidou 2000; Reiser 2004). Lee and Calandra (2004) reported that annotations embedded in a Web-based unit facilitated students' prior knowledge, which is crucial for understanding background information and developing arguments with evidence during the problem-solving process. Reiser (2004) found that hard scaffolding provided a supplementary structure that assisted learners' problem-solving processes with opportunities to better understand underlying scientific concepts. In another study, 10th grade students engaged in problem-solving processes utilizing Web-based organizational scaffolding tools in the form of a research plan template and question prompts (Zydney 2010). This results were consistent with findings from other studies that revealed students demonstrated a basic understanding of a problem if assisted by scaffolding tools.

In addition, some researchers have found that different types of hard scaffolding are effective in fostering students' scientific inquiry skills such as scientific reasoning and argumentation, skills that are considered a part of group performance in this study since they can be acquired through group inquiry work (Lee and Calandra 2004; Walker and Zeidler 2007). For example, in Belland's (2010) study, a "Connection Log" was utilized in a Web-based environment to allow students to respond to prompts and share answers with peers. The students used the Connection Log to organize information, share their work, and manage and monitor group work throughout the problem-solving process. The results of this study found that scaffolds may assist students in articulating their thoughts and facilitating their thinking process in problem-solving activities. Kim and Hannafin (2011a) explored how sixth graders used peer, teacher, and technology-enhanced scaffolds in their classroom during a scientific inquiry activity centered in the Web-based Inquiry Science Environment (WISE), which online resources that promotes knowledge integration of science topics. Embedded scaffolds were available to the students and included inquiry maps, evidence pages, hints, and prompts to help them monitor and reflect on their inquiry activity. The students used electronic notes as a metacognitive scaffold to build an inquiry plan and construct and revise their conceptual understanding of the topic, and they frequently used WISE's scaffolds to identify and resolve the problem. The researchers found that the students perceived the embedded scaffolds (e.g., Web links) as useful in helping them focus on important resources as well as organize the resources and evidence needed to support their argumentation. Walker and Zeidler (2007) investigated the use of WISE in SSI (socio-scientific issues) instruction, which highlights the application of scientific and moral reasoning to real-world situations, in science education. Their findings suggested that, by presenting various resources, WISE assisted students' learning processes with respect to identifying multiple viewpoints. The study also emphasized the role of hard scaffolding embedded in WISE; the embedded guiding questions may have helped students in identifying potential bias in online information. However, the researchers found that engaging in inquiry instruction using WISE was not sufficient to promote students' understanding of topics or acquisition of scientific skills. Without any guidance in inquiry-oriented learning, students produced hasty generalizations and did not make explicit references to a conceptual understanding of the nature of science during the classroom debate. This suggests that hard scaffolding tools embedded in Web-based instruction may partially, though not fully, facilitate learners' scientific inquiry skills in IBL.

While the potentially positive effects of scaffolding tools are compelling, few studies have investigated the effectiveness of hard scaffolds in light of its interactions with other types of scaffolds provided by peers and teachers (Liu and Tsai 2008; Van de Pol et al. 2010). Although the scaffolding framework is constructed based on previous studies, most scaffolding research in this area has focused on how hard scaffolding impacts students' learning outcomes (Belland 2010; Cho and Jonnasen 2002; Demetriadis et al. 2008; Zydney 2010). In K–12 classrooms, teachers and students negotiate many factors that may shape the implementation of IBL, such as students' prior knowledge and experience, teachers' roles and practices, or the overall classroom culture (Coll et al. 2014; Gonzalez and Dejarnette 2015). By extension, students use embedded scaffolding tools designed to alleviate difficulties in substantially different ways depending on situational factors, prior knowledge, and teacher instructions (Kim et al. 2007). Features that serve as guides to the direction of activities, such as instructions, hints, or prompts, can be employed to support different learning goals and activities (Hmelo-Silver and Barrows 2006; Simons and Klein 2007).

Although scaffolding is designed and provided to better support learners' activities, students may differ in how they perceive hard, peer, and teacher support when they interact with these tools. Learners' perceptions of scaffolding are based on their own interpretation and internalization of the scaffolding (Shabo et al. 1997; Sharma and Hannafin 2005), which ultimately influence both their use of scaffolding and their learning experiences. Students' perceptions of scaffolding are positively associated with learning outcomes in areas such as student achievement, critical thinking skills, and attitude (Lee et al. 2011; Mullen and Tallent-Runnels (2006); Yu 2009). For example, Yu (2009) investigated students' perceptions of the usefulness of hard scaffolding designs in promoting their ability to generate questions, which is a critical thinking skill required of self-directed learners in online learning environments, and its influence on their attitudes towards student-generated questions. The finding of this study revealed that students' perceived usefulness of hard scaffolding tended to influence attitude formation, which can be predictive of students' intention to act and use the scaffold in their learning. These results suggest that learners' perceptions of the usefulness of scaffolding as a form of support may be a critical factor that can impact both their actual use of scaffolding and learning outcomes. However, little research has been conducted on the relationship among hard, peer, and teacher scaffolding and student achievement, especially in technology-enhanced IBL classroom environments. Given that multiple forms of hard, peer, and teacher scaffolding interact in dynamic ways in a classroom context, it is essential to further research whether students' perceptions of the usefulness of these three scaffolding types impact their achievement in actual K–12 classroom settings.

Research questions

The purpose of this study was to empirically test whether students' academic achievement and group performance relate to the perceived usefulness of hard, peer, and teacher scaffolding. Specifically, this study focused on the following research questions:

1. How is students' academic achievement related to the perceived usefulness of hard, peer, and teacher scaffolding?
2. How is group performance related to the perceived usefulness of hard, peer, and teacher scaffolding?

Method

Research design and context

This study was designed as an instrumental case study (Stake 1995). It focused on gaining a comprehensive understanding of three different types of scaffolds in IBL activities by exploring students' inquiry learning process with scaffolding tools in a particular case. Specifically, this case study aimed to examine learners' perceptions of the usefulness of hard, peer, and teacher scaffolding and how their perceptions relate to individual academic outcomes as well as group performance.

This study took place in 6 ninth-grade biology classes taught by the same teacher during the 2015 spring semester in a rural community in the Midwestern United States. The teacher had 10 years of experience teaching secondary science and math, and had taught IBL units in his classes for the previous 2 years that he worked at the high school. This biology course was designed so students could pursue inquiry-oriented questions within inquiry activities, which allowed students to identify problems that incorporate scientific phenomena and examine their reasonable solutions in class. The six courses consisted of all freshman students and met twice a week for 90 min. This course was designed to provide students a unique opportunity to develop inquiry skills through addressing authentic and complex issues using Web-based learning materials for their investigations. The high school had provided mobile devices for all students to use for course work, so each student had a laptop or Chromebook with internet access to use the Web-based IBL units, search for relevant resources, and create a group presentation while engaged in the inquiry task. Students were familiar with the IBL process since they had experienced IBL activities in the previous and current school year before engaging in the IBL unit in this study.

Participants

Although 163 students (46% female, 54% male) signed consent forms, four students were excluded from this study because they did not take the posttest. As a result, there were 159 valid responses. The students worked in groups during this project; a total of 41 groups composed of three to five students were included in this study. The teacher grouped students based on their preferences, and each group had been collaboratively working together during the normal course of the curriculum during the school year.

Inquiry unit design

The goal of the unit was for students to be able to understand the flow of energy through an ecosystem in order to help them make connections between related scientific principles and the food that they eat. The 5-day unit posed the central question "Should there be a meat tax?" and included four activities: (1) entry event: exploring background concepts and knowledge about ecology systems, (2) class debate: antibiotic use in healthy animals, (3) pros and cons of eating meat: identifying and defining issues, and (4) culminating activity: constructing and evaluating their argumentation (see Table 1).

Hard scaffolding

The unit was developed in a Web-based learning environment, the Socio-Scientific Inquiry Network (SSINet; https://education.indiana.edu/ssinet), in which students explored authentic socio-scientific issues in the classroom. SSINet supports science teachers in the creation and implementation of IBL curriculum with Web-based design tools that easily allow them to link to and sequence a wide variety of Web-based resources and deliver those resources to students. The "Activity Creator" tool allows teachers to organize resources and hard scaffolds for students via a Web-based "Viewer" (see Fig. 2).

In this activity, in the two categories of hard scaffolding provided (i.e., conceptual and strategic), three scaffolds used color-coded annotations to focus student attention on

Table 1 Description of meat tax unit

Activity	Description
Activity 1: entry Event	An entry event was designed to (a) provide an overview of energy flow through an ecosystem, (b) introduce the driving question for the unit (e.g., should be there a meat tax?), and (c) provide rationale for the societal importance of the driving question The teacher provided a video clip and articles focusing on taxing sugary foods to familiarize students with the concepts of a food tax
Activity 2: class debate	The goal of this activity was to (a) conduct research so that students could understand the use of antibiotics in raising livestock, and (b) understand how "science" research outside of the classroom impacts their daily lives Students were asked to individually read news articles embedded in the Activity Viewer, and then engage in a whole-class discussion focusing on the question "Should antibiotics be used in healthy farm animals to promote their growth?"
Activity 3: quick pros/cons research	Groups of 3 to 5 students generated a list of reasons for meat consumption and against meat consumption. In each group, one student was asked to be an activity sheet recorder and two or four students used the resources embedded in the Activity Viewer to search for details on the pros and cons of each position. While identifying the issues, students were asked to consider the question "Should people consume meat as their primary source of protein?" Based on their research, groups chose their position
Culminating activity	Students engaged in a committee hearing (presentation) in which they played specified roles in society and attempted to persuade the class to adopt their position (either for or against a meat tax)

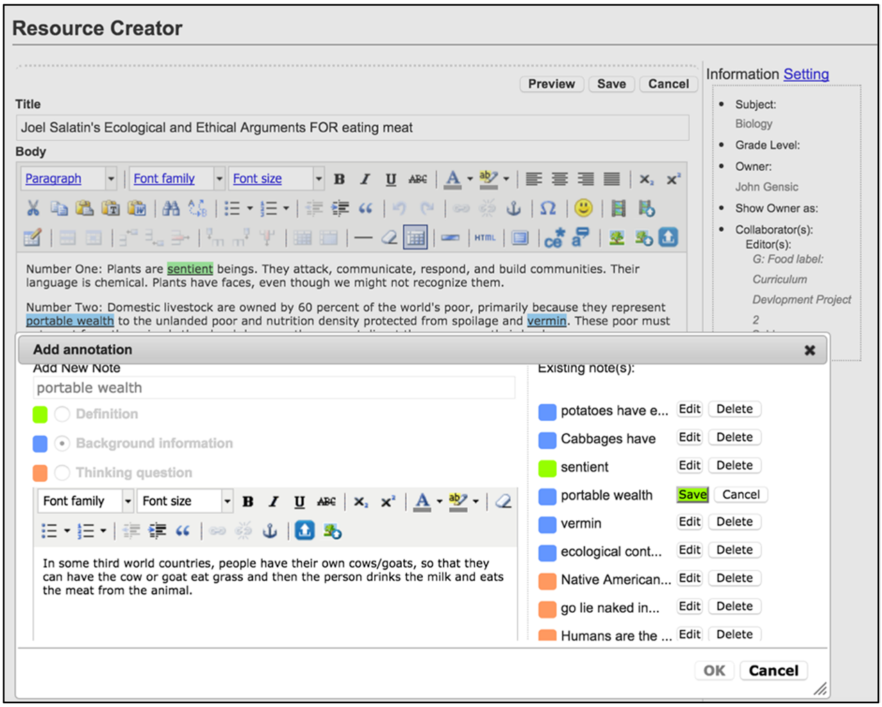

Fig. 2 Annotation tool in SSINet

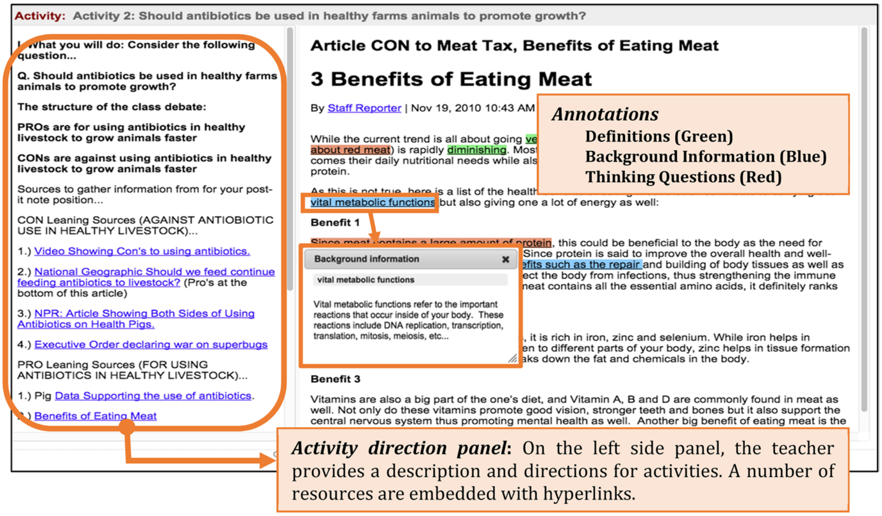

Fig. 3 Activity viewer on mobile devices

Table 2 Hard scaffolding designed for the IBL unit

Types of hard scaffolds	Definitions	Hard scaffolds designed for the IBL unit
Conceptual scaffolds	Provide definitions of new terms or web-based resources (Hannafin et al. 1999; Jackson et al. 2000; Saye and Brush 2002)	Definitions (Green color-coded annotations) Background information (Blue color-coded annotations)
Strategic scaffolds	Embed expert advice in the form of text-based responses (Simons and Klein 2007) or video clips (Hmelo-Sliver and Barrows 2006; Pedersen and Liu 2002) to assist students in evaluating alternative approaches to address problems	Thinking questions (Red color-coded annotations)

important concepts and issues related to the unit (see Fig. 3, Table 2). In addition, the teacher was able to create additional scaffolds using Web 2.0 tools such as Google Forms and Google Docs, and link them to information within the IBL activity. For example, the activity sheet was a Google document that described role assignments and contained group discussion questions embedded in the culminating group activity for the unit. The unit design utilized in this study can be accessed via the SSINet viewer (https://156.56.1.74/pbltec/pad/activity.html?2299).

Measurement

Student survey: students' perceptions of the usefulness of hard, peer, and teacher scaffolds

All scales used in this study were 5-point Likert scales to measure students' perceptions of the usefulness of hard, peer, and teacher scaffolds, ranging from 1 (strongly disagree) to 5 (strongly agree). The 11 items with three constructs were validated in studies by Schepers et al. (2008) and Chu and Chu (2010), and were adopted in this study. Three experts in instructional education and measurement reviewed and validated the developed survey items to ensure they were measuring what they were supposed to measure. In addition, before administering the survey, all items were validated using a "think aloud" method. Seven ninth-grade students who did not participate in the study were asked to complete the survey. After the survey, an interview was conducted with each student to investigate if these students could understand the meaning of the survey as it was developed. Willis's (2005, p. 51) guidelines were used during the interview. To briefly summarize these guidelines and the steps they outline: The interviewer asks the target question (survey item) and the subject responds. Then, the interviewer asks a probing question to which the subject answers. Additional cycles of probing questions and answers are possible, after which the interviewer asks the next target question. Each interview lasted approximately 10 min. Based on the interview responses, examples and descriptions of hard scaffolding (e.g., thinking questions [red], definitions [green], background information [blue]), unit titles (e.g., Matter Cycles, Energy Transfer, and Interdependence), and the website URL, which were embedded hard scaffolding, were added to the items to further facilitate understanding.

The three constructs used in the scales were incorporated based on a study by Schepers et al. (2008). In their study, the scales for the perceived usefulness of hard scaffolding consisted of four items utilized to assess learners' perceptions of the usefulness of hard scaffolds embedded in the IBL unit (e.g., "Using color-coded annotations improved my performance in class"). However, one item was not included in this study as it was not appropriate within this IBL learning context (i.e., "Using tools enhances my study effectiveness"). Two other constructs focused on the perceived usefulness of peer and teacher scaffolds and consisted of four items. These were used to measure students' perspectives about peer and teacher support during IBL activities (e.g., "The students in my group appreciated any extra effort from me," "My teacher showed a lot of concern for me"). In the current study, Cronbach's alpha was calculated to assess internal consistency among items and the reliability coefficient alpha for hard scaffolding was 0.86, peer scaffolding was 0.68, and teacher scaffolding was 0.70.

Posttest: Individual academic achievement

A 22-item multiple-choice test related to content knowledge on the food chain and ecology system was given to students at the end of the unit to measure their individual academic achievement. The posttest included the same items developed by the teacher, who had expertise in the learning content. Students could earn up to 22 points on the test.

Student artifacts: group performance

After the completion of the unit, the artifacts produced during the culminating projects were collected and used to evaluate the quality of the group presentations. A scoring rubric was adapted and modified from Belland, Glazewski, and Richardson's (2011) and Saye and Brush's (1999) rubric for group project presentation ratings. Group performance was measured as interval data according to the quality of their presentations. Each component consisted of specific attributes and criteria, including claims (12 points), evidence (12 points) and connection of claims to evidence (12 points), and each case was worth a total of 36 points (see Appendix Table 10). Two independent raters, an individual who holds a PhD in instructional technology and the researcher were trained together on the scoring rubric until agreement of 90% or better on each component was reached. The initial inter-rater agreement was 0.72 as measured by Cohen's kappa. The raters then discussed differences to reach a consensus. This brought the final agreement level to 0.96.

Data collection

Before implementing the IBL unit, the teacher explained the purpose of the study and distributed the consent form to students and their parents. After collecting the consent forms, the teacher facilitated the unit for 5 days, with the final day spent on their culminating presentations. During implementation of the unit, each class met twice a week for 3 consecutive weeks. On the first day, the teacher introduced the unit and assigned students to groups based on students' preferences. On the second through fourth day of the unit, students engaged in preparing for the culminating activity and worked in groups of three to five students. Each group was assigned a role with a related position of being for or against the meat tax. In the culminating activity, each group identified the issues and developed their own claims based on evidence while representing the assigned position (either for or against a meat tax). On the last day of the unit, each group had 10 min to present their argument in a persuasive presentation and 5 min to answer questions from other groups. After the group presentations were finished, the survey was administered to students, and the next week, the posttest was administered on the final day of the unit to measure individual academic achievement.

Data analysis

Pearson's correlations were employed to examine the relationships among (1) students' perceptions of the usefulness of hard, peer, and teacher scaffolds and individual academic achievement, and (2) students' perceptions of the usefulness of hard, peer, and teacher scaffolds and group performance.

Based on the literature review, two models were developed and tested to determine if the proposed model could explain variance in students' learning outcomes and to assess which independent variables would create the best prediction equation. To answer the first research question, a multiple regression analysis using the enter method was an appropriate analysis technique for testing the model that included a set of all possible predictor variables built from the theory. To analyze the relationships among these factors, the following model specification was formulated:

$$Achievement = \beta_0 + \beta_1 hard + \beta_2 peer + \beta_3 teacher + \varepsilon_i$$

In this model, students' individual academic achievement was a dependent variable, and students' perceptions of the usefulness of hard, peer, and teacher scaffolds were force entered as predictors in the regression equation simultaneously.

Second, a multiple linear regression using the enter method was employed to determine whether students' perceived usefulness of hard, peer, and teacher scaffolds could be used to predict group performance. The model presented below was formulated to analyze the relationships among these factors:

$$Performance = \beta_0 + \beta_1 hard + \beta_2 peer + \beta_3 teacher + \varepsilon_i$$

In this formula, *performance* indicates group performance scores derived from evaluations of group presentations using the rubric developed in this study, while *hard*, *peer,* and *teacher* are measures of each group's perceptions of the usefulness of the three types of scaffolds. For the purpose of analyzing group performance, the scores of individuals' perceptions of the usefulness of hard, peer, and teacher scaffolds in each group were averaged together and used as an independent variable. Before conducting Pearson's correlations and a multiple regression, a preliminary analysis was done. All statistical analyses were performed with SPSS 22.0.

Results

Preliminary analysis

The dataset was examined to assess the accuracy of data entry, the presence of missing values, outliers, and the assumptions underlying Pearson's correlation and multiple regression analyses. The analysis examined the degree to which standard assumptions of Pearson's

Table 3 Pearson correlations and descriptive statistics for hard-, peer-, and teacher scaffolding in academic achievement (n = 159)

Variable	1	2	3	4	*M*	*SD*
1. Hard scaffold	–**				4.13	.85
2. Peer scaffold	.277**	–**			3.89	.86
3. Teacher scaffold	.246**	.582**	–**		4.06	.74
4. Achievement	.801**	.355**	.291**	–	18.73	3.89

**$p < 0.001$ (2-tailed)

Table 4 ANOVA table of the regression model

	Sum of squares	df	F	*p*
Regression	1583.58	3	101.04	.000**
Residual	809.79	155		
Total	2393.37	158		

$R^2 = .67$; $R^2_{adj} = .65$; Durbin–Watson = 1.748

**$p < .001$

correlation and multiple linear regression were met. First, standard assumptions for Pearson's correlation were met; the models were fit, and it appeared that there was a linear relationship between the various bivariate relationships and no concerns were noted with respect to normality and variance assumptions. The linearity assumption was tested with scatter plots which were linear and in which no curve was present and thus there was also no need to trim outliers. Second, attention was given to meeting the assumption of a multiple linear regression analysis. Graphical plots were examined to investigate the assumptions of homoscedasticity and linearity (Hair et al. 2010). The results revealed that there was no pattern of non-linearity and heteroscedasticity. In addition, multicollinearity was examined. The tolerance statistic for all variables was found to be greater than the cut-off point of 0.10 and the variance inflation factor (VIF) was less than 10 (see Tables 4, 9), indicating that multicollinearity was not an issue for the modeling used in this study (Hair et al. 2010).

Correlations among perceived usefulness of hard, peer, and teacher scaffolds and individual academic achievement

Table 3 provides means, standard deviations, and the correlation matrix among variables. The results indicated that students perceived that hard scaffolds ($M = 4.13$, $SD = 0.85$) were the most beneficial and useful to them, followed by teacher scaffolds ($M = 4.06$, $SD = 0.74$) and peer scaffolds ($M = 3.89$, $SD = 0.86$). This implies that students perceived that utilizing hard scaffolding, such as annotations embedded in an IBL unit, was the most beneficial to them in terms of understanding the issues and learning content during IBL activities. The results also revealed that the teacher's scaffolding was perceived as a useful form of assistance in terms of helping them understand the topic of the unit and reducing the difficulties they encountered during IBL activities.

The correlation analysis showed that students' perceived usefulness of hard scaffolding was significantly correlated with students' perceived usefulness of peer scaffolding ($r = 0.277$; $p < 0.001$) and teacher scaffolding ($r = 0.246$; $p < 0.001$), and was strongly correlated with individual academic achievement ($r = 0.801$; $p < 0.001$). The coefficients of peer and teacher scaffolding were $r^2 = 0.077$ and $r^2 = 0.060$, respectively. Even though the $r = 0.277$ and $r = 0.246$ values were statically significant at $\alpha = 0.001$, only 7.7% of the variance in peer scaffolding perception scores and 6% of the variance in teacher scaffolding perception scores could be explained by hard scaffolding perception scores. In contrast, 64% of the variance in achievement was accounted for by perceived usefulness of hard scaffolds, meaning that perceptions of hard scaffolds accounted for the largest portion of variance in learners' individual achievement.

Students' perceptions of the usefulness of peer scaffolding were moderately correlated with the perceived usefulness of teacher scaffolding ($r = .582$; $p < 0.001$) and individual academic achievement ($r = .355$; $p < 0.001$). The coefficients of peer and teacher scaffolding were $r^2 = 0.338$ and $r^2 = 0.126$, respectively. In addition, students' perceptions of the usefulness of teacher scaffolding were found to be positively correlated with individual academic achievement ($r = 0.291$; $p < 0.001$). The coefficient of individual academic achievement was $r^2 = 0.085$, indicating that only 8.5% of the variance in individual academic achievement could be accounted for by perceived usefulness of teacher scaffolding.

Relationships among perceived usefulness of hard, peer, and teacher scaffolds on individual academic achievement

Table 4 presents the ANOVA results of the model. The results of this analysis indicated that the model was statistically significant, F (3,155) = 101.04, $p < 0.001$. The results showed that $d = 1.748$, which is between the two critical values of 1.5 and 2.5, indicating that there is no first order linear auto-correlation in the multiple linear regression data. Thus, the residuals are uncorrelated and there is no direct relationship between error terms that are more than a one-time period apart from each other. In this model, the adjusted R^2 was 0.65 and the R^2 was 0.67, which represents a medium effect (Cohen 1988). This indicates that 67% of the variance in the students' achievement scores could be explained by the factors in this model.

Table 5 shows standardized coefficients and significance levels of the variables in the regression model. Students' predicted academic achievement is equal to 1.555 + 3.459 (hard) + 0.571 (peer) + 0.166 (teacher). The results indicated that students' perceptions of the usefulness of hard scaffolding was the most significant factor in predicting academic achievement ($t = 15.51$, $p < 0.001$, $\beta = 0.76$), followed by their perceptions of peer scaffolding ($t = 2.16$, $p < 0.05$, $\beta = 0.126$). However, students' perceptions of the usefulness of teacher scaffolding was not a significant factor in predicting individual academic achievement ($t = 0.55$, $p > 0.05$, $\beta = 0.032$).

Table 5 Multiple regression results predicting individual academic achievement with hard-, peer-, and teacher scaffolds

Predictor	B	*SE*	Beta	*T*	*p*	Tolerance	VIF
Constant	1.555	1.219		1.28	.204		
Hard	3.459	.223	.759	15.51	.000**	.913	1.096
Peer	.571	.264	.126	2.16	.032*	.642	1.558
Teacher	.166	.302	.032	.55	.583	.913	1.096

**$p < 0.001$, *$p < 0.05$

Table 6 Pearson correlations and descriptive statistics for hard-, peer-, and teacher scaffolds in group performance (n = 41)

Variable	1	2	3	4	*M*	*SD*
1. Hard scaffolds	–**				3.42	.62
2. Peer scaffolds	.101	–**			3.86	.58
3. Teacher scaffolds	.058	.706**	–**		4.05	.46
4. Group performance	.026	.547**	.478**	–**	28.78	4.89

**$p < 0.001$(2-tailed)

Correlations among perceived usefulness of hard, peer, and teacher scaffolds and group performance

Table 6 presents means, standard deviations, and correlations among the variable findings. The scores indicating individual students' perceptions of the usefulness of hard, peer, and teacher scaffolds in each group were averaged and used as the variable. The results suggest that students perceived teacher scaffolds ($M = 4.05$, $SD = 0.46$) as the most beneficial to them, followed by peer scaffolds ($M = 3.86$, $SD = 0.58$) and hard scaffolds ($M = 3.42$, $SD = 0.62$). This implies that students perceived the teacher's scaffolds as the most useful form of assistance when they engaged in IBL group work.

Table 7 shows that students' perceptions of the usefulness of peer and teacher scaffolds were significantly and positively correlated, while students' perceptions of the usefulness of hard scaffolds were not statistically significant. Specifically, students' perceived usefulness of peer scaffolds was strongly correlated with their perceived usefulness of teacher scaffolds ($r = 0.706$; $p < 0.001$), and moderately correlated with group performance ($r = 0.547$; $p < 0.001$). The variable of students' perceived usefulness of teacher scaffolds was also found to be positively correlated with group performance ($r = 0.478$; $p < 0.001$). In addition, the coefficient of teacher scaffolds was $r^2 = 0.228$, which explains approximately 23% of the variance in group performance scores. These results show that teacher scaffolding perception scores accounted for the largest percentage of variance in peer scaffolding perception scores, and both peer and teacher scaffolding perceptions accounted for the largest percentage of variance in learner's individual academic achievement.

Relationships among perceived usefulness of hard, peer, and teacher scaffolds on group performance

Table 8 illustrates that the model was statistically significant, $F(3,37) = 5.728$, $p < 0.001$. The Durbin-Watson statistic was 1.710, which is between the two critical values of 1.5

Table 7 Group achievement (n = 41)

	Min	Max	Mean	SD
Claim	6	12	9.61	1.91
Evidence	4	12	9.32	2.48
Reasoning	6	12	9.95	2.74
Total	18	36	28.78	4.89

The possible ranges of scores for claim, evidence, and reasoning are 0–12, 0–12, and 0–12, respectively

Table 8 ANOVA table of the regression model

	Sum of squares	df	F	*p*
Regression	299.072	3	5.728	.003**
Residual	643.953	37		
Total	943.024	40		

$R^2 = .32$; $R^2_{adj} = .26$; Durbin–Watson = 1.710

$^{**}p < 0.001$; $R^2 = .32$

Table 9 Multiple regression results predicting group performance with hard-, peer-, and teacher scaffolds for the initial model

Variable	B	*SE*	*Beta*	*t*	*p*	Tolerance	*VIF*
Constant	6.651	5.775		1.287	.206		
Hard	.208	1.067	.027	.195	.847	.989	1.011
Peers	3.535	1.613	.422	2.191	.035*	.501	2.008
Teacher	1.918	2.023	.182	.948	.341	.502	1.994

$^{*}p < 0.05$

and 2.5, indicating that there is no first order linear auto-correlation in the multiple linear regression data. However, the R^2 was 0.32 and the adjusted R^2 was 0.26, indicating that this model explained 32% of the variance in group performance, which represents a small effect (Cohen 1988).

Table 9 presents standardized coefficients and significance levels of the variables in the regression model. Students' predicted group performance is equal to 6.651 + 0.208 (hard) + 3.535 (peer) + 1.918 (teacher). The results show that students' perceived usefulness of peer scaffolding was a significant factor in predicting group performance ($t = 2.191$, $p < 0.05$, $\beta = 0.422$), while the perceived usefulness of hard scaffolding ($t = 0.195$, $p > 0.05$, $\beta = 0.027$) and teacher scaffolding ($t = 0.948$, $p > 0.05$, $\beta = 0.182$) were not significant factors in predicting group performance.

Discussion

The relationship among hard, peer, and teacher scaffolds, and individual academic achievement

An analysis of the results indicates that the perceived usefulness of hard and peer scaffolding were the most significant factors in predicting students' individual achievement in the model developed in this study. Teacher scaffolding was not a statistically significant predictor of students' individual achievement. One important point related to the finding that hard scaffolding was a significant predictor of students' individual achievement was that students perceived hard scaffolding as the most useful type of assistance for their IBL activities among the three scaffolding categories. These results are consistent with previous studies, which found that hard scaffolds are effective in promoting gains in students' content knowledge after engaging in problem-solving processes (Belland 2010; Walker and Zeidler 2007). This implies that for students in this study, hard scaffolds (e.g., color-coded annotations embedded within the Web-based IBL unit) may have facilitated their learning and helped them focus on important resources and critical aspects relevant to the central driving question of the unit. In this study, three different color-coded annotations were designed and embedded as hard scaffolds into the IBL unit, including definitions, background information, and thinking questions. Hard scaffolds may have the potential to aid students in better comprehending the content and topic, given that Web-based color-coded annotations may assist students' learning in terms of (1) providing different words or terms that offer essential information to understand content (Shin et al. 2017; Simons and Klein 2007), (2) providing contextual information, which helps students' understanding of new information and encourages them to access prior knowledge to facilitate their understanding of central issues (Lee and Calandra 2004; Shin et al. 2017; Simons and Klein 2007), and (3) emphasizing critical aspects of the problem, and monitoring and evaluating their progress in completing specific learning activities (Davis and Linn 2000; Raes et al. 2012). The results of this study suggest that students who perceived hard scaffolds as useful were likely to gain higher content knowledge through the IBL activities.

The findings also suggest that the perceived usefulness of peer scaffolding was a factor in predicting individual academic achievement. Previous research, which has focused on peer feedback, questioning, and evaluation, has shown that students may improve their work and more effectively engage in knowledge construction when provided opportunities for receiving additional feedback on their progress from their peers (Gielen et al. 2010; Li et al. 2010; Tsivitanidou and Constantinou 2016). This may be due to the fact that peers tend to share similar perspectives and express themselves on a similar language level, which may result in feedback that is more comprehensible when transmitted from peer to peer rather than from teacher to student (Hovardas et al. 2014). As a result, students may perceive peer scaffolding as a useful strategy in their learning which may benefit individual students' academic achievement. This implies that peer scaffolds may have helped students gain knowledge and facilitate comprehension while they engaged with their group members.

Although the perceived usefulness of hard and peer scaffolding seemed to be important factors in accounting for individual students' academic achievement, the perceived usefulness of teacher scaffolding was not found to be a significant factor in predicting students' individual learning outcomes. This may be due to the fact that the teacher's scaffolding may have been more focused on group-level work than on individual learning in this specific unit. While the teacher answered some questions asked by individual students seeking help, observation data gathered to complement the quantitative data collected in this study suggested that the teacher mainly interacted with groups of students or facilitated peer scaffolding as opposed to interacting with individual students. Similarly, students also sought the teacher's help as a group rather than as individuals. Thus, although survey responses suggested that individual students perceived the teacher's scaffolds as useful in their learning, teacher scaffolding may not have had a strong impact on individual students' academic achievement since the support provided by the teacher focused on group-level activities.

The relationships among hard, peer, and teacher scaffolds, and group performance

An analysis of the results revealed that students' perceived usefulness of peer scaffolding was a significant factor in predicting group performance. This finding is consistent with previous studies demonstrating that peer scaffolds, such as peer assessment and questioning, improve group performance and individual reflection on activities (Hovardas et al. 2014; Li et al. 2010; Xiao and Lucking 2008). It has been reported that peer scaffolding can potentially be more helpful than teacher scaffolding in terms of promoting learners' thinking processes (Cho and MacArthur 2010; Cho and Schunn 2007; Hovardas et al. 2014; Tsivitanidou and Constantinou 2016). This may be because students can receive and respond to peer assistance more readily than to teacher scaffolding, although students may not provide higher quality feedback than teachers. Given that students in this study worked collaboratively with their group members while engaged in IBL processes, peer scaffolding may have been the most robust and useful form of scaffolding and may have better assisted group performance as compared to hard and teacher scaffolding.

A noteworthy finding is that even though the perceived usefulness of teacher scaffolding had the highest average score among the variables, and the perceived usefulness of teacher scaffolding was positively correlated with the perceived usefulness of peer scaffolding and group performance, this factor was not statistically significant in the developed model in this study in predicting group performance. Although it was not found to be a significant factor, it should be noted that the standard deviation for perceived usefulness of teacher scaffolding was 0.46, meaning that students' responses were narrowly distributed around the mean score of 4.05. This suggests that most students may have perceived the teacher scaffolding as a useful support; therefore, this factor may not yield significant differences in group performance. In addition, a regression analysis showed that perceived usefulness of peer scaffolding was the only significant factor in predicting group performance in the developed model in this study. This suggests that some groups perceived peer scaffolding as a useful support whereas some groups did not. Given that the quality of peer scaffolding can be influenced by students' individual abilities such as prior knowledge or critical thinking skills (Choi et al. 2005; Land 2000; Liu and Tsai 2008) and by group interactions (Barron 2000; Fung et al. 2016; Kwon et al. 2013), the quality of peer scaffolding in each group may vary depending on different variables within groups.

Lastly, it was found that hard scaffolding was not a significant factor in predicting group performance. This may be related to the fact that the hard scaffolding was designed and embedded in the Web-based IBL unit to assist individual learners' understanding of reading content. In this study, hard scaffolds, such as thinking questions, were provided to assist students' inquiry learning process by directing their focus to aspects of the issue that they might consider and incorporate into their group discussion. However, the results imply that students may utilize hard scaffolds individually when they interact with the content of the inquiry unit and they may find peer scaffolds to be more useful and beneficial to their IBL group activities than hard scaffolds. This may explain why students perceived hard scaffolds as useful to their individual learning more so than to their group interactions, and why hard scaffolding may have shown a significant impact only on individual achievement and not on group performance.

Conclusion

The current study provides a theoretical scaffolding framework which empirically confirmed that hard, peer, and teacher scaffolds positively impact individual achievement and group performance. The results extend the scope of previous studies by suggesting that students perceive hard and peer scaffolding as better supports in terms of gaining domain knowledge in technology-enhanced IBL classroom environments. Individual students may have benefited from utilizing hard scaffolds to gain domain knowledge when they searched for and explored the learning content embedded in a Web-based inquiry-based unit, whereas peer scaffolding was perceived as the most critical component that benefited students by enhancing both individual academic achievement and group performance in IBL. This result highlights the different roles that scaffolding may play in assisting and facilitating different learning outcomes since scaffolding types interact in dynamic ways in a classroom setting.

It is important to note the limitations of our findings: First, the students were not randomly assigned into groups, other variables may yield different findings, and it is unclear whether preferences for different scaffolding had an effect on students' actual learning outcomes. For instance, group interaction patterns may have impacted group performance instead of the peer scaffolding factor. In addition, there is a possibility that students with high prior knowledge earned high scores in individual achievement. Although our findings contribute to the body of knowledge on the relationship between students' perceptions of the usefulness of scaffolding and learning outcomes, due to the absence of a causal relations framework, little was known about how the effectiveness of different types of scaffolds impacted students' outcomes. Thus, further research needs to be conducted to examine these effects.

Second, since the student survey was administered at the end of the unit, it is possible that the students' perceptions were influenced by their most recent experiences with the unit, such as the group presentation. Thus, future research needs to utilize different methods to measure students' use of the three types of scaffolding. Specifically, results in this area could be confirmed by quantifying elements for the three types of scaffolding, such as usage or frequency of use.

Third, the findings of this study can shed light on the role of peer scaffolding strategies that facilitate IBL in the context of technology-enhanced classroom environments. It was found that students perceived peer scaffolding as the most useful and beneficial to both individual learning and group work. Given that peer scaffolding strategies play a pivotal role in supporting students' IBL activities, it is important to investigate what types of peer scaffolding strategies occur and what support students look for during IBL. Thus, future work should closely investigate how these different types of scaffolds interact with one another and provide rich contextual explanations of technology-enhanced classroom environments.

A final limitation regards the uniqueness of hard scaffold designs and how to utilize them in a typical classroom setting. This study was situated in a single research site using a particular web-based IBL unit. As such, the design of scaffolds may affect students' perceptions of the usefulness of the three scaffolding types. The specific classroom context should be taken into account when applying the findings from this study to another classroom context. In future research, these findings should be articulated and expanded to include more participants and different settings.

Compliance with ethical standards

Conflict of interest The authors declare that they no conflict of interest.

Appendix

See Table 10.

Table 10 Culminating project rubric

Argument component	Score	Criteria
Claim (12)		
Relevance (topic, stakeholder)	6	Group makes assertion that is related to (1) the meat tax composition (pro or con) and (2) the group's stakeholder position
	4	Group makes assertion that is related to the meat tax composition (pro or con), but less so to the group's stakeholder position
	2	Group makes assertion that is related to the meat tax composition (pro or con), but not the group's stakeholder position
	0	Group does not make any assertion
Clarity	6	The assertion is clear and complete
	4	The assertion is either not clear or not described in enough detail to be complete
	2	The assertion is neither clear nor described in enough detail to be complete
	0	The assertion is not related to the meat tax issue or the group's stakeholder position
Evidence (12)		
Genuine Evidence	6	Evidence is provided with clear citations and references with claim
	4	A few citations and references are missing for evidence. (1–2 pieces of evidence)
	2	Group provides evidence with claim, but fails to provide citations and references for evidence
	0	Group does not provide evidence with claim. This would also apply if the evidence has nothing at all to do with the claim
Clarity	6	All evidence is clear and described in enough detail
	4	Some evidence lacks either clarity or details
	2	Most evidence lacks either clarity or details
	0	All evidence has neither clarity nor details

Table 10 (continued)

Argument component	Score	Criteria
Connection of claims to evidence (12)		
Connection (claim—evidence)	6	Group clearly shows relevance of evidence to its associated claim (both link and pertinence)
	4	Group shows relevance of evidence to its associated claim (pertinence), but they do not present the link between the evidence and claim clearly
	2	Group shows relevance of evidence to its associated claim, but they neither present the link between the evidence and claim clearly nor establish the pertinence of the combination of the claim
	0	Group does not show the relevance of evidence to its associated claim. If they do not have a claim and/or evidence, they cannot get higher than a zero here
Quality (Articulation)	6	Articulates the connection between the detailed position (claims) and evidence with well-informed reasoning behind each
	4	Articulates the connection between the detailed position (claims) and evidence with basic reasoning underlying each
	2	Discusses the connection between the position and evidence, but does not present clear lines of reasoning behind each position
	0	Does not articulate any connection between the position and evidence

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