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ORIGINAL RESEARCH

Distributed Scaffolding: Synergy in Technology-Enhanced Learning Environments

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Abstract When technology is employed challenges increase in learning environments. Kim et al. (Sci Educ 91(6):1010–1030, 2007) presented a pedagogical framework that provides a valid technology-enhanced learning environment. The purpose of the present design-based study was to investigate the micro context dimension of this framework and to analyze interactions between the student and tool, teacher and student, and teacher and tool. In this respect, to understand how the roles of the teacher and technology tool are balanced in a technology-enhanced learning environment, the distribution of scaffolds between

Distributed scaffolding: "Multiple forms of support that are provided through different means to address the complex and diverse learning needs" (Tabak 2004, p. 307).

Synergy: "Characteristic that different components of distributed scaffolding address the same learning need and interact with each other to produce a robust form of support" (Tabak 2004, p. 305).

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TELE: Technology-enhanced learning environment—"Technologies that support students' scientific understanding, activities and support practices that facilitate students' inquiry processes, and methods to sustain technology-enhanced innovations in everyday science classrooms" (Kim et al. 2007, p. 1010).

WISE: Web-Based Inquiry Science Environment. KIE: Knowledge Integration Environment.

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teacher and the tool were analyzed. Forty-one middle-school students attending an international school in Turkey were scaffolded with technology-based scaffolding treatments in two groups supervised by two teachers. Qualitative analysis was conducted. The results showed that the students benefited from the use of hints, sentence starters and question prompts, which led the students to develop their ability to construct arguments with a claim, ground, backing, warrants, and in some cases, more sophisticated arguments using rebuttals as in the Toulmin argumentation pattern (Toulmin 2003). The results of the study also showed that technology-based scaffolds, which are provided with active support by the teacher, create a more effective environment, and students need multiple forms of support and multiple learning opportunities to learn science successfully in the dynamic and complex environment of the classroom. Since there is a strong interaction and balance between teacher support and the technology scaffolds, there is also a synergetic relationship that promotes student learning and improves the student's ability to construct arguments.

Keywords Argumentation · Distributed scaffolding · Synergy · Technology-enhanced learning environment

1 Introduction

Constructing argumentation is necessary for students to engage in scientific inquiry (Hsu et al. 2015). However, argument construction is challenging for students, because they experience difficulty determining what counts as evidence, as well as justifying their claims with evidence via warrants (principles that connect the claim to the grounds). Scaffolding has been found to support students' engagement in argumentation and to facilitate their argumentation skills, helping them to solve ill-structured problems and to elaborate arguments. Students require more support for solving ill-structured problems because of the importance of generating alternative solutions (Cho and Jonassen 2002).

1.1 Scaffolding Technology-Enhanced Science Inquiry

Aleksei Leontiev's activity theory emerged as an outgrowth of the socio-cultural perspective (Leontiev 1978, 1981). The concept "activity" is understood as developing interaction between subjects and object (the world). A version of activity theory, based on Leontiev's framework, was proposed by Engeström (1987). Activity theory has been established as a post-cognitivist approach in Human Computer Interaction and interaction design (Kaptelinin and Nardi 2006; Nardi 1996). The theory employs a number of ideas developed by Vygotsky, Leontiev's mentor and friend.

Scaffolding is a socioconstructivist concept that suggests learning occurs with a more knowledgeable person's guide in a context of social interactions. When discussing successful scaffolding, Vygotsky's zone of proximal development (ZPD) is of critical importance. ZPD illustrates the distance between the child's actual developmental level, as

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determined by independent problem solving, and his higher level of potential development, as determined through problem solving under adult guidance and in collaboration with more capable peers. According to Vygotsky (1978), a child learns with an adult or with a more capable peer, and learning occurs within the child's zone of proximal development (ZPD).

Wood et al. (1976) defined scaffolding as the process in which a child solves a problem or achieves a goal, which is beyond his/her unassisted efforts. Therefore, adult assistance is essential for the child to be able to complete a task that is within the child's range of competence (p. 90). A learner who completes a task, learns from the process and so improves his performance in future tasks by means of successful scaffolding (Reiser 2002). Thus, scaffolding provides support, functions as a tool, and helps the learner to accomplish a task otherwise not possible.

There has been much interest in using technological tools to scaffold learners in complex tasks and many different approaches to scaffolding techniques have been presented for a broad range of such tools. Technology-based scaffolds are useful in supporting explanations when prompts and questions are provided by computer tools to individuals or small groups (Land and Zembal-Saul 2003). Bell and Davis (2000) had earlier argued that scaffolding in the form of prompts and hints that support argumentation actually helped students' knowledge integration in a technology-enhanced learning environment. Additionally, Demetriadis et al. (2008) stated that students' learning and problem-solving performance in ill-structured domains can be improved if elaborative question prompts are used. Progress Portfolio (Land and Zembal-Saul 2003), Knowledge Integration Environment (KIE) (Oliver and Hannafin 2001), and ExplanationConstructor (Sandoval and Reiser 2004) all describe how to embed supports in software. Sandoval and Reiser's (2004) findings showed that the epistemic tool ExplanationConstructor helps students' thinking and plays an important role in supporting students' inquiry.

1.2 Distributed Scaffolding

According to Cho and Jonassen (2002), scaffolding with technology-based tools helps students to construct higher-level arguments. However, not all of scaffolding can be provided with only one tool in the dynamic and complex environment of the classroom. Technology-based scaffolds must also be designed to provide support in conjunction with other scaffolds (Sharma and Hannafin 2007). Students require diverse supports and learning opportunities and the notion of distributed scaffolding, which is the need for giving support through diverse tools in the learning environment, is emphasized as an approach to support hands-on inquiry learning in a classroom (Puntambekar and Kolodner 2005).

Puntambekar and Kolodner (2005) went on to say that students need multiple forms of support and multiple learning opportunities to learn science successfully. Examples are instructional materials, task sequencing, social arrangements, templates and prompts embedded in tools and timely teacher interventions. Zacharia et al. (2015) reviewed the literature on guidance within computer supported inquiry learning (CoSIL) environments in science education and examined whether the types of guidance were effective in supporting student learning in the design and development of such environments.

Three complementary patterns of distributed scaffolding are:

1. Differentiated scaffolding, which combines multiple forms of support provided through different means to address several diverse learning needs; the BGuILE project

(Reiser et al. 2001; Tabak and Reiser 1999) and the tool ExplanationConstructor (Sandoval and Reiser 2004) are both differentiated scaffolding,
2. Redundant scaffolding, which refers to different means of support that target the same need at different points in time, and
3. Synergetic scaffolding, which is multiple co-occurring and interacting supports for the same need (Tabak 2004).

Hence, scaffolds may be integrated using a variety of synergetic tools in the form of curricular materials, resources and teachers in dynamic environments. However, Zydney's (2010) study raised questions about the effectiveness of combining multiple scaffolding tools since these tools had varying effects on students' understanding of a problem. In this context, technology-based scaffolds and their integration within a learning setting must be considered carefully by designers taking into consideration both goals and contexts.

Since it is important to understand the factors that affect the use of technology tools, Kim et al. (2007) emphasized the need for a pedagogical framework for teaching and learning science using technological tools in a classroom setting. A framework with which to guide teaching and learning in technology-enhanced science classes was presented by Kim et al. (2007). Their proposed framework analyzes factors at the macro level (the systemic level), the teacher level (teacher community) and classroom level (technology-enhanced class). Kim et al. (2007) pointed out that it is not the innovative technologies but the interactive and iterative learning environments that have an effect on students' learning. Students construct arguments, ask for peer review, consult teachers, do research, reflect and revise their work.

Factors at the micro level in this framework involve three types of interactions:

1. Student–tool interaction: when students solve meaningful problems with technological tools,
2. Teacher–tool interaction: when the teacher selects and organizes the tools in the class, and
3. Teacher–student interaction: when the teacher provides scaffolds such as hints and questions (Kim et al. 2007).

*Student–tool interaction o*ccurs when students use technology and are supported through scaffolds. Even though technology increases the students' motivation in science classrooms, some students have difficulty in science inquiry, especially those who lack confidence in self-directed learning and depend on traditional teacher guidance in tool use (Kim et al. 2007). As a result, students' scientific inquiry must be scaffolded in the case that tools are used by students who do not have difficulties and avoid cognitive overload. However, since there has been little research on student–tool interaction, little is known about when student–tool interactions are meaningful, how students use tools and the drawbacks of students' use of technology. For example, with a web browser tool, students generally use web resources without guidance and tend to find answers quickly rather than to think about the information deeply. More research needs to be done on student–tool interaction in science classrooms.

*Teacher–tool interaction e*merges when the teacher selects and organizes the tools for the class. Interaction between a teacher and the technology tool improves a student's performance. Even though tools offer flexibility, the teachers' customization of tool use is important. It is especially crucial when teachers do not possess deep content knowledge or experience in technology integration. Since extensive studies have not been done, teachers' interaction with tools must also be researched and the role of the teacher must be well understood in scaffolding students' scientific argumentation.

*Teacher–student interaction a*rises when the teacher provides scaffolds such as hints and questions for the student. In a technology-enhanced learning environment, the teacher scaffolds students with question prompts and monitors students' learning processes. Teacher coaching and questioning are especially useful when students have difficulties with evidence. As an illustration of this point, in Land and Zembal-Saul's (2003) study, students who were supported by technology-based scaffolds in Progress Portfolio were more successful when instructors helped them. Even though a teacher has several roles in a science classroom—such as guide, mentor, and motivator—it is unclear what the teacher's role in tool use should be during the inquiry. Again, there has been little research on teacher facilitation in a technology-enhanced learning environment and managing a balance between technology and teacher scaffolding.

1.3 Prior Studies

In Belland's (2010) study, the effect of technology-based argumentation scaffolds was found to be significant on middle school students' argumentation ability during a problem-based learning unit. Additionally, the effects of argumentation scaffolds on academic success were examined by Köroğlu (2009), who concluded that computer-supported environments may increase academic success yet teaching thinking, reasoning, and argumentation skills requires an appropriate design. With technology-based scaffolds, a learner will be able to complete the task, learn from the process and complete future tasks according to Quintana et al. (2004), who further proposed a scaffolding design framework for software to guide designers in successful scaffolding.

Kim and Hannafin (2011a, b) identified critical issues in scaffolding students' technology-enhanced problem solving in everyday classrooms. They proposed a framework that included essential dimensions to be considered when teachers scaffold student problem solving in technology-rich classes. They also investigated issues related to peer-, teacher-, and technology-enhanced scaffolds.

In a project, a range of tools were designed to support learning such as design diaries for individual and group work; pinup sessions and online discussion forums to help students present their ideas and critique each other's ideas; and teacher-facilitiated whole class discussions to provide opportunities for students to listen to ideas from groups other than their own (Puntambekar 2015). Each of these tools played a different role in the learning process and when scaffolding is provided in multiple formats, there are more chances for students to notice and take advantages of the environment's affordances.

In another study, the interactive whiteboard showed the teacher all the information shared within the various subgroups of a class, broadening the basis for informed classroom scaffolding. The results showed that although appropriate scaffolding is still based on the teacher's domain knowledge and pedagogy experience, technology can help by expanding the scaffolding choices that an instructor can make (Lu et al. 2010).

Hsu et al. (2015a) proposed a design model for distributed scaffolding. Synergies between teacher facilitation and lesson scaffolds appeared to make effective and efficient results which clarified functions as navigating inquiry, structuring tasks, supporting communication, and fostering reflection.

A study investigated how argumentative knowledge construction in multidisciplinary Computer-Supported Collaborative Learning (CSCL) groups can be facilitated with a transactive discussion script prompt which helped learners to paraphrase, criticize, ask meaningful questions, construct counterarguments, and propose argument syntheses. The results showed that the transactive script prompt facilitated argumentative knowledge construction during discourse. Learners also acquired significantly more domain-specific and domain-general knowledge on argumentation (Noroozi et al. 2013).

In a paper, the components of (e.g., claims and evidence) and processes of making (e.g., define problem and make claim) evidence-based arguments are discussed and various scaffolding models designed to help students perform various tasks associated with creating evidence-based arguments (e.g., link claims to evidence) and present guidelines for the development of computer-based scaffolds to help middle school students build evidence-based arguments were reviewed (Belland et al. 2008).

In another study, Er and Ardaç (2008) supported middle school students' science learning with a Web-based science learning tool (WebFEN). How students use evidence, determine and measure progress in understanding light using Knowledge Integration Environment was examined by Bell and Linn (2000).

A mobile peer-to-peer messaging tool provided support and tutors and a nature guide provided more dynamic scaffolding in order to support argumentative discussions between groups of students during the creation of knowledge claims in Laru et al. (2012) study. The results showed that the use of mobile tool promoted interaction during inquiry learning, but led to superficial epistemological quality in the knowledge claim messages. Furthermore, the use of warrant in the mobile tool, social modes of argumentation and participation differences were significant between the top and the lowest performers. The use of warrants was also found to be a critical variable in Hsu et al. (2015b) study.

Özçinar (2015) investigated the effect of scaffolding computer-mediated discussions to improve moral reasoning and argumentation quality in pre-service teachers. Participants were in three groups: computer-supported argumentation group, computer-mediated discussion group, control group. Participants in the computer-supported argumentation group were instructed in argumentation, and were provided with note starters and graphical argumentation tools. The computer-mediated discussion group, however, was engaged in unstructured interaction on the Moodle forum. The control group did not receive any instruction and neither did they participate in any discussions. The results showed that the computer-supported argumentation group outperformed the control group, but not the computer-mediated discussion group on argumentation quality.

In their paper, Linn et al. (2003) described the diverse features of a Web-based Inquiry Science Environment (WISE) as a technology-enhanced, research-based, flexibly adaptive learning environment. In Walker and Zeidler's (2007) study, students were scaffolded using WISE for a debate on genetically modified foods and prompted with questions throughout the unit. The authors concluded that a socio-scientific issues approach should be designed to explore aspects of the nature of science according to students' answers.

How students use evidence and claim in debate projects designed in a knowledge integration environment (KIE), which scaffolds the argument construction with a knowledge representation tool, SenseMaker, using internet resources was examined by Bell and Linn (2000), who found that students generally use unique warrant and a few use multiple warrants but without backing in their explanations. A project in Wise is created by Cuthbert and Slotta (2004) for middle school students to design and use their knowledge to evaluate evidence. According to the authors, the initial results showed that there were some gaps that needed to be improved. For example, some science content was ignored, students' designs tended to rely on initial design ideas without any diversity, there was a lack of opportunities for students to collaborate and revision of ideas was almost impossible.

Belland et al. (2015a) examined the use and impact of computer based scaffolding to support middle school students' argumentations during a 3-week problem-based learning unit focused on the water quality of a local river in their mixed method study and found a significant effect on the lower-achieving students' argument evaluation abilities. They also found that students used various support such as computer-based scaffolding, teacher scaffolding, and group support in different ways.

Iordanou and Constantinou (2015) examined how students used evidence in argumentation in a web-based learning environment, Sokrates and found that students who engaged in an evidence-focused dialogic intervention increased the use of evidence in their dialogs. Belland et al. (2008) presented guidelines for the development of computer-based scaffolds to help middle school students to construct evidence-based arguments. Van Dijk and Lazonder (2016) showed that high school students who were supported by a tool developed a more differentiated and interconnected conceptual understanding compared their unscaffolded peers. Land et al.'s (2015) project called Tree Investigators presented five empirically based design guidelines for mobile learning outdoors to help families learn about tree life cycles.

In a study, the effect of teacher guidance on the quality of collaborative argumentation in middle level classrooms was investigated and two groups, one with teacher guidance and the other with minimal teacher guidance were compared. The findings showed that using argumentative scripts for teacher guidance led to more in-depth argumentation (Hsu et al. 2015c, d). Similarly, Raes and Schellens (2016) encouraged teacher-led class interventions to optimize the learning environment in a WISE Climate Change project. In a study in which students argued about how to optimize the water quality of their local river, a middle school science teacher's provision of one-to-one scaffolding during a problem-based learning unit was explored (Belland et al. 2015b).

In Smagorinsky et al.'s (2015) study, the distributed nature of the course involved a set of interrelated settings: a tutoring experience at the city's alternative high school; the reading of books from a menu of texts that cover a range of diversity topics; the discussion of these books in book club meetings independent of the professor's direct influence; and the whole-class discussion of these texts, led by each student book club.

Consequently, there has been much interest in using technological tools to scaffold learners and many different scaffolding techniques have been used. Even though inquiry-based science teaching and accordingly the construction of scientific argumentation have received considerable attention in education research and theory, technology-enhanced learning environments and distributed scaffolding still require more research as challenges increase when technology is employed. Moreover, there is a gap in research in Turkey for scaffolding argumentation in technology-enhanced learning environments.

In the present study, student journals, hints, sentence starters and question prompts in student journals and the SenseMaker tool in a Web-Based Inquiry Science Environment (WISE) were used as scaffolds, which helped students to learn argumentation. Students used student journals to record everything they learned so that they could later use and think about the information as facts when constructing argumentation. Students were more focused with sentence starters. The study also examined the synergetic relationship between technology-based scaffolds and teacher scaffolds and clarified how they interact and contribute to the argumentation abilities of students in WISE. The main research question was "How are the roles of teachers and the technological tool balanced to scaffold students' scientific argumentation in TELE?"

In this respect, the research questions, “What are the roles of the teachers in scaffolding students’ scientific argumentation in TELE?” and “What is the role of the technological tool in scaffolding students’ scientific argumentation in TELE?” were also examined.

2 Methods

2.1 Research Design

The present study investigated the interaction among the teacher, the technological tool and the student to support scientific argumentation in a technology-enhanced learning environment. The study involved design-based research method and an observational case study, thus making a qualitative analysis of a school classroom and activity within that classroom.

The complexity of the setting, multiple interacting paths, and the new possibilities of emerging technologies are reasons for adopting a design-based study and they contribute to understanding real-world contexts of learning (Bell et al. 2004). This method, which blends empirical educational research with the theory-driven design of learning environments, is an important methodology for understanding how, when, and why educational innovations work in practice (The Design-Based Research Collective 2003). Wang and Hannafin (2005, p. 6) defined design-based research as “a systematic but flexible methodology aimed at improving educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings and leading to contextually-sensitive design principles and theories”.

For example, in Sandoval and Reiser’s design-based research method on the Explanation-Constructor tool, the design has been refined through iterative cycles of implementation, analysis, and revision. Likewise, providing students with templates to organize their ideas such as Inquiry map and SenseMaker in WISE, using prompts for reflection-on-action by responding to prompts with WISE and note-taking in WISE was refined through iterative cycles of implementation, analysis and revision. The design-based research method had been widely used in prior research of Web-based inquiry science environment (WISE) and knowledge integration environment (KIE; Bell and Linn 2000; Linn et al. 2003), biology guided inquiry learning environment (Sandoval and Reiser 2004), etc.

Moreover the purpose of the study, which was to test and investigate the microcontext dimension and to analyze the student-tool, teacher-student and teacher-tool interactions of Kim et al.’s pedagogical framework (2007), is another reason for adopting a design-based research method. Design-based research processes are flexible, as during implementation, the theoretical framework upon which the design is based may be extended and developed; in some cases, a new framework may emerge (Wang and Hannafin 2005).

2.2 Participants

Forty-one-sixth grade students aged 11–12 years were organized into two groups with two science teachers for this study. The first teacher was an American, with five years of experience, who was teaching a class of 16 students (eleven males and five females). The second teacher, who was Turkish and had 2 years of experience, was teaching two classes with 12 students (six males and six females) and 13 students (six males and seven females). The students’ computer skills were adequate for the purposes of this study. As shown in

Table 1 Demographics of participants

		Number	%
Gender	Female	18	44
	Male	23	56
Age	11	34	83
	12	7	17
Computer proficiency level	Beginner	3	7
	Intermediate	37	90
	advanced	1	3
Frequency of the use of the computer	None	0	0
	Rare	3	7
	Often	38	93

Table 1, the demographic data used for this study were limited to the age and sex of students, as these were sufficient for defining relevant characteristics of the students for the study.

The school in which the research was conducted was selected with convenience-type sampling because of its accessibility. Bilkent Laboratory and International School (BLIS), in Ankara, Turkey, is a private school that provides an international education to approximately 600 4–19 year-old students of various nationalities. The school is recognized by the Turkish Ministry of Education and accredited by the New England Association of Schools and Colleges and the Council of International Schools. BLIS is an international school, which has a different school and student profile from other Turkish schools. BLIS is not a traditional institution, but rather a model school, which aims to reflect the latest educational practices from IBPYP (The International Baccalaureate Primary Years Programme), IGCSE (The International General Certificate of Secondary Education from University of Cambridge) and IBDP (The International Baccalaureate Diploma Programme). The school's philosophy is to recognize the individual abilities, interests and talents of each child, foster critical and independent thinking and encourage questioning ideas and searching for knowledge. Students are prepared for success in leading universities throughout the world. The school is also a laboratory school for the Bilkent University Graduate School of Education. BLIS was selected for this study because there was no national exam (SBS) pressure in this school, which makes it possible to implement the study. The results of the study may be generalized to students of other international schools that have similar missions.

2.3 Materials

The unit "Light: Particle or Wave?" was designed for sixth-grade students as part of a physics chapter about "Light" as a WISE module. WISE, a free online environment of the University of California at Berkeley and supported by the National Science Foundation, was used in the study because it offers both proven technological tools and flexibility and adaptiveness with its knowledge representation and argumentation tool, SenseMaker according to Linn et al. (2003, p. 535). The science department preferred implementing the study on this unit in the curriculum since students had had difficulty in understanding it in previous years. They indicated that "Light" was a difficult topic especially for this age group. Technology could have supported students' learning in this unit. Students did not work in the digital environment before. Students did not have opportunity to construct argumentation before either. The main goal of the module was to improve students' understanding of light by exploring evidence that describes how light is made up. In addition to the science content, key learning goals focused on scientific inquiry practices to encourage students to construct arguments.

As shown in Table 2, students were expected to complete a number of investigations. Tasks included warm-up exercises, an introduction to the project and exercises that focused on reflection and lateral inversion, different surfaces and refraction, and color, and preparation and engagement in a classroom debate on "Light: particle or a wave?" Throughout the module, students had multiple opportunities to construct scientific arguments that included claims, grounds, warrants, backing for evidence, as well as rebuttal and relevant conceptual ideas grounded in personal knowledge and experience.

Different types of scaffolds were embedded in the WISE environment. Students were supported with SenseMaker as a domain-generic scaffold and hints, student journals and sentence starters and question prompts in SenseMaker as domain-specific scaffolds. As a generic scaffold, the features of SenseMaker helped students to understand the general framework for scientific argumentation: claims, grounds, warrants, backing, and rebuttal.

The following types of scaffolds were used within the WISE module as shown in Table 3.

1. Student journals: Students recorded their answers with the help of sentence starters and question prompts in journals.
2. Hints: Throughout the activities, hints were provided.
3. SenseMaker: Students first constructed their arguments as subarguments for the topics, each of which had a different question. They then constructed their main arguments for each activity with the same question.

The study was conducted during 22 class periods over 4 weeks, extending from April 18 to May 12 during the spring semester of 2010–2011. A pilot study was conducted with three classes, each comprising 18–19 students, over 3 weeks during the spring semester of 2009–2010. A total of 56 students participated in the pilot study during which observed problems were noted and the study design was consequently improved.

2.4 Data Collection, Sources and Measurement

Technology-based scaffold treatments were assigned to the two groups. Each group was assigned to one teacher; one group with one teacher who was teaching a class of 16 students and the other group with the second teacher who was teaching two classes with 12 students and 13 students. The aim was not to compare the groups. Instead, the analysis was conducted within the groups and students' interactions with the learning environment were studied to understand how students engaged in the activities. Consequently, to determine how the roles of teacher and technology-based scaffolds are balanced to support students' scientific argumentation in an technology-enhanced learning environment, video recordings, observation reports and interviews were analyzed across 22 class periods during the four-week "Light" unit. According to Bogdan and Biklen (2007), the primary data collections are participant observation supported with interviews (to verify observation, document data), notes (reporting observations, reflections), videotaped recording (holistic look at process), questionnaires (feedback from a larger sample), and peer observations (feedback, triangulation).

Table 2 Activities, learning goals, and classroom practices and experiments

Activities	Learning goal	Classroom practice and experiment
Activity 1—Warm-up (2 periods—Week 1)	This activity serves as a pre-test for the project and an introduction to science argumentation patterns with examples	Students were informed that their responses would not be assessed. They were free to guess because what they knew prior to doing the project was important
Activity 2—Introduction to the Project (2 periods—Week 1)	Students should have a clear understanding of what the project is about and will understand the different types of light in the electromagnetic spectrum	This activity helped students to focus. It was essential that the students learned all they can about light as they participated since they had to use the knowledge they acquired in the class debate. Moreover, this activity helped students to identify the differences between light types in the electromagnetic spectrum
Activity 3—Reflection and Lateral Inversion (6 periods—Week 2)	Students will be able to identify and explain types of reflection	The reflection and lateral inversion experiments were conducted (first 2 periods). This activity helped students to understand the main light concepts such as law of reflection, specular and diffuse reflection and lateral inversion
Activity 4—Different Surfaces and Refraction (4 periods—Week 3)	Students will be able to understand the difference between types of surfaces and how light interacts. Students will also describe how light behaves as it refracts through different media (prism, lens, water, etc.)	The refraction experiment was conducted (first 2 periods). Students were assisted in understanding the differences between translucent, transparent and opaque surfaces and what happens when light enters a new medium
Activity 5—What a Colourful World: Rainbows and Spectra (4 periods—Week 3 and 4)	Students will be able to understand the concepts of colour and colour reflection and absorption	The colour reflection and absorption and colour addition experiments were conducted (2 periods—week 3). This activity helped students to understand the concepts of primary colours, colour reflection and absorption, rainbows, Newton's disc, colour addition, colour subtraction and filters
Activity 6—Prepare for the Debate Appendix of supplementary material 7 (2 periods—Week 4)	Students will receive their debate position assignments and look for evidence as they begin to prepare for the debate	This activity helped students to focus on preparing for the debate. Debate directions and preparation sheets were handed out. Students were prepared to not only promote their own position but also defend their position against the evidence offered by the opponents. At this point, it was important to give students some directions about how they could provide constructive criticism by means of peer review. Students looked back at their student journals and got all useful information they had created

Table 2 continued

Activities	Learning goal	Classroom practice and experiment
Activity 7—Classroom Debate "Light: Particle or a Wave?"(1.5 periods—Week 4)	Students debate "***Light: Particle or a Wave***?"	This activity facilitated students' thinking about what they had learned in this project so they could finalize their point of view

2.4.1 Video Recordings

The interaction between students and the teacher in a small-group format as a subset of the class discussion was video recorded to capture the verbal contribution to the lesson. The camera was placed in the corner of the classroom and left alone during the video recordings by the researcher. Conversation analysis was conducted where the focus was on the procedural analysis of talk-in-interaction.

2.4.2 Observation Reports

Observation schedule matrices were developed. After each observation and interview, what had happened was transcribed. Descriptions of students and teachers, places, events, activities and conversation were all noted down. Ideas, strategies, and reflections were also recorded. The observation reports brought about a better understanding of the teacher strategies and role in students' argument construction (Appendix of supplementary material 5). One researcher prepared observation reports.

2.4.3 Interviews

Interview schedule matrices were developed (Appendices of supplementary materials 1 and 3). The main data for the interviews were the transcripts; therefore, interviews needed to be transcribed. Open-ended questions were used. Interviews helped clarify the roles of the teachers and the technological tool in scaffolding students' scientific argumentation in TELE. The interviews were conducted with both teachers and four randomly selected students in each class, one student each day for 15 min before the classes start.

2.5 Data Analysis

The data of the present study were analyzed employing qualitative analysis and constant comparative analysis. Video recordings, observation reports and interviews was conducted to understand the dynamics of student–tool, teacher–student and teacher–tool interactions of Kim et al.'s pedagogical framework (2007).

2.5.1 Qualitative Analysis/Constant Comparative Analysis

In this study, the researcher analyzed the data qualitatively by transcribing and coding the video recordings, the observation reports and the student and teacher interviews. In this respect, the researcher continually sorted through the data collection, coding and analysis. The Miles and Huberman approach (1994) was used to analyze the questions "How are the roles of teachers and technological tools balanced to scaffold students' scientific

Table 3 Types of scaffolds (StudentJournal, Hint, SenseMaker)

Activities	Step 1—StudentJournal	Step 2—Hint	Step 3—SubArgument SenseMaker	Step 4—Main Argument SenseMaker
Activity 2—Introduction to the Project	What do you know about light?	When light travels from a source, it transfers energy. Think about light energy from the sun which travels all the way through space and comes in through your window, lighting up the room		*What do you think, is light made up of particles or waves?*
Activity 3—Reflection and Lateral Inversion	**Reflection:** What do you know about the law of reflection?	Think about a bar code. It gives information about a product. At the checkout, a laser scans the bar code and a computer turns the pattern of reflected light into a code number. This identifies the product from a database and its price comes up on the till	What different things could happen to a light beam when it hits different objects?	*What do you think, is light made up of particles or waves?*
	Lateral Inversion: What do you know about lateral inversion?	The image in the mirror shows the left-hand side on the right, and the right-hand side on the left	Why do you think you see yourself as reversed when you look in the mirror?	
Activity 4—Different Surfaces and Refraction	**Different surfaces:** What do you know about different surfaces?	If you cannot even tell where the Sun is, you have opaque clouds. If you can see the Sun but it is just a brighter spot that does not hurt your eyes, you have translucent clouds. If the Sun can be seen as a bright circle you have transparent clouds	What is the difference between transparent and translucent?	*What do you think, is light made up of particles or waves?*

Table 3 continued

Activities	Step 1—StudentJournal	Step 2—Hint	Step 3—SubArgument SenseMaker	Step 4—Main Argument SenseMaker
	Refraction: What do you know about the refraction of light?	A car approaches mud at an angle. When it hits the mud, the right front wheel slows down while the left one keeps travelling fast. When the left wheel enters the mud too, the car travels in a straight line again, but its direction is changed at the boundary As the car leaves the mud the opposite happens. The right wheel speeds up first as it hits smooth tarmac, but the left wheel is still in the mud. This turns the car away from the normal	What happens when light enters a new medium? Why or why not?	
Activity 5—What a Colourful World: Rainbows and Spectra	**Spectrum:** What do you know about spectrum?	There are normally 7 colours in a spectrum but indigo is hard to see. The colours blend into one another making a continuous spectrum, rather than separating into individual colours	Think about a beam of normal (white) light. How can you get colours out of it?	*What do you think, is light made up of particles or waves?*
	Colour reflection and absorption: What do you know about colour reflection and absorption?	A banana looks yellow because it absorbs, transmits and reflects different colours of light. The light that eventually gets to our eyes from the banana makes it look yellow	A black cat looks black. A red apple looks red. This is due to which colours being absorbed and then reflected. Why does a white sheep look white?	

argumentation in TELE?" In this approach, analysis of qualitative data involves data reduction, data display and conclusion drawing and verification.

A coding system was developed and the underlying characteristics of patterns in the classroom were observed (Appendices of supplementary materials 2, 4, 6 and 8). The data were coded into the categories of Teacher Scaffolding, Technology Scaffolding, Student–Technology Interaction, Student–Teacher Interaction, Student–Student Interaction, Student–Teacher–Technology Interaction, Problems in a Technology-enhanced Learning Environment, Teacher Role and Technology Role as shown in Table 4, which were investigated within the framework of Kim et al. (2007) to guide teaching and learning in technology-enhanced science classes.

Table 4 Coding system

Theme: Teacher Scaffolding	***Theme:*** Technology Scaffolding
Codes:	***Codes:***
Introduction of SenseMaker and Wise	Use of Wise
Explanation how to construct arguments in SenseMaker	Use of SenseMaker
Explanation how to use components of Toulmin Argumentation Pattern	Use of Student Journals
Explanation how to use Student Journals	Use of Inquiry Map
Support with examples	Use of Experiment Pages
Give support	Use of Video
Give a direction	Use of Internet
Answer to students' questions	
Encouragement	
Description: Teachers scaffolded students' scientific argumentation by giving explanations how to use technology tool, supporting with examples, giving a direction and encouraging them	***Description:*** Students were scaffolded by the technology by studying in WISE, using SenseMaker, Student Journals and other tools
Representative Observation: "One male student calls the teacher for help and asks what to write where and she explains that the same info goes into both boxes"	***Representative Observation:*** "The students are filling the student journals on WISE"
Theme: Student-Technology Interaction	***Theme:*** Student-Teacher Interaction
Codes:	***Codes:***
Study in the computer	Give some direction to students
Typing	Ask-Give support to students
Study in WISE	Give explanations to students
Make search in Internet	Ask-Answer questions
Construct arguments in SenseMaker	Give explanations how to construct arguments in SenseMaker to students
Watch Video	Give explanations how to use components of Toulmin Argumentation Pattern
Write in Student Journals	Give explanations how to use Student Journals
	Support students with examples
	Encourage students
Description: Students were interacting with technology by studying in computer, in WISE, making search in Internet, using SenseMaker, watching video and writing in Student Journals	***Description:*** Students were interacting with their teachers by asking and answering questions, having explanations how to construct arguments and use the component of model as well as write in student journals, having a direction and being encouraged by their teachers
Representative Observation: "The students on the left side of the class are typing while looking at their notes"	***Representative Observation:*** "One student is explaining something to the teacher and the teacher talks with him"
Theme: Peer Interaction	***Theme:*** Student-Teacher-Technology Interaction
Codes:	***Codes:***
Ask questions to each other	Study in the computer with the help of teacher Study in WISE with the help of teacher
Study in pairs	Making search in Internet with the help of teacher

Table 4 continued

Look at each others' screen	Construct arguments in SenseMaker with the help of teacher
Discuss between them	Write in Student Journals with the help of teacher
	Introduction of experiment pages by teacher
Description: Students were interacting with each other by discussing, asking questions, studying in pairs and looking at each others' screen.	***Description:*** Students were interacting with their teachers and the technology tool by studying in WISE with the help of teachers
Representative Observation: "Two male students are working together on the left side of the class"	***Representative Observation:*** "The teacher demonstrates how students should enter the data and work on the experiment. She reminds the students to save, view the paragraphs and go to the student journal"
Theme: Problems in TELE	
Codes:	
Malfunction of Video	
Malfunction of Computer	
Description: The problems were malfunctioning of Video and Computer.	
Representative Observation: "The teacher detects a problem in a student's system	

2.6 Trustworthiness of the Study

To ensure the trustworthiness of this study, issues related to validity and reliability were studied.

2.6.1 Validity

Video recordings and interviews and the transcriptions of these recordings minimized the threat to the description validity, which is concerned with the factual accuracy of the study such as making sure one is not making up or distorting the things one hears and sees. Listening to the participants, attempting to learn how the participants make sense of what is going on rather than pigeonholing their words and actions eliminated any threats to the interpretation validity, which is the accuracy of the concepts as applied to the perspective of the individuals included in the study.

Collecting or paying attention to discrepant data and considering alternative explanations or understandings of the phenomena eliminated any threat to the theoretical validity, which is concerned with not only the validity of the concepts but also their postulated relationships to one another. Triangulation was also an important theoretical validity check as it strengthens a study by combining several kinds of methods or data. External validity (generalizability) also needed to be addressed. Even though generalizability is not a useful standard or goal for qualitative research since in qualitative research the findings are limited to participants and not generalizable to the entire population (Patton 2002), studies conducted to examine a particular phenomenon in a unique setting can still contribute to the development of a body of knowledge accumulating about that particular phenomenon of interest.

2.6.2 *Reliability*

The reliability of the study was enhanced by standardizing data collection techniques, documentation, and interrater reliability (a consideration during the analysis phase of the research process). The statistical measure of interrater reliability (Cohen's Kappa, which ranges generally from 0 to 1.0 where large numbers mean better reliability) is an important measure in determining how well the implementation of the coding of the study works. In the analysis phase of the research, the researcher first developed a code and theme sheet that included tentative names of the codes and themes and a tentative definition of each code and theme. Then the researcher met with the second researcher to explain the code and theme sheet. This sheet was revised according to the recommendations of the second researcher. Following approval of the codes and themes, the second researcher also checked some of the sample passages that the researcher had coded based on the definitions in the code sheet and the researcher and the second researcher had discussions on the different ones. They then completed the coding until they reached a 100% of agreement.

3 Results

3.1 Constant Comparative Analysis

The main research question was "How are the roles of teachers and technological tools balanced to scaffold students' scientific argumentation in TELE?"

In this respect, the research questions, "What are the roles of the teachers in scaffolding students' scientific argumentation in TELE?" and "What is the role of the technological tool in scaffolding students' scientific argumentation in TELE?" were also examined.

Therefore, various data sources—video recordings, observation reports, and student and teacher interviews—were separately analyzed in a complementary manner and a qualitative constant comparative analysis was conducted. The findings of these analyses were combined to reach our conclusions.

3.1.1 *Group 1*

Video Recordings Analysis

Observation Schedule Categories were organized as Teacher Scaffolding, Technology Scaffolding, Student–Technology Interaction, Student–Teacher Interaction, Peer Interaction, and Student–Teacher–Technology Interaction as shown in Appendix of supplementary material 6. In each category, the "evidence" was woven into a narrative account since the study took an observational case study design type of qualitative approach. The results for these categories were as follows.

1. The teacher indicated that her aim was to enable students to study on their own by following the inquiry map in WISE and to leave the initiative to the students until some strategic questions emerged. When such questions arose, the teacher generally asked the researchers for help in explaining the meaning of Toulmin argumentation pattern components with examples.
2. The technology support involved working with WISE and SenseMaker tool, writing in student journals, reading hints, filling out experiment pages and watching videos. The teacher interacted with students by monitoring them to check their performance and

understanding, asking questions, and giving explanations when necessary as shown in the below transcript.

Teacher: "Be careful between ground and claim".
Teacher: "Ground is little fact but they are going to use information for claim".
Teacher: "If somebody says, "farm chickens are yellow" it is a ground but if somebody supports this with hereditary reasons it is a claim. It is clear or not?"
Some students: "No".
Student: "We can never really know whether it is a lie or not".
Teacher: "I know. It is not a problem. The idea is whether you can make some correlations".

3. Students interacted with their peers by holding discussions, asking and answering questions, talking with each other, studying together, and exchanging ideas and words as shown below.

   Student: "What warrant was?"
   Other student: Look at board, teacher wrote the steps".

4. Student–Teacher–Technology Interaction occurred when a student asked the teacher about something on the computer screen and the teacher answered the students' questions as shown in the below transcript.

   Student: "Could you help me how I should write in the SenseMaker?"
   Teacher: "You are going to make your first argumentation. You are going to click boxes in which you can put your arguments in Wise".
   Teacher: "Click "new claim" and proceed on Wise. You then need to write your ground into that box".

5. Problems that occurred in the technology-enhanced learning environments were the screens sometimes freezing, video downloading taking a while, and the experiment pages not showing the saved data on the screen as shown below.

   Student: "My computer does not work"
   Teacher: "Your screen was frozen, restart your computer and until then we will watch the video from data show".

6. During the debate, the teacher was generally passive and she only interrupted to call for silence in the class and to inform students about how long they could continue to talk for.
7. The role of the students in terms of how the students participated in the debate was also examined. It was observed that only some (and the same) students participated in the debate while others just listened, which was criticized by the teacher in the interview. Generally, the chair organized the debate in such a way that all students had the opportunity to talk even though some students talked more than others. After each group representative makes the groups' arguments with their opening statements, the students take turns to give evidence for their claims. They support their ideas by giving examples and scientists' views. They sometimes support their claims by drawing on the board. When a group member asks a question, a member from the other group

makes a response. The explanations are generally in claim and example-evidence form but Toulmin argumentation pattern components (such as grounds, backing, and even warrants but no rebuttal) are also involved in some of the arguments. Finally, the chair closes the debate by voting and announcing the winner after groups finalize their presentation by summarizing their position. Group dialogs was emphasized by the representative observations below.

Group A: "Good afternoon! As a group we argue that light is made of wave that travels through waters like oceans, water pumps and sea. With evidences and challenging questions, we will persuade "the particles" group that light travels as waves as sound that travels by waves".
Group B: "We think that light is made out of particles and it travels as particles. Light travels by particles because particles come together to make light travel fast".
Group A: "Interference, refraction and reflection show that light is made out of waves".
Group B: "When we applied it to another… inconsistency… When light is on surface, electrons can be affected from that surface. This is called the photoelectric effect which makes impossible that light travel by wave".

Observation Report Analysis

The meaning and context of the video recordings were more effective when the recordings were supplemented with observation reports. As shown in Appendix of supplementary material 6, the same coding system was used in the analysis of observation reports.

1. The teacher scaffolded students by explaining experiments, asking and answering questions, directing students to write in their student journals and to complete arguments, organizing the laboratory and allowing students to learn by themselves.
2. Technology scaffolded students and students interacted with technology when the students filled in the experiment pages, filled in student journals, constructed arguments in WISE, conducted experiments and completed tasks. This can be seen in the following representative quote.

   Teacher: "Did you finish writing your student journal?"
   Student: "Yes".
   Student: "Light is a type of energy. There are two types of light sources: Manmade and natural. Usually light looks white or yellow, but it is actually made of different colors. We can use special glass triangles to break the white light into its separate colors. My father once said that light could only be seen inside the atmosphere. You cannot see it while it is coming from the sun to earth because there is no gas"

3. The teacher interacted with students by asking and answering questions.
4. Students interacted with their peers by discussing with and helping each other.
5. Student–Teacher–Technology Interaction occurred when the teacher looked at a students' screen to understand if the student could manage all the steps in WISE, gave an explanation to the students and showed the students something on a computer screen, and asked the students to write in their student journals and argumentation boxes.

6. Problems that arose related to difficulties in constructing arguments with the components in the technology-enhanced learning environment. This can be seen in the following representative quote.

   Student: What is our next step?"
   Teacher: "You should write a rebuttal".
   Student: "Could you give an example?"
   Teacher: "Rebuttal will be your counterargument"
   Student: "It is difficult"
   Teacher: "What is your claim?"
   Student: "Light travels in straight lines"
   Teacher: "Now, think about the opposite argument"
   Student: "unless it goes through a prism then it breaks into its colors and more rays"
   Teacher: "Good"

Interview Analysis
Teacher interviews;

Teacher interviews helped clarify the roles of the teachers and the technological tool in scaffolding students' scientific argumentation in TELE. Using the coding scheme presented in Appendix of supplementary material 2, four categories—Teacher Scaffolding, Technology Scaffolding, Student–Teacher–Technology Interaction and Problems in a Technology-enhanced Learning Environment—were analyzed.

1. Teacher 1 indicated that she was not scaffolding students much by teaching argumentation or providing any help. Her main responsibilities were asking what the students know and what they have seen and telling students to write down their hypothesis. This can be seen in the following representative quote.

"I don't think that I play much role in the scaffolding part. Not in the WISE program…"

2. The teacher also indicated that students were scaffolded by SenseMaker, hints, sentence starters, student journals, and the Toulmin argumentation pattern with technology. This is clear in the representative quote below.

"Technology-based scaffolds help students in constructing scientific arguments. Sentence starters help students to figure out what they are supposed to write. Hints are not particularly useful and most of the students didn't read them because of the way they are linear However, student journals might help students get ideas. The inquiry map was useful but different from the way I would teach some concepts. However, students do best with my help".

3. The teacher indicated that she minimized her role in scaffolding students in their use of WISE. She generally left the initiative to the students until strategic questions arose. This can be seen in the following representative quote.

"Well, in this I did not provide help like I would normally do. So I get to the question and that's about it, I don't think that I play much role in the scaffolding part. Not in the WISE program".

4. The teacher also indicated that students had difficulty in understanding the terms of the argumentation model. The following representative quote shows this.

> "The terms 'argumentation', 'claim', 'grounds', and 'backing' were not familiar to the students, so they had a hard time understanding them. They don't understand what's going on by reading a book or by reading what's online. They need a lot more interaction. The examples given in WISE at the beginning of the study were not very comprehensible. Students pull text from the Internet for a debate but not for learning concepts. The Internet is not a good way of learning and teaching. Students should understand the concepts before doing research and looking for facts to help them construct arguments. It is not useful to start with experiments for all topics".

Student interviews;

Student interviews helped clarify the roles of teachers and technology and how they balanced in scaffolding students' scientific argumentation in TELE. According to the coding system in Appendix of supplementary material 4, four categories—Teacher Scaffolding, Technology Scaffolding, Student–Technology–Teacher Interaction and Problems in a Technology-enhanced Learning Environment—were analyzed.

1. Students indicated that they were scaffolded by the teacher when they asked for their teacher's help in using WISE.
2. They were scaffolded by technology when using a computer, studying in WISE and SenseMaker, writing in student journals and on experiment pages, and receiving hints.
3. The students reported that their main problems were using rebuttal, constructing arguments and the malfunctioning of technology in TELE. These points are illustrated by the following representative quotes.

> "WISE made me organize myself, because in class for example I didn't take notes and actually I just ask the teacher. But in WISE, there are student journals and stuff and we can research from the Internet".

> "It helps because writing and drawing all these things out is really hard but with technology it is just up there so I can do it easily. If it is a quiz or test or something hints are not really useful, but in student journals hints like sentence starters are really useful".

> "Java takes one common download that is difficult and was the biggest technical problem I faced, and also not saving the data".

3.1.2 Group 2

Video Recordings Analysis

1. Teacher scaffolded students by giving instruction when students were new to the topic, directing students to focus on the lesson and on specific points, organizing the class, providing clarifications, modeling the desired behavior, motivating students, giving hints about strategies, encouraging research, controlling frustration in constructing argumentation, and answering students' questions about the components of the Toulmin argumentation pattern. These are shown in the following representative observations.

Teacher: "With practice you will improve and it is not a problem if things are not perfect the first time".
Teacher: "Grounds are facts that you are going to use to support claims".

2. Technology supported the students via the students working with WISE itself with all its components and the SenseMaker tool, filling out experiment pages, watching videos, using the Internet, searching on Google, writing in student journals, and reading hints.
3. Students interacted with technology by using a computer and studying within WISE, conducting research on the Internet, writing arguments in SenseMaker, writing in student journals, reading hints and watching videos. This can be seen in the following representative quotes.

Student: "I am doing research in Internet".
Student: "My claim would be same as my ground".
Student: "I write one warrant and one backing".

4. The teacher interacted with students by giving explanations about the nature of WISE and the project, moving around the classroom and answering students' questions, motivating and encouraging students to construct many arguments, and confirming students' work.
5. Students interacted with their peers by talking with and asking questions to each other and studying together.
6. Student–Teacher–Technology Interaction occurred when the teacher explained the topic to the students while looking at a computer screen, when something was shown to the students on a computer screen, when something was shown to the teacher on a computer screen, and when the teacher asked students to write in student journals and argumentation boxes.
7. The problems that students encountered were frozen screens, video downloading taking a while, and the experiment pages not showing the saved data on a screen even though the data were saved in the teacher's account.
8. The teacher's role in debate was generally as follows. She was active by interrupting groups and informing them about what they had to do. The teacher also directed the chair and gave instructions. This can be seen in the following representative quotes.

Teacher: "Group B should also do their opening statement and say what their argument is".
Teacher: "The chair can give time to groups for discussion among themselves".
Teacher: "Let's have two or three questions".

9. The role of the student in terms of how the student participated in the debate was also examined. It was observed that groups made their opening statements and explained their arguments. Students constructed their arguments in the form of the Toulmin argumentation pattern. Students used warrants but not backing or rebuttal. The chair managed the debate.

Observation Report Analysis

1. The teacher scaffolded students by explaining content, checking the progress of each student, directing students, organizing the class, helping students conduct their experiments, asking and answering questions, checking hypotheses, helping students understand the components of the argumentation pattern, facilitating, guiding, mentoring, and encouraging students in the dynamic environment.
2. Technology supported students when students filled in experiment pages, watched videos, wrote in student journals, constructed arguments using the SenseMaker tool, submitted brainstorming questions and searched on the Internet.
3. Student–teacher interaction was generally in the form of the student asking the teacher for help and the teacher answering a question.
4. Peers interacted by discussing their points of view in pairs and looking at each other's screens, coming to a consensus in a debate and exchanging ideas even though students were working on their own. This can be seen in the following representative quote.

Student 1: "How light is bending in water?"
Student 2: "We can maybe find the answer by watching the video".

5. Student–Teacher–Technology Interaction was in the form of the teacher taking care of each student, visiting each student's computer and checking the student's work, observing how students use SenseMaker and providing hints, constructing arguments, writing in student journals during the task and asking questions. This can be seen in the following representative quote.

Teacher: "You should finish the data table, and for this table you don't need to click on the graph view because this is just data. But I know that you have more than five sections as a part of your results so when you click this one save data. So you will be able to record all of the results. Save again and view the paragraphs and go to the student journal"

6. The difficulty of comprehending components of the Toulmin argumentation pattern—claim, ground, warrant, backing, rebuttal—was the main problem that students faced when construction arguments.

Interview Analysis
Teacher interviews;

1. Teacher 2 indicated that she scaffolded students by giving directions, supporting with examples, helping students, answering questions, summarizing points, giving guidance, presenting different methods and giving lectures and demonstrating experiments. This is illustrated by the following representative quote.

"As I said before, I was just a facilitator. Time to time, I lectured them I guess, on points that they found difficult to understand, because the unit itself, light, was a very hard concept for this age group. Maybe in later years, the technology may help more. For grade 6, I just realized that they struggle a lot for the addition of colours, reflecting, and refraction. Also, this is not their native language, this is another challenge too. So they needed to overcome two challenges in a difficult unit using technology but they did it".

2. She also indicated that students were scaffolded by SenseMaker, hints, sentence starters, student journals, and the Toulmin argumentation pattern in SenseMaker. This is emphasized with the following representative quote.

"I think all of them help. When the hint appears on the screen, it a bit interesting; they start to think something else. Student journals were very good also, because yes, they were thinking about the unit but in the argumentation there is nothing about their own idea. So they can record into somewhere else. It was a good way of showing their own ideas about the other parts, the other sections of the same unit. I think these were very good and the variety was a good thing because if they have the same thing again and again it would be just boring for them. But after they finished an argument, a journal appeared and it was organized and as a teacher you don't need to explain every step. You explain once and if there is no problem they follow easily".

3. The teacher explained how she balanced her role with technology as first technology then teacher then technology-scaffolded students. This can be seen in the following representative quote.

"I leave everything to technology first, then I fill the gaps. In WISE, students followed everything from the technology but when they cannot make a connection between two steps then I helped them. Then I left them to the technology again. I think that this was a good way".

4. The teacher identified problem area as the difficulty of the topic and argumentation model and a poorly organized screen, repeated steps, and too many experiments and arguments in WISE. This is expressed in the following representative quote.

"An easier visual model would be a good example for a scientific argumentation model. It is better for students to name the steps as evidence, example and conclusion instead of ground, backing, and claim. Rebuttal was the hardest part for the students. The 'light' topic itself is difficult, especially for this age group, so it was hard for them to understand some points. The long sentences that students wrote for their arguments did not fit into the SenseMaker screen. If there was more flexibility and a better organized screen, students would do much better. The several experiments, too many arguments and the difficulty of the concept resulted in the students disliking the idea of making arguments. If it was something that they observe every day, they could write arguments more easily".

Student interviews;

1. Students indicated that the teacher scaffolded them by giving directions, giving support, explaining how to construct arguments and explaining the components of the Toulmin argumentation pattern and explaining how to write in student journals.
2. The role of technology related to the use of a computer, studying in WISE and SenseMaker, and writing in student journals and on experiment pages. This is expressed in the following representative quotes.

"I could not understand grounds and warrants at first but when the teacher explained them, it was better. I received help mostly from hints and the teacher. I also benefited from my friends' support. Teacher guidance and explanation is the help I most needed. With the teacher's help I understood how to construct arguments and I became confident. The teacher helped a lot in using the argumentation model".

"Technology helped me to learn and using technology was fun. The technological tool, SenseMaker, helped me in learning how to construct arguments. With technology scaffolds, I think that I understood and learned more easily. WISE was helpful in constructing arguments. The argumentation model enabled me to construct arguments by helping me organize my answer. Mostly, I benefited from student journals and hints. The hints in the little paragraphs gave me some descriptions about the arguments and facilitated my construction of arguments. Student journals helped me to revise all the knowledge I got. Sentence starters were sometimes helpful in staying focused. Before WISE, I had never constructed an argument. Using the Internet helped me a lot in constructing arguments since I accessed many resources. I think the components of the argumentation model are like pieces of a puzzle. When I put them all together, I can create an argument but if I had only one of them then I can't make a scientific argument".

3. In the context of Student–Teacher–Technology Scaffolding, how the roles of teachers and technology tools are balanced to scaffold students' scientific argumentation in TELE was examined and students indicated that they interacted with the technology and teacher by receiving help from the teacher first and then technology. Difficulties in using rebuttal and constructing arguments and the malfunctioning of technology were also mentioned by the group.

3.2 Distributed Scaffolding—Synergy

All the results of the video recording analysis supported by observation reports suggest that learning took place in an interactive environment in which the teachers, students and technology all have roles in the process.

1. Since there is a strong interaction and balance between teacher support and the technology scaffolds, there is a synergetic relationship that promotes student learning and improves a student's ability to construct arguments.
2. According to the video recordings and observation reports, the teacher's role was important in the class. Teachers, as facilitators, were knowledgeable of the skills and strategies for effective learning. Their responsibilities generally included engaging the student's interest, reducing the number of degrees of freedom by simplifying the task, modeling and highlighting the features of the task, maintaining direction in the class, demonstrating ideal solutions, and providing hints and asking questions that helped students to reflect and control their frustration.
3. As students worked on the "Light" project in WISE, technology helped them by providing sentence starters and question prompts in student journals and presenting the technological tool, SenseMaker, in the process of constructing arguments. Hints, the WISE-inquiry map, student journals and SenseMaker questions were all prepared according to the change in the students' level of knowledge. Students indicated in the interviews that technology facilitated learning via the students' reading of information pages in WISE and the student's use of a mouse instead of a pencil and eraser. Students also indicated that they used student journals to keep everything they learned

for later use and to think about this information as a fact when constructing argumentation. Hints and SenseMaker were useful tools with which to construct an argument. Students believed that WISE, as a whole, made them organized. With WISE, they were able to follow the topic easily because of the opportunities provided by, for example, the student journals and inquiry map. Another great opportunity was the ability to search the Internet while participating in the project. Video recordings and observation reports supported this result, revealing that the technology facilitated the construction of argumentation better than a teacher did in some cases.

4 Discussion

4.1 Distributed Scaffolding—Synergy and Verification of Kim et al.'s Framework

The results showed that technology-based scaffolds were especially conducive to improving the scientific argumentations of the students in Group 1. However, the researcher's argument is that even though technology creates opportunities and motivates students, the improvements in learners' ability to construct arguments rely on how the teacher implements the instruction. The teacher is the one who plans and organizes the teaching and learning in a complex technology-enhanced learning environment. The three types of interaction and the micro-level factors in Kim et al.'s (2007) framework are analyzed in this context and the findings are as follows.

Student-Tool Interaction;

Student–tool interaction is when students solve meaningful problems using technology and are supported by scaffolds. The classroom synergy, the dynamic between the participants and tools and fading (i.e., the removal of tools when students no longer need them) are important aspects that must be considered (Pumtambekar and Hübscher 2005). The results of the study showed that technology increased the students' motivation to learn science. Even though there were many barriers such as the difficulty of the "Light" unit, the students were able to improve their ability to construct arguments through technological scaffolds as shown in the analyses.

The technological tool helped them to be more organized and gave them access to many resources. While students might have found instant answers, precluding in-depth thought processes as mentioned for a study carried out by Kim et al. (2007), in this particular study, it appears that in constructing argumentation, the students forced themselves to find the appropriate information and place it in the appropriate component of the argumentation model, which could not have been done without in-depth thought. Examples include:

Teacher: "The boxes in which you can put your arguments in WISE. Click on "new claim" and proceed in WISE. Now, you need to write your ground into that box"
Teacher: "This is how you need to organize the boxes. Your sentences should not exceed the line".
Teacher: What do you already know about light? Write your answers in SenseMaker.
Student:
Claim—We think light is a form of energy that can be called electromagnetic radiation. It can be seen by the human.
Ground—The energy of light is called Radiant Energy. We can only see the Radiant Energy that comes out from the sun.

Warrant—Every light has a different wavelength depending on the color; for example, red has the longest while violet has the shortest wavelengths.
Backing—Waves are measured in nanometers. The energy of light is called Radiant Energy.
Rebuttal—Unless, there are types that cannot be seen by the human eye. All radiant energy that we can't see is called Invisible Spectrum.

As domain-generic scaffolds, the features of SenseMaker enabled students to understand the general framework for scientific argumentation; i.e., the claim, ground, warrant, backing, and rebuttal. In several cases, students lacked a few of these, especially rebuttal, in their arguments, which was proof that the students did not come up with the answers easily. Examples include:

Teacher: "When you did the ground and warrant continue with rebuttal"
Student: "I will do this for the first time and it is so hard"

Domain-specific scaffolds were synergetic since they provided additional support for the students to improve their abilities to construct argumentation, compared with the case for domain-generic scaffolds, which only helped students understand the general framework of the argumentation pattern. As for specific scaffolds, in their interviews, students indicated how they had benefited from the hints and the student journals as well as the question prompts and sentence starters, which showed the effectiveness and meaning of the student–tool interaction, leading the researcher to suggest that both must be embedded in technological tools in such a dynamic and multi-dimensional learning environment. Examples include:

Teacher: "Hints will give you idea about what you will write in your student journal"
Teacher: "Did you finish writing in your student journal?"
Student: "Yes".
Student: "Light is a type of energy. There are two types of light sources: Manmade and natural. Usually light looks white or yellow, but it is actually made of different colors. We can use special glass triangles to break the white light into its separate colors. My father once said that light could only be seen inside the atmosphere. You cannot see it while it is coming from the sun to earth because there is no gas".

One of the barriers in using scaffolds in the study was that there were many argumentation questions, which resulted in reluctance in the students, according to the teachers' interviews. However, this also led students to practice constructing arguments many times, which resulted in greater gains in the ability to construct arguments.

Teacher-Tool Interaction;

Teacher–tool interaction is when the teacher selects and organizes the tools in the class. In this study, the teachers and researchers worked together to integrate WISE. The study was conducted over a 2-year period and included a pilot study, during which the teacher from year 1 was consulted in designing the environment while the school curriculum was being planned. However, this was indicated as a barrier by Teacher 1 since the work was not her own. This results is also supported by Kim et al. (2007) who argued that the inquiry tools developed by the researcher must have perspectives similar to those of the teacher.

Teacher reluctance in integrating technology and implementing a new innovation in the classroom was a big drawback. This result is also supported by Kim et al. (2007) who argued even though a tool offers flexibility the teacher's customization of tool use is important, especially when teachers do not have experience in technology integration. In the present study, teachers were not experienced in using and integrating the content into WISE.

Another challenge could be online resources in terms of their questionable accuracy and quality; however, many secure resources were integrated into WISE to eliminate this factor.

In terms of *synergetic scaffolding* (Tabak 2004), which is multiple, co-occurring and interacting supports which address the same need, teacher support was synergistic with the scaffolds provided by the tool, which resulted in greater student learning in terms of the ability to write scientific arguments in the present study as shown in the example below.

> Teacher: "I can see your results on my screen. I will check several things on WISE. If you did it, you will get nice homework grade. You will click on "go to next activity", then you will write student journal four. Then follow the steps. Read the hint. Make another argumentation. One more thing you need to read is about surfaces and there is a little questionnaire here. On Monday, I will check and if you did it we will do very nice experiment at the science class.

The results are supported by Puntambekar and Kolodner's (2005) "distributed scaffolding" which was described as distributed support throughout diverse tools in the learning environment such as instructional materials, technological tools (templates and prompts embedded in tools) and teacher interventions.

Teacher-Student Interaction;

Teacher–student interaction is when the teacher provides scaffolds such as hints and questions for the student. The results of the study showed that the teachers had several roles in a technology-enhanced learning environment. The teacher was a facilitator, guide, mentor, and motivator. Even though the content was provided through WISE, the teacher explained unclear areas when necessary. The teacher also supported students with prompts and monitored their progress. This was not an easy task considering all the factors, and was, in fact, rather frustrating. However, the relationship between technology and teacher scaffolding was balanced and worked well, especially for Group 2. The teacher of Group 2 was very active in providing support at each stage and in informing students on what they were required to do, while the teacher of Group 1 chose to let the students follow the instructions from WISE on their own. These results are supported by the research of Kim et al. (2007), who argued that even though technology increases student motivation in science classrooms, teacher coaching and questioning are especially useful when students have difficulties with evidence. Examples are shown below:

> Teacher: "Listen, ok. I am noticing when you guys are turning your labs in that a lot of you don't know what refraction is. So even though you did a reading on WISE, it seems like you had sort of an understanding. So make sure that you understand it before you turn your lab into me. I want your labs at good explanations. So let me ask you, who can tell me roughly what they think refraction is?"
>
> Teacher: "You guys probably know the word medium as in something like medium size or a small size. But when we are talking about light. What is a medium?"
>
> Student: "Anything that light goes through".
>
> Teacher: "Yes anything that light travels through, transparent, translucent; we call them medium or media. Media is plural. Air is one medium, water is a medium, glass is a medium, anything that light travels through is a medium".
>
> Teacher: (She goes to the board with marker and starts to draw while explaining) "So imagine that over here is air (showing the up side of an arrow), And here is water

(writing water down the arrow). When light travels through air to water what happens to the speed of the light?"
Teacher: "When the light is travelling straight down like this. (She draws a wavy line down from air to water). And the waves go like this. It slows down but it doesn't change the direction. It goes straight into the water. So you know it doesn't bend or anything like that but it does slow down"
Teacher: "You should type it in separately and finish it and then copy into the boxes".

It was clear that without the strong interaction and balance between the teacher support and the technology scaffolds, there would not have been a synergetic relationship that promoted student learning or improved the student's ability to construct arguments. This is supported by the research of Sharma and Hannafin (2007), who also found that scaffolds must be integrated, considering various synergetic tools such as curricular materials, resources and teachers in dynamic environments.

Other findings include the importance of peer interaction, which is supported by Albe (2008), who explored how students elaborated arguments on a socio-scientific controversy in small-group discussions and found that students' social interactions affected the patterns of argumentation within the group discussions, which was in contradiction with the research of Ge and Land (2003), who found that peer interactions were unimportant in scaffolding.

4.2 Limitations of the Study

The participants of the study were students at the Bilkent Laboratory and International School, which has a student profile different from that of other Turkish schools. Therefore, the results of the study may only be generalized to students of other international schools that have similar missions.

Since the study was qualitative research, the data collection and data analysis procedure may be limited by the researchers' background. Since different teachers were involved in the pilot and actual studies, teacher reluctance limited the students' generation of appropriate arguments. Another limitation was that video recording did not explicitly focus closely on teacher–student–tool interaction. Therefore, the data collection and data analysis procedures may be limited by a lack of clarity in what the student asked for and how the teacher replied and what the student specifically wrote into the argument.

5 Conclusions

Even though inquiry-based science teaching and accordingly the construction of scientific argumentation have received considerable attention in education research and theory, technology-enhanced learning environments and distributed scaffolding require more research as challenges increase when technology is employed. In this context, the present study examined the synergetic relationship between technology-based scaffolds and teacher scaffolds and clarified how they interact and contribute to the argumentation abilities of students in WISE. The research questions "How are the roles of teachers and the technological tool balanced to scaffold students' scientific argumentation in TELE?", "What are the roles of the teachers in scaffolding students' scientific argumentation in TELE?" and "What is the role of the technological tool in scaffolding students' scientific argumentation in TELE?" were examined.

The results showed that technology-based scaffolds, which are provided with active support by the teacher, create a more effective environment, and students need multiple forms of support and multiple learning opportunities to learn science successfully in the dynamic and complex environment of the classroom. The study has also provided evidence that without the strong interaction and balance between the teacher support and the technology scaffolds, there would not have been a synergetic relationship that promoted student learning or improved the student's ability to construct arguments.

In the study student journals, hints, sentence starters and question prompts in student journals and the SenseMaker tool in a Web-Based Inquiry Science Environment (WISE) were used as scaffolds, which helped students to learn argumentation. Students used student journals to record everything they learned so that they could later use and think about the information as facts when constructing argumentation and they were more focused with sentence starters. The results showed that the students benefited from the use of hints, sentence starters and question prompts, which led the students to develop their ability to construct arguments with a claim, ground, backing, warrants, and in some cases, more sophisticated arguments using rebuttals as in the Toulmin argumentation pattern (Toulmin 2003).

Replicating this study in another school would help showcase the importance of the synergetic relationship between technology, teacher, and student in improving students' ability to construct arguments. In order to overcome the limitations mentioned above, another school that has a different student profile can be chosen. Additionally, same teachers should be involved in every step of the study and a medium that focuses on teacher-student-tool interaction should be selected.

In order to facilitate students' learning and argumentation skills, the roles of the teacher and technology and the interactions between student and tool, student and teacher and teacher and tool must be analyzed, and scaffolding must be designed carefully in a technology-enhanced learning environment as indicated by Kim et al.'s (2007) framework.

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