SUPPORTING STUDENTS' SCIENTIFIC ARGUMENTATION IN TECHNOLOGY-ENHANCED LEARNING ENVIRONMENTS: DISTRIBUTION OF SCAFFOLDS

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ABSTRACT

SUPPORTING STUDENTS' SCIENTIFIC ARGUMENTATION IN TECHNOLOGY-ENHANCED LEARNING ENVIRONMENTS: DISTRIBUTION OF SCAFFOLDS

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Over the twenty years, researchers and practitioners have developed technology tools and designed technology-enhanced learning environments to support and teach argumentation. Relevantly, Kim et al. (2007) presented a pedagogical framework to provide a valid technology-enhanced learning environment. The purpose of this design-based study was to investigate micro context dimension of this framework and to analyze the interactions between student-tool, teacher-student, and teacher-tool. In this respect, in order to understand how they balance the roles in a technology-enhanced learning environment, the effect of various scaffolds on forty-one middle school students' argumentation in a technology-enhanced learning environment and the distribution of scaffolds between teacher and the technology tool were analyzed. The results of the study showed that students benefited from the use of hints, sentence starters, and question prompts. Moreover, teacher support was important and led students to develop their ability in constructing arguments with claim, ground, backing, warrants and in some cases more sophisticated ones using rebuttals as in Toulmin's framework. The study presents guidelines and strategies for designing scaffolds in technology-enhanced learning environment to facilitate students' learning and argumentation.

Keywords: scientific inquiry, argumentation, scaffolding, distributed scaffolding, technology-enhanced learning environment

ÖZ

TEKNOLOJİYLE ZENGİNLEŞTİRİLMİŞ ÖĞRENME ORTAMLARINDA ÖĞRENCİLERİN BİLİMSEL BİR TEZDE BULUNMALARINI SAĞLAMAK: YAPI İSKELESİ DESTEKLERİNİN DAĞILIMI

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Yirmi yıldır araştırmacılar ve uygulayıcılar, hem öğrencilerin bir tezde bulunmalarını sağlamak ve hem de onlara bunun nasıl yapılacağını öğretmek için teknoloji araçları geliştirmişler ve teknoloji ile zenginleştirilmiş öğrenme ortamları tasarlamışlardır. Bununla ilgili olarak, Kim et al. (2007) geçerli bir teknolojiyle zenginleştirilmiş öğrenme ortamı sağlamak için pedagojik bir çerçeve sunmuştur. Bu tasarım tabanlı araştırmanın amacı bu çerçevenin mikro kapsam boyutunu araştırmak ve öğrenci-araç, öğretmen-öğrenci ve öğretmen-araç arasındaki etkileşimleri analiz etmektir. Bu bağlamda, teknoloji ile zenginleştirilmiş bir öğrenme ortamında rolleri nasıl dengelediklerini anlamak için, kırk bir ortaöğretim öğrencisinin teknoloji ile zenginleştirilmiş bir öğrenme ortamında kurdukları tezleri üzerinde verilen çeşitli yapı iskelesi desteklerinin etkisi ve öğretmen ile teknoloji aracının arasındaki yapı iskelesi desteklerinin dağılımı analiz edilmiştir. Araştırmanın sonuçları öğrencilerin ipuçlarından, cümle ve soru başlatıcılarından çok fayda gördüklerini göstermiştir. Ayrıca, öğretmen desteği önemli bulunmuştur ve öğrencilerin Toulmin modelindeki bileşenleri ve bazı durumlarda çürütmeyi kullanarak daha da ileri tez kurma becerilerini geliştirmelerine yöneltmiştir. Bu araştırma öğrencilerin öğrenme ve tez kurmalarını kolaylaştırmak için teknolojiyle zenginleştirilmiş öğrenme ortamında yapı iskelesi desteklerini tasarlamak için kılavuz ve stratejiler sunmaktadır.

Anahtar Kelimeler: Bilimsel araştırma-soruşturma, tezde bulunma-kurma, yapı iskelesi-destekleme, dağıtılmış yapı iskelesi-destekleme, teknoloji ile zenginleştirilmiş öğrenme ortamı

This dissertation is dedicated to my mother and grandmother who passed away during my graduate studies.

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CHAPTER 1

INTRODUCTION

Instead of teaching science as a body of facts to be memorized, focusing on scientific inquiry in science classes with a wide variety of practices enables students to develop their reasoning and thinking skills as well as their understanding of science. As an emerging perspective in science education, designers should support scientific inquiry in student-centered science learning environments (Kim & Hannafin, 2004a), constructing arguments (argumentation) is an essential component of scientific inquiry. Asking students to construct scientific argumentation instead of asking abstract questions about science, which they have no experience with, will provide better learning (Sandoval & Reiser, 2004). Sandoval and Reiser (2004) illustrated how constructing arguments helped students to learn science in their studies. According to Van Emeren et al. (1996), argumentation is a verbal (written or oral) and social activity aimed at justifying or defending a standpoint for an audience (cited in McNeill, 2006).

However, constructing arguments is not easy for students because they have difficulty in knowing what counts as evidence and in justifying their claims with evidence via warrants. For this reason, several methods have been proposed to help students to construct arguments such as:

(1) Direct instruction of reasoning skills based on an explicit model of argumentation. Cerbin (1988) argued that teaching students to reason more effectively is an important but difficult goal of higher education. Teaching reasoning requires providing students with a model for reasoning, frequent opportunities to practice it and direct instruction of reasoning skills.

(2) Scaffolding argumentation through the use of cognitive tools such as computer-supported collaborative argumentation (CSCA) software. Cho and Jonassen (2002) suggested that when scaffolding argumentation, part of the task is performed by the system for the student and cognitive tools are imposed to help the student to learn. In their study, they found that "Belvedere", a technology-based tool, effectively supported students' argumentation construction with scaffolds and concluded that scaffolding with technology-based tools is one way to support students' construction of higher level arguments. Erduran et al. (2004) also emphasized the necessity for science education research to focus on the improvement and development of such tools for the implementation of features of argumentation in teaching and learning.

(3) Toulmin's (1958) model of argumentation which is structured as claim, grounds support that claim, warrant connects claim to grounds, backing strengthens the warrant and rebuttal is the counter argument according to Erduran et al. (2004).

1.1 Statement of the Problem

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 still require more research as challenges increase when technology is employed. To support students' development of argumentation in science education, technology-enhanced learning environments which enable students to distinguish scientific conceptions have been designed (Tabak, 2004) and a variety of tools to support scientific inquiry have been used. Nonetheless, facilitation of inquiry-based activities and constructing argumentation, especially when technology is employed, is a complicated task. Employing technology to facilitate scientific inquiry and argumentation may be unsuccessful due to a variety of factors such as lack of effective guidance for students (Kim et al., 2007) and the difficulty of understanding how specific technological tools function in classrooms (Sandoval & Reiser, 2004).

Relevantly, to support the facilitation of students' inquiry processes and provide a valid technology-enhanced learning environment, Kim et al. (2007) presented a pedagogical framework. This framework helps science teachers to implement computer and web-based technologies that scaffold science learning (Hill & Hannafin, 2001). However, this framework has some flaws: (1) In microcontext student-tool interaction, even though student motivation is increased due to the use of technology, students need traditional teacher direction. When tool-based activities are not properly scaffolded, students face problems such as reading the online text or using web browser inappropriately. (2) Moreover, how to balance technology and teacher scaffolding is another issue in technology-enhanced learning. There is no consensus as to how far teachers should guide their students in inquiring with tools. (3) In teacher-tool interaction context, even though there are unlimited web-based resources available, their accuracy and quality can be problematic. Tools which include particular activities and assessment criteria developed by different researchers may present similar or different views from the teachers' views. As a result, how argumentation as a component of scientific inquiry in a technology-enhanced learning environment, must be promoted and how a technology-enhanced learning setting can best be designed with the above considerations (microcontext interactions of the framework) requires further research and qualitative study.

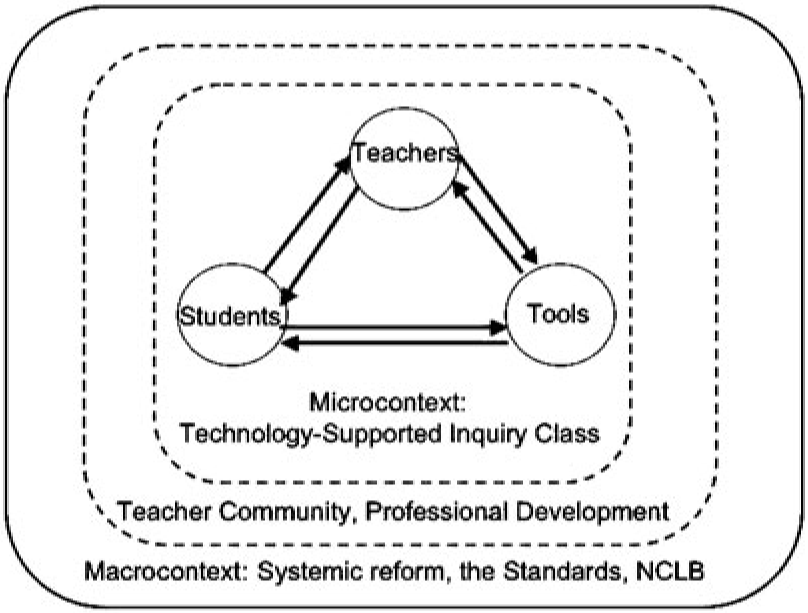

Figure 1.0.1 A pedagogical (theoretically ideal) framework for teaching and learning with inquiry tools (Kim et al., 2007)

1.2 The Purpose of the Study

As mentioned earlier, a pedagogical framework for guiding a design of student-centered inquiry-oriented technology-enhanced learning environments is presented by Kim et al. (2007). Yet, this framework must be investigated. Hence, the purpose of this study is to validate the microcontext dimension (analyzing student-tool, teacher-student, and teacher-tool interactions) of this framework.

In other words, my goal is to gain a more detailed understanding on how technology-based scaffolds help students' argumentation construction as well as the problems experienced by learners. To this end, the effect of various scaffolds on middle school students' argumentation in a technology-enhanced learning environment and the distribution of scaffolds between teacher and the technology tool are investigated to understand how the roles of teacher and technology are balanced in a technology-enhanced learning environment since scaffolding needs to be distributed and integrated for students to take advantage of the learning environment with teacher, tool, resources and peers. To this end, data is collected and the changes are recorded iteratively over time in designing scaffolding.

The study examines the following questions:

1. How do technology-based scaffolds (student journals, hints and SenseMaker) change students' scientific argumentation over time in a technology-enhanced learning environment (TELE)?
2. How do students use technology-based scaffolds and teacher scaffolds to construct scientific arguments in TELE?
    2.1 How does students' prior knowledge in science shape their use of the technology-based and teacher scaffolds?

2.2 What are the barriers to students' use of technology-based and teacher scaffolds?

3. How are the roles of teachers and technological tool balanced to scaffold students' scientific argumentation in TELE?

3.1 What is the role of teachers in scaffolding students' scientific argumentation in TELE?

3.2 What is the role of the technological tool in scaffolding students' scientific argumentation in TELE?

1.3 The Significance of the Study

As has been explained in the purpose, the main significance of the study is validating the microcontext dimension of Kim et al.'s (2007) framework and demonstrating how a technology-enhanced learning environment can best be designed within that framework. Research explains how students build their understanding with the help of diverse scaffolding and examines teacher facilitation as well as the generalizability of findings related to student-tool interaction (Kim et al, 2007). Moreover, more qualitative study is performed to observe this interaction in the microcontext framework of TELE.

Another significance of the study is validating that the scaffolds embedded in a technology-enhanced learning environment will elicit student argument construction. As a technology-enhanced learning environment, WISE (Web-based Inquiry Science Education) helps students to construct arguments, which include evidence and conceptual ideas. By using technology-based scaffolds, students restructure and communicate their understanding; in other words, they learn from each other and make conceptual progress.

The third significance is demonstrating how technology-based scaffolds and teacher scaffolds interact and contribute to argumentation. In this respect, the synergetic relationship between technology-based scaffolds and teacher scaffolds, which has not received much attention in the past (Tabak, 2004), is examined. This is done in accordance with what Tabak (2004) stated as the need for multiple scaffolds and how different elements interact as a system is a concern for future studies. Relatively, Puntambekar and Kolodner (2005) observed that scaffolding could not be provided with any one tool in the dynamic and complex environment of a classroom and argued that students need multiple forms of support and multiple learning opportunities to learn science successfully. On the other hand, Zydney (2010) raised some questions concerning the effectiveness of combining multiple scaffolding tools since they had varying effects on students' understanding.

Consequently, this study attempts to determine how a technology-enhanced learning environment can best be designed within Kim et al.'s (2007) framework and how the scaffolds embedded in a technology-enhanced learning environment elicit student argument construction in the WISE (Web-based Inquiry Science Education). Lastly, it examines the synergetic relationship between technology-based scaffolds and teacher scaffolds.

1.4 Definition of Terms

- Inquiry: “Engaging students in the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, revising views, researching conjectures, searching for information, constructing models, debating with peers, communicating to diverse audiences, and forming coherent arguments.” (Linn et al., 2003, p. 518).

- Scientific inquiry: “Diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work.” (National Research Council, 1996, p. 23).

- Argumentation: “Argumentation is a verbal, social and rational activity aimed at convincing a reasonable critic of the acceptability of a standpoint by putting forward a constellation of propositions justifying or refuting the proposition expressed in the standpoint” (van Eemeren & Grootendorst, 2004, p.1).

- Scaffolding: ‘‘Process by which a teacher or more knowledgeable peer provides assistance that enables learners to succeed in problems that would otherwise be too difficult” (Wood, Bruner, and Ross, 1976) (cited in Quintana et al., 2004, p.338).

- 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).

- Technology-enhanced learning environment (TELE): “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)

CHAPTER 2

LITERATURE

In this chapter, the researcher begins by discussing the importance of scientific argumentation for students and why it is essential to enable students to develop and improve their skills in science classes. Then the researcher reviews the literature on argumentation models and the difficulties students have in constructing arguments. Finally, the researcher turns to the scaffolding, scaffolding argumentation, frameworks for technology-enhanced learning environments – synergy (distribution) of scaffolds literature and discusses how the scaffolds embedded in a technology-enhanced learning environment elicit student argument construction and examines the synergetic relationship between technology-based scaffolds and teacher scaffolds.

2.1 Scientific Argumentation

Argumentation is an important skill in everyday life since people are usually faced with situations in which they have to decide which action to take based on evidence after evaluating several scenarios. Argumentation is making claims by providing justification using evidence. According to Kuhn and Udell (2003), argumentation is "the advancement of a claim in a framework of evidence and counterclaims" (p. 1245). As Jimenez-Aleixandre and Erduran (2007) argued, the use of argumentation must be encouraged since it improves meaningful learning and develops students' communicative and critical reasoning skills. Furthermore, argumentation increases scientific literacy and scientific understanding.

Science involves theories that provide explanations about the natural world. Models, observation, creative thinking and argumentation are important aspects in the construction of these theories. Driver, Newton, and Osborne (2000) argued that since scientists often collect and interpret data, and therefore deal with argumentation, argument construction is the core of science. Moreover, when talking about the interpretation of evidence, conflict and argumentation are more valid than agreement (Erduran et al., 2004). Scientists make use of argumentation to prove or refute hypotheses or theories.

According to Evagorou & Avraamidou, argumentation is an important practice in science that emphasizes the nature of its discourse (2008). Similarly, Erduran, Simon, and Osborne (2004) argued that argumentation provides the structure for developing communication and discourse skills. Thus, it is necessary to enable students to develop and improve their skills in science classes. In science classes, argumentation is relevant to two aims: knowledge justification and persuasion (von Aufschnaiter et al., 2008 p.13). Students learn to express their ideas by understanding the meaning and the relationship between claim, evidence and warrants when they practice scientific argumentation (Erduran et al., 2004). They search for different opinions and then make claims supported by evidence or explanation. Scientific argumentation requires students to evaluate the accuracy of their claims.

2.1.1 Argumentation models

Argumentation is generally in three forms: analytical, dialectical and rhetorical as explained by Duschl (2008a). In 2003, the European Science Education Research Association in a session entitled "Communication and Discourse Analysis in the Science Classroom", presented some theoretically driven analytical frameworks for the study of discourse in science classrooms. Such frameworks correspond to Jimenez-Aleixandre and Pereiro Munoz's (2005) use of Toulmin's framework to study students' interactions in small groups. Similarly, Castells et al.'s (2007) use of Perelman's Theory of Argumentation to study teacher-student interactions, Marquez, Izquierdo and Espinet's (2006) use of Halliday's model of Functional Grammar, Piccinini and Martins' (2005) use of Kress and colleagues' semiotic modes, and Scott and Mortimer's (2005) study of several interactions including student-student interactions in the classroom (Erduran, 2008) are all in accordance with the above mentioned analytical framework of the 2003 session.

Analytical arguments are grounded in the theory of logic, whereas dialectical arguments are those which occur during discussion and debate. Rhetorical arguments, on the other hand, stress knowledge of audience (Dusch, 2008). Duschl and Ellenbogen (1999) pointed out that argumentation will develop from the dialectical structures/patterns to the analytical structures/patterns. Dusch (2008) further claimed that designing learning environments to promote argumentation is complex due to the fact that those three different forms of argumentation in the discourse of science depend either on the application of analytical forms of arguments or Toulmin's model of practical arguments.

Toulmin's model argument is structured as claim, grounds support that claim, warrant connects claim to grounds, backing strengthens the warrant and rebuttal is the counter argument (Erduran et al., 2004). Cho and Jonassen (2002) explained that stating claim is like stating hypothesis, grounds are data stating a measurement or observation that provide evidence for a possible answer, warrant is the principle giving the reason why the grounds are for or against the possible answer (claim), backing is implying support for the argument and rebuttal is implying rejection of the argument in Toulmin's model.

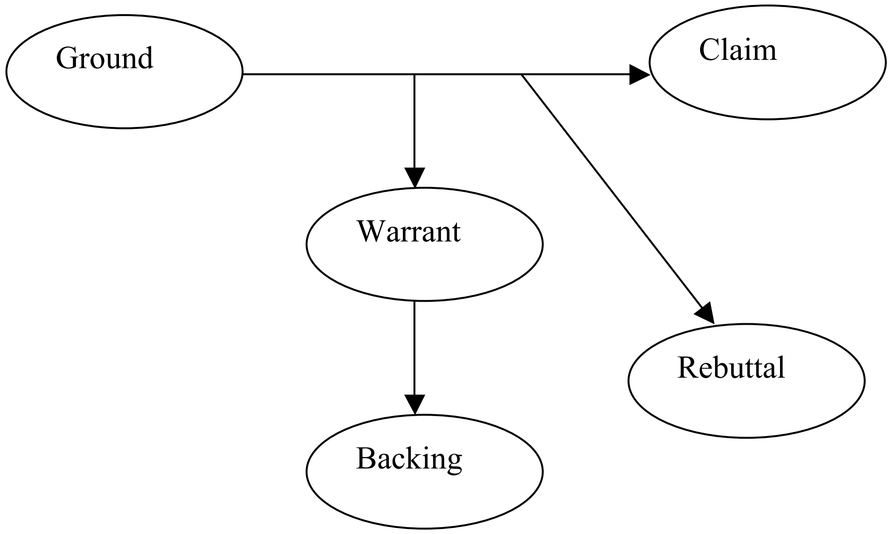

Figure 2.0.1 Toulmin's argument pattern (Toulmin, 1958) (cited in Erduran et al., 2004, p. 918)

Toulmin's argument pattern has been used to examine students' reasoning and justification. However, there are some difficulties in the application of this model due to varying and vague definitions for claim, grounds, warrant, and backing. To illustrate, all the statements can be called claims since they can very easily be considered as grounds or rebuttal when reasoning in different contexts.

A number of studies have investigated Toulmin's Argument Pattern and found that concerning the quality of argumentation and reasoning, whether the claim is justified, whether there is a link between claim and grounds such as warrants, whether a rebuttal exists and whether grounds are strengthened with backings are all important considerations. For example, Erduran et al. (2004) collaborated with middle school science teachers to develop instructional activities for making argumentation a component of instruction. Using Toulmin's Argument Pattern in their study, they asserted that students' ability to construct strong rebuttals is significant for effective argumentation (Erduran et al., 2008). Therefore, the quality of the argument was evaluated based on the presence or absence of rebuttals. Consequently, in their study they considered evidence-based rebuttal as a high level of argumentation, whereas irrelevant counter argumentation lacking evidence was low-level argumentation.

Onyancha and Anderson (2010) used a modified version of Toulmin's (1958) model of argument analysis to examine the elements of grounds, warrant and backing that students used to support their claims. They illustrated that more sophisticated students prefer to use elements that appeal to scientific principles, while less sophisticated students tend to use analogical or tautological elements as well as personal beliefs to support their claims.

Consequently, argumentation needs to be practiced by students, who are required to collect data and evidence, produce reports, support their knowledge claims with evidence for developing their argumentation skills when working with authentic problems. Teachers' support for students' understanding of argumentation is also important in determining the quality of argumentation.

2.1.2 Difficulties in schools

In order to encourage students to practice talking science and challenge each other's ideas in a more open form of instruction, a different type of discourse needs to be employed instead of traditional science discourse patterns in classrooms (McNeill & Pimentel, 2009). In this respect, McNeill (2010) emphasized the importance of engaging students in inquiry where they construct arguments by making claims with evidence rather than just participating in fun hands-on activities. Even though inquiry instruction is also emphasized by National Standards, scientific inquiry activities are not employed much in science classes since it emphasizes the depth of knowledge and requires learners to focus on higher-order problem solving such as making hypotheses based on evidence, which is difficult with direct question-answer strategies (Kim & Hannafin, 2004a).

Linn et al. (2003) also pointed out that scientific inquiry requires students to diagnose the problems, conduct and critique the experiments, search for information, debate with peers and construct arguments – making it difficult to employ inquiry practices in science classes. Indeed, facilitating inquiry-based activities is a difficult task and employing technology to support scientific inquiry increases the challenges (Kim et al., 2007). Moreover, as a component of scientific inquiry, incorporating argumentation into classroom science is challenging (Osborne et al., 2004).

Therefore, argumentation must be carefully studied in order to understand the nature of students' discussions, which involve doing and talking science (Jiménez-Aleixandre et al., 2000). Moreover, research examining students' argument construction is new and students face difficulties in constructing high-level arguments even with specially designed instructional materials (Cho & Jonassen, 2002). Students either do not use any evidence to support their claim or they use only one item of evidence rather than a set of evidence (Cho & Jonassen, 2002). Students also tend to support their arguments with their beliefs rather than evidence (Jonassen & Kim, 2010). Belland et al. (2008) also commented on how middle school students struggle to find evidence and integrate gathered information into their arguments (cited in Belland, 2010). Constructing arguments by justifying claims with evidence and debating in order to defend their arguments are particularly difficult tasks for students, especially when reasoning with warrants, even though better solutions are generated when connecting the claims with warrants to support arguments (Bell & Linn, 2000). A common weakness in argumentation is the lack of counter argumentation (Jonassen & Kim, 2010).

Despite all the difficulties students face in constructing arguments, argumentation can be improved through rehearsal and teachers have a crucial role in facilitating student engagement in argument but unfortunately they generally lack experience in this area (Driver, Newton, and Osborne, 2000). Moreover, teachers lack the pedagogical skills to support argumentation in class, there is no time for skills development due to the external pressures, and learners lack prior knowledge (Driver et al., 2000). According to Jonassen and Kim (2010), instructional designers also lack knowledge of argumentative pedagogies. Some other studies looked into whether or not students were engaged in argumentative discourse and also the teacher's role in supporting argumentative discourse (McNeill & Pimentel, 2009). Kaya, Erduran, and Çetin (2010) enquired into the connection between students' argumentation perceptions and their improved engagement in argumentation and found that most students are enthusiastic about participating in an argumentation discourse.

2.2 Scaffolding

Scaffolding helps support students' engagement in argumentation and facilitate their argumentation skills. Students need such support especially when solving ill-structured problems, due to the importance of generating alternative solutions (Cho & Jonassen, 2002). Wood, Bruner, and Ross (1976) defined scaffolding as the process in which a child solves a problem or achieves a goal which is beyond his unassisted efforts. Therefore, adult assistance is essential to enable the child to complete a task that is not within the child's range of competence (p.90). Hannafin, Land, and Oliver (1999) defined scaffolding as guiding and supporting the learning effort.

Scaffolding is a socio-constructivist 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 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). In view of this, scaffolding is the support that an adult or an expert provides to the learner until the learner is able to perform the task independently when the support is removed. An expert is a knowledgeable person who is well informed about the strategies and processes for effective learning and thus qualifies to guide a student to accomplish a task and to provide support by modeling and highlighting the critical task features as well as to provide hints and questions that will help the learner to reflect.

There are six types of support that an adult can provide:

(1) Recruiting the child's interest,
(2) Reducing the degree of freedom by simplifying the task,
(3) Maintaining the direction,
(4) Highlighting the critical task features,
(5) Controlling frustration, and
(6) Demonstrating the ideal solution paths (Wood et al., 1976).

Key elements of scaffoldings are:

(1) The shared understanding of the objective,
(2) The support provided based on the ongoing diagnosis of the student's current level of understanding since the student's capabilities change as the instruction progresses.
(3) The interaction between a student and the teacher. Though the teacher plays an important role, the student's participation in the process is crucial. Reciprocal teaching is a well-known scaffolding interaction in the classroom.
(4) The dialogical and bi-directional nature of scaffolding is important, especially in peer interactions since peers can motivate each other.
(5) Fading, which means removing the scaffolding as the responsibility moves from the teacher to the student and the learner goes on to independent learning (Puntambekar & Hübscher, 2005).

Puntambekar and Kolodner (2005) also confirmed that important features in scaffolding are:
(1) Shared understanding of the objective,
(2) Understanding and assessing students' understanding,
(3) Helping them to engage in interactions, and
(4) Giving them the responsibility of learning after the completion of the task; i.e. fading, which is described as internalization by Vygotsky.

According to Vygotsky's (1978) internalization, cognitive processes first occur on an inter-psychological plane and then move on to an intra-psychological plane. 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.

Social engagement and interaction are essential for cognitive development and learning rooted in Vygotsty and learning argumentation and other epistemic practices are involved in constructivist science classrooms' goals and are grounded on social constructivist views of learning (Jimenez-Aleixandre, 2008). Classroom discourse involves interaction between students and the teacher, teaching, reasoning and the construction of scientific knowledge. It is organized as cognitive apprenticeship, which requires students to support their claims with evidence. In order to support the argumentation role of students, the role of the teacher, curriculum, assessment, metacognition and communication are the main issues to be considered when designing constructivist learning environments (Jimenez-Aleixandre, 2008).

In this respect, the task must be scaffolded and the level of students must be understood within their own ZPDs for a successful design of scaffolding in classrooms. (Puntambekar and Kolodner, 2005). In building scaffolds in complex learning environments, there are multiple ZPDs that designers have to take into consideration. Scaffolding exists as environments and resources as well as between individuals. The classroom synergy, the dynamic between participants and tools and fading, removing tools when students do not need them anymore, are the key aspects that must be considered (Puntambekar & Hübscher (2005).

Pea (2004) shared this view by pointing out how software serves to advance learner performance and which processes of fading need to be employed to enhance learners' independent performance. Puntambekar and Hübscher (2005) restated the recommendation of Palincsar (1998) regarding the theoretical use of scaffolding and the ways of scaffolding the activities for learning as well as the relationship between scaffolding and good teaching when designing complex learning environments.

Since a classroom is synergetic, scaffolding can be described as interactions between a teacher and a student. Student support is provided with technological tools, peer interactions and discussions. To scaffold students, the teacher should form small groups and provide tools such as computers or written materials. Working with small groups is important since it is not efficient for a teacher to carry out this process with the whole class (McNeill, 2006).

Throughout the whole process, students face many challenges. They are often unable to engage in activities or to make sense of their work or have difficulty finding a direction. To overcome such problems, several tools have been developed and graphic representations are provided, such as KIE (Knowledge Integration Environment), to support and scaffold the students.

As technological tools have become increasingly used for supporting learning in classrooms, the concept of scaffolding has also been employed to determine which features of these tools are helping learning. Within project-based and design-based learning environments in math and science classes, the notion of scaffolding is used with hints, and prompts provided in tools. From the multiple types of hints in KIE to the conceptual and epistemic supports in Explanation Constructor, three types of scaffoldings – supportive (what to do hints), reflective (prompts that promote reflection) and intrinsic – in Model-it are used. KIE has been extensively used in middle schools.

A number of studies have examined scaffolding and teachers' use of scaffolding. For example, the application of the concept of scaffolding to situations that go beyond its original context of one-to-one learning to interactions between teacher and a whole classroom and the social context of scaffolding interactions have been examined (Littleton, 2013) and the findings emphasized the significance of scaffolding as it acknowledges power and authority. Another study, which aimed to promote whole-class scaffolding of mathematical language, investigated seven strategies as identifiable by its key characteristics: diagnosis, responsiveness and handover. The results provided empirical evidence of the long-term realization of whole-class scaffolding (Smit & VanEerde, 2013).

With the development of a professional development program (pdp) based on a model of contingent teaching, teachers' scaffolding knowledge, use of scaffolding in practice and reflections on practice were analyzed (Van de Pol et.al, 2012). The results showed that insights regarding openness, students' understanding and co-construction fostered teachers' scaffolding development. In another study, the scaffolds supported teachers' practice and suggested strategic improvement in the focus and organization of different types of scaffolds (Sleep et.al, 2012).

2.2.1 Scaffolding argumentation

Engaging students in argumentation by encouraging them to find evidence from the web is a knowledge integration activity. Bell and Davis (2000) claimed that scaffolded knowledge instruction is an approach to support knowledge integration. The important principles of scaffolded knowledge instruction are:

(1) To make thinking visible by showing how links are made,
(2) To make models for scientific phenomena that make sense so that students can connect the new information to the existing knowledge,
(3) To provide social support so students can learn from their peers, and finally
(4) To enable students to become autonomous learners.

Linn et al. (2003) and Bell and Linn (2000) outlined those principles as making thinking visible, making science accessible, helping students learn from each other and promoting lifelong learning. The aim of KIE (Knowledge Integration Environment) is to improve student understanding of complex scientific concepts, and its framework includes a project-based curriculum structure to scaffold students' science activities along with appropriate software tools (Bell, 2000), One software component and tool of KIE is SenseMaker. A graphic representation, SenseMaker is an argumentation tool, which helps students to construct arguments with claims and evidence. Even though there are a number of software tools for argument construction, SenseMaker is a knowledge representation tool, which supports the construction of rhetorical arguments by individuals and also provides an intermediate representation involving evidence, claims, and explanations (Bell, 2000). In Bell's study (2000), the use of SenseMaker is encouraged at individual and collaborative levels. In other words, students are encouraged to include their prior knowledge, make their thinking visible in SenseMaker by allowing reflection and self-expression of ideas, and collaborate with their peers and teachers by sharing their ideas on claims and evidence.

Studies showed that several diverse supports are required for students to make a transition from everyday life to the scientific practice of supporting claims with evidence (Bell & Linn, 2000). Those supports are defined by McNeill (2006) as the temporary structures and scaffolds, which are provided by people or tools to promote the learning of complex problem solving. Scaffolds have been provided in different format: technology-based scaffolds, written scaffolds given as prompts, teacher coaching and peer support (Bulu, 2008). The process of peer review, according to Cavagnetto (2010), is also important for knowledge construction as it builds up knowledge through quality control.

As regards written scaffolds and technological tools, Bell and Linn (2010) studied domain-specific and domain-general scaffolds for argumentation in science. In her study, McNeill (2006) was interested in incorporating both domain-specific and domain-general scaffolds to support students because she believed that they need to both understand the content and be able to justify claims using reasoning in order to construct strong arguments. McNeill (2006) used hints about content knowledge as domain-specific scaffolds and a general framework for argumentation as domain-general scaffolds to support students in understanding the content as well as enabling them to justify claims using reasoning in order to construct strong arguments.

The Knowledge Integration Environment (KIE) also provides prompts as technology-based scaffolds for helping students to complete complex science projects (Davis, 2003). The prompts are provided as activity hints which provide definitions and examples, evidence hints to help in thinking about particular evidence, claim hints to help in thinking about a particular claim. Such scaffolds are especially useful when students work in small groups and help them to reflect on their own, especially when specific and general prompts are provided. Highly specific prompts help students develop the warranted explanations and contribute to knowledge integration with the other important scaffolding in a learning environment. KIE also provides sentence starter prompts, which aim to enhance reflection in metacognitive (one's own thinking) and sense-making (content) tasks.

As previously mentioned in WISE, SenseMaker as an argumentation tool of KIE helps students to construct argumentation with claims and evidence. In *SenseMaker*, students organize sets of evidence by dragging elements into frames, thus showing which arguments the evidence supports or refutes. Student Journal is a persistent journal in which students revisit the same text and edit it over time in response to evidence and new ideas. It also shows how the ideas change over time stage by stage. Hints helps students to focus on inquiry and probe for connections.

Therefore, in this study the researcher used Hints and Student Journals as domain-specific scaffolds to help students understand the content and practice reasoning. The researcher also used *SenseMaker* as a domain-general scaffold to represent a general framework for argumentation and help students to construct argumentation in an organized framework. Research about argumentation is focused on in a variety of domains. Numerous studies have been carried out and countless studies have been conducted on scaffolding argumentation. Different aspects of the same subject matter were pointed out in many ways. Below are some of the studies, which contributed to the background knowledge for the topic.

2.2.1.1 Studies on scientific literacy

A study examined the definition of scientific literacy provided by the Programme for International Student Assessment (PISA) (Sadler & Zeidler, 2009). The authors compared the socio-scientific issues (SSI) framework with the PISA approach and found that they are compatible in terms of the general aims of science education.

In his study, Cavagnetto (2010) examined fifty-four articles from the research literature about how argument interventions promote scientific literacy in categories – the nature and the emphasis of the argument activity and the aspects of science included in the argument activity – and concluded that researchers approach the learning of argument through immersion, instruction on the structure of argument and emphasis on the interaction of science and society.

Some questions about the characteristics of argument interventions in schools were:

(1) When argument interventions are used during an instructional unit?
(2) What are interventions designed to stimulate argument about?
(3) What aspects of science are present in argument interventions?
Based on these questions, the following can be considered:
(1) The nature of the argument intervention,
(2) The emphasis of the argument intervention, and finally,
(3) The aspects of science included in the argument intervention (Cavagnetto, 2010).

Junior high school students' processes of argumentation and cognitive development were investigated and it was found that students draw on their prior knowledge and experiences, consolidate their existing knowledge and elaborate their science understanding at a relatively high level of abstraction (Von Aufschnaiter et al., 2007). Other studies focused on different age groups. McNeill (2010) studied fifth grade students' perspective of explanation, argument and evidence in three contexts – what scientists do, what happens in science classrooms and what happens in everyday life. They found that students' perspectives of explanation, argument and evidence varied in these three different contexts, but students developed more sophisticated views of these scientific practices and they were able to write stronger scientific arguments by the end of the year.

Since there has been little research concerning how students draw on their prior knowledge and what happens in science classrooms in the construction of arguments, the researcher is interested in focusing on these areas. In this research, the researcher investigates how does students' prior knowledge in science shape their use of the technology-based and teacher scaffolds and what happens in science classrooms in the construction of arguments?

2.2.1.2 Studies on how to promote argumentation and thinking skills

Non-science major students' ability to use various thinking skills are investigated through case studies in the Biotechnology Module by Dori et al. (2003) and a significant improvement was found in students' knowledge and understanding and higher order thinking skills – question posing, argumentation, and system thinking – at all academic levels. Jonassen and Kim (2010), in their study, proposed methods and guidelines for developing students' argumentation skills along with problems that students experience when constructing arguments and found that students who evaluated alternative arguments better supported their arguments on the immediate transfer task and provided more justifications for their solutions to ethics problems.

Driver et al. (2000), in their review of the existing literature, concluded that even though classroom practice provides opportunities for students to develop their ability to construct argument in science classes, there is a lack of opportunities for the practice of argument and teachers often lack the necessary pedagogical skills to organize argumentative discourse. Four factors – role of teacher, role of students, the context and the use of writing frames – promoted student argumentation in a study in which a science teacher participated in a professional learning session and then taught argumentation skills to classes studying genetics (Dawson & Venville, 2010a). They also looked into the effect of classroom-based argumentation on high school students' argumentation skills, informal reasoning and conceptual understanding of genetics and found that students improved significantly in the complexity and quality of their arguments, rational informal reasoning, and the conceptual understanding of genetics (Dawson & Venville, 2010b).

Furthermore, the difference in effectiveness between two on-line scientific learning programs was demonstrated by Yeh and She (2010) and it was found that the one with an argumentation component facilitated students' argumentation abilities and conceptual change. In their research, Jimenez-Aleixandre et al. (2000) discussed developing effective contexts to promote argumentation and science discussion in the classroom. They used Toulmin's Argumentation Pattern, focused on the different arguments constructed and found that students developed a variety of arguments with a predominance of claims and in some cases more sophisticated ones using justifications, backings, or warrants.

Student motives in engaging in scientific practices are examined and identified three objectives: sensemaking, articulating, and persuading (Berland & Reiser, 2009). They found that students use evidence to make sense of phenomenon and articulate it but do not persuade others of their understanding because it requires social interaction, which is often not allowed in traditional classrooms. The effects on low achieving high school students of open inquiry instruction in argument construction of a general science course were studied by Yerrick (2000) and it was found that students' arguments shifted to a more consistent nature depending on students' uncertainty of knowledge claims, students' use of evidence, and students' views of scientific authority.

How students apply genetics content knowledge as they justify claims is examined in Sadler and Fowler's (2006) study. They found that college science majors frequently referenced specific science content knowledge in the justification of their claims and they outperformed the other groups in terms of justification quality and frequency. However, argumentation, which was assessed in terms of the number and quality of justifications, did not differ among non-science majors or high school students.

Developing a learning progression for scientific practice is focused on by Berland and McNeill (2010), who claimed that "argumentation is a central goal of science education because it engages students in complex scientific practice in which they construct and justify knowledge claims”. They found that the instructional context may be used as a tool to support students in argumentation and increase the complexity of their written arguments.

Keys et al. (1999), in their study on a science writing heuristic tool, which has been used by teachers as a framework to design classroom activities, found that the use of this tool facilitated students in generating meaning from data. This contributed to students' understanding of the nature of science becoming more complex, rich, and specific.

In a study conducted by Engle and Conant (2002), students developed arguments, used evidence and provided questions about biological classification as a problematic subject matter. The authors provided a set of guiding principles about how to promote productive disciplinary engagement in a learning environment, reviewed two cases in the literature and found that these principles can be used in understanding those cases as well.

The process by which students solve scientific problems, the difficulties students encounter in developing scientific arguments and the ways in which their social roles shape the development of the arguments were studied by Richmond and Striley (1996). They found that knowledge building involves the construction of scientifically appropriate arguments, which depends on students learning to use the tools of the scientific community, their expectations about and roles in the tasks and their access to the social context in which they practice the skills.

In their qualitative case study, Oliver and Hannafin (2001) developed mental models for improving student problem solving by means of open-ended learning environments incorporating students’ hypotheses and analogical reasoning. They found that students’ content understanding improved only in some macrolevel earthquake engineering concepts and concluded that their findings do not support or refute the development of mental models.

Kim and Hannafin (2008) later argued that the use of cases is integral to an individual’s problem-solving process and presented findings from recent implementations on how novices become experts through case-based activities and reasonings with transfer of learning. They also presented the theoretical assumptions and principles for a grounded, web-enhanced case-based activity.

The relationship between Socio-scientific Issues (SSI) instruction and students' development of reflective judgment is investigated. The Reflective Judgment Model is used as a tool for assessing the value of SSI, which involves ill-structured problems that call for evidence-based reasoning. Statistically significant results were obtained (Zeidler et al., 2009). Consequently, as Driver et al. (2000) concluded, even though students need to be able to construct arguments in science classes, there is a lack of opportunities for the practice of argument. This researcher is interested in providing practice opportunities for students to develop their abilities to construct arguments. In the analysis of students' argumentations, the researcher will examine their justifications of claims and the use of evidence.

2.2.1.3 Studies on how to analyze arguments and frameworks

A study by Naylor et al. (2007) looked into the extent to which primary school pupils engage in argumentation. A framework developed for analyzing argumentation illustrated how students co-constructed arguments without teacher guidance. The types of argument representations were reviewed by Scheuer et al. (2010). They found that a variety of systems for different types of argumentation have been developed and the designers have chosen different ways to represent arguments, design the interaction between the student and the argument, automatically analyze arguments and provide students with intelligent feedback to support argumentation.

An analysis of several analytic frameworks to assess the quality of scientific arguments in three aspects – structure, justification, and content – is provided by Sampson and Clark (2008). They found that many of the frameworks describe the structure of an argument in terms of claims and justification and some of them include a generic reason and justification component to simplify difficulties such as in differentiating between grounds, warrants and backings in Toulmin's framework. The authors also argued that the diversity of perspectives provided insight to students in generating arguments in science education.

Since there has been little research on Toulmin's framework in analyzing the quality of arguments, the researcher is interested in conducting an analysis using a rubric based on Toulmin's model. With this model, individual scores will be achieved by adding the number of points in each category – claim, ground, warrant, backing and rebuttal – so that the difficulties in differentiating between categories will be overcome.

2.2.1.4 Studies on the role of collaboration in constructing arguments

In improving learning and argumentation, collaboration scripts play an important role in online settings by forming groups of students (Clark et al., 2009). In this context, their study compared the personally-seeded script with a variant augmented-preset script and the results showed the highest gains in learning when students were engaged in a diverse set of preset discussion seed-comments with a conflict schema approach. In their study about engaging middle school students working in collaborative groups in a problem-solving activity through instruction and guidance in scientific explanation, Palincsar et al. (1993) examined the processes and outcomes of students' problem solving to find the fastest and the slowest way to dissolve sugar and found that the role of explanation in students' discourse, scientific concepts which interacted with everyday concepts and opportunities that students had to experience the activity of science were important.

In their study, Sampson and Clark (2009) looked into the effect of collaboration during scientific argumentation and found that groups of students did not produce better arguments than students who worked alone, but they showed better performance in the mastery and transfer problems. The authors concluded that collaboration was beneficial for individual learning but not for initial performance on the task. In their research, Maloney and Simon (2006) were concerned with the development of children's skills of interpreting and evaluating evidence in science and found that collaborative activities with a mapping technique can develop those skills and promote children's ability to argue effectively in making decisions.

A few studies looked at the effect of collaborative activities in constructing arguments. When analyzing the results, the researcher will also evaluate whether students produce better arguments when they study with their peers and how peer support can influence their way of constructing arguments.

2.2.1.5 Studies on the effect of CSCL in constructing arguments

Computer-supported collaborative learning environments (CSCL) provide new opportunities for learning, and the results of a study showed that teachers' belief in good discussions and good moderation related to face-to-face discussions contrast with those related to synchronous, CSCL-mediated discussions (Gil et al., 2007). Weinberger and Fischer (2006) proposed a multi-dimensional framework to analyze argumentative knowledge construction in computer-supported collaboration learning (CSCL). The results showed that each script component successfully facilitated participation and the process dimension and the argumentative script components facilitated the construction of arguments. With the help of a coding scheme, the authors also showed that computer-supported collaboration scripts can support specific process dimensions of argumentative knowledge construction in CSCL.

The relationship between procedural and conceptual problem solving in a computer-supported collaborative learning (CSCL) environment in science education was examined by Krange and Ludvigsen (2008), who found that procedural problem solving dominated students' interactions compared to conceptual problem solving. They also argued that conceptual knowledge construction in science education must be explicit in the CSCL environment and must be encouraged by teachers and the administration. In designing effective science inquiry, text-based computer-supported collaborative learning environments (CSCL) offer great potential for supporting students and teachers (Clark et al., 2003). They further proposed a set of design guidelines and strategies for supporting science inquiry learning through text-based CSCL for curriculum designers and educators and concluded that the combination of these strategies create significant synergies.

Even though computer-supported collaborative learning environments have gained attention in the research, there is lack of guidance in designing such environments. In this research, student-centered inquiry-oriented technology-enhanced learning environments will be investigated. To this aim, the researcher will propose a set of explicit guidelines and strategies for designing such environments.

2.2.1.6 Studies on how to support argumentation

Producing arguments is an important skill in problem solving and students need more argumentation support when solving ill-structured problems because students search for different opinions and perspectives, adopt a solution and support it with evidence and data while attempting to solve problems (Cho & Jonassen, 2002). In this respect, the authors found that providing students with online argumentation scaffolds during group problem-solving activities increased the generation of coherent arguments.

In another study, students were guided by a set of question prompts, an argument sheet and an argument diagram while working in groups for collaborative argumentation in science (Chin & Osborne, 2010). The authors found a positive correlation between the number of questions written, the concepts addressed and the quality of written arguments. Thus, they concluded that students make explicit claims, construct explanations, and think about alternative propositions with the help of initial focus questions.

How to best support middle school students in constructing scientific explanations was studied by McNeill (2006). Their results showed that the context-specific scaffolds provided greater student learning for scientific explanations in terms of evidence and reasoning and also fostered greater student learning of the science content. Constraint-based argumentation scaffolds during group problem-solving activities also increased the quality of students' arguments (Cho & Jonassen, 2002).

Domain-specific scaffolds and domain-general scaffolds are combined in McNeill et al.'s (2006) study and they found that students showed greater improvement with faded scaffolds. Bulu (2008) also focused on those two areas in terms of the effects of domain-general and domain-specific scaffolds with different levels of support, continuous or faded, and found that domain-specific scaffolds could better assist students in learning and integrating knowledge compared to domain-general scaffolds. In her study of the effectiveness of scaffolding treatment on college students, Shimek (2013) found no statistically significant differences in students' epistemological reasoning about how data are used as evidence; however, pretest domain knowledge was a statistically significant covariate for post-test domain knowledge and a statistically significant main effect for scaffolding treatment.

Another discussion concerning argumentation in science education was the debate about controversy. With a micro-ethnographic approach, Albe (2008) explored how students elaborate arguments on a socio-scientific controversy in small group discussions and found that students' social interactions significantly influenced the patterns of argumentation within the group discussions. Kelly and Chen (1999) in their ethnographic research focused on students' participation in creating scientific discourse on the physics of sound and studied how students used evidence to make claims. They found that students' scientific discourse was determined by the framing activities of the teachers and the social practices established over time in the classroom. A case study to teach argumentation for pre-service secondary science teachers and to illustrate how teachers structure their lessons and support argumentation was presented by Erduran, Ardaç and Yakmaci-Güzel (2006). Following the training sessions, they found that teachers used group discussions and presentations as pedagogical strategies.

Research shows that supporting argumentation had been a focus of attention in the past, but still requires more research. In this study, the researcher also examines whether scaffolds have any effect on students' scientific argumentation over time. During the study, the researcher uses domain-specific and domain generic scaffolds as well as other scaffolds. Students also participate in a debate.

2.2.1.7 Studies on Scaffolding with Technology-based Tools

The effect of switching from typical to inquiry instruction in students' understanding of complex science topics, was studied by Lee et al. (2010). They found that technology-enhanced inquiry instruction significantly affects students' learning. 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 in a broad range of such tools. Specially designed technological tools can help teachers understand the process of argument construction in the science class (Evagorou & Avraamidou, 2008).

Technological tools can help structure the learning task as well as guide and support the learners in their performance (Reiser, 2004). How game structures affect students' thinking, the effect of role-playing on learning, and the role of the physical environment in shaping one's learning was examined by Squire and Jan (2007). Students were required to develop scientific argumentations through game play. They showed that augmented reality games increase students' engagement in meaningful scientific argumentation and scaffold their thinking process.

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.

Scaffolding with technology-based tools helps students to construct higher level arguments according to Cho and Jonassen (2002). They further asserted that argumentation can be supported effectively by online argumentation scaffolds using a tool called "Belvedere". Duschl (2008b) also pointed out that there is a need for tools that support and scaffold students' participation in argumentation discourse and teachers' assessment of the students' argumentation (p. 160).

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). Progress Portfolio (Land & Zembal-Saul, 2003), Knowledge Integration Environment (KIE) (Oliver & Hannafin, 2001), ExplanationConstructor (Sandoval & Reiser, 2004) all describe how to embed supports in software. Sandoval and Reiser's (2004) findings showed that an epistemic tool "ExplanationConstructor" helps students' thinking and plays a significant role in supporting students' inquiry. Bell and Davis (2000) had earlier argued that scaffolding in the form of prompts and hints for supporting argumentation actually helped students' knowledge integration in a technology-enhanced learning environment – Mildred study. Demetriadis et al. (2008) also stated that students' learning and problem-solving performance in ill-structured domains can be improved if elaborative question prompts are used.

Three kinds of epistemic explanation scaffolds are provided by Lee and Songer (2004): exemplars, questions and sentence starters in a technology-enhanced curriculum. They illustrated that treatment groups exhibited gains in knowledge and ability to strengthen claims with evidence and high ability students used and benefited more from the explanation scaffolds compared to low ability students. The ThinkerTools curriculum created by White and Frederiksen (2000) depicted a significant difference between tools with reflection prompts and those without (McNeill et al. 2006). How students use evidence, determine and measure progress in understanding light using Knowledge Integration Environment was examined by Bell and Linn (2000). In another study, Er and Ardaç (2008) supported middle school students' science learning with a Web-based science learning tool (WebFEN).

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.'s (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.

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 for middle school students to design and use their knowledge to evaluate evidence is created by Cuthbert and Slotta (2004). 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.

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.

Consequently, there has been much interest in using technological tools to scaffold learners and many different scaffolding techniques have been used. In this study, the researcher uses Web-based Inquiry Science Environment (WISE) as a technology-enhanced learning environment and various technology-based scaffolds such as student journals, hints and SenseMaker since this area still requires more research. As previously mentioned, in the analysis of students' argumentations in SenseMaker and student journals, the researcher examines whether various technology-based scaffolds contribute to students' ability to write scientific argumentation in each category; claim, ground, warrant, backing and rebuttal.

2.2.2 Technology-enhanced learning environments – Synergy (Distribution) of scaffolds

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 & Kolodner, 2005). Some examples are instructional materials, task sequencing, social arrangements, technological tools (templates and prompts embedded in tools) and timely teacher interventions.

Not all of the scaffolding can be provided with only one tool in the dynamic and complex environment of the classroom, as observed by Puntambekar and Kolodner (2005) in their study. They went on to say that students need multiple forms of support and multiple learning opportunities to learn science successfully. Technology-based scaffolds must also be designed to provide support in conjunction with other scaffolds (Sharma and Hannafin, 2007). For example, interaction between a teacher and the technology tool facilitates student's performance by modeling or voicing. Thus, technology-based scaffolds that are supported by the teacher's active support create a more effective environment.

To guide future designs, three complementary patterns of distributed scaffolding are:

(1) Differentiated scaffolding, which is combining multiple forms of supports provided through different means to address several diverse learning needs; the BGuILE project (Reiser et al., 2001; Tabak et al., 1999) and the tool ExplanationConstructor (Sandoval & Reiser, 2004) are both differentiated scaffolding,

(2) Redundant scaffolding, which is different means of supports that target the same need at different points in time,

(3) Synergetic scaffolding, which is multiple co-occurring and interacting support for the same need (Tabak, 2004).

Hence, in dynamic environments, scaffolds may be integrated using a variety of synergetic tools in the form of curricular materials, resources and teachers. Consequently, synergetic scaffolds support a single need through multiple, co-occurring and interacting supports. However, Zydney's (2010) study raised some 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.

2.2.2.1 A Pedagogical Framework by Lakkala (n.d.)

Designing complex and authentic tasks requires a review of instructional design models to obtain qualitatively better learning results. A successful application of technology poses many challenges in the learning environment, even requiring that the teaching be designed in a whole new way. When considering the effect of technology, its pedagogical implementation is important since technology does not simply mean integrating the tools. A framework of pedagogical infrastructure consists of these types of components:

(1) Technical (technological tools),
(2) Social (promoting students to collaborate effectively),
(3) Epistemological (helping students to understand that knowledge is something that can be improved and shared),
(4) Cognitive (enabling students to understand the working strategies and learn to work independently as an expert), as introduced by Lakkala (n.d.), which can aid in designing the elements of a learning environment based on technology-enhanced collaborative learning.

Interactive and iterative learning environments have a greater effect on students' learning than innovative technologies. However, many factors such as students' readiness, teacher role, teaching practices and classroom culture have an effect on implementing tools in such complex classroom contexts. Some students were unable to solve higher level problems even when using carefully designed tools such as locating and categorizing web resources using KIE's SenseMaker (Kim et al., 2007). They stated that research is needed to examine student problem solving strategies and cognitive and social learning patterns linked to different characteristics. According to them, some students can use scaffolds like indexed activities, hints or prompts, whereas others can browse through the structured activities with no mindful engagement.

2.2.2.2 A Pedagogical Framework by Kim et al. (2007)

Another framework to guide teaching and learning in technology-enhanced science classes was presented by Kim et al. (2007). Since it is important to understand the factors that influence 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. Their proposed framework in Figure 2.0.2 analyzes factors at the macro level (the systemic level), the teacher level (teacher community) and classroom level (technology-enhanced class).

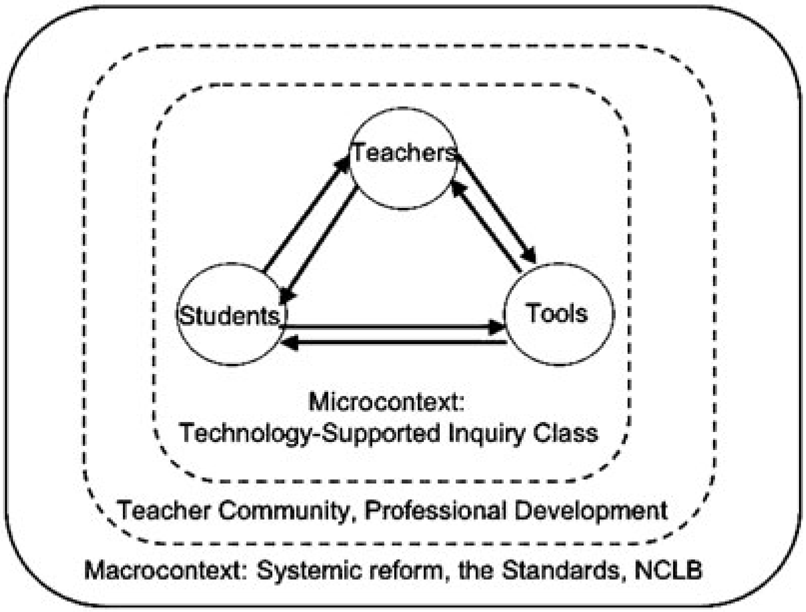

Figure 2.0.2 A pedagogical (theoretically ideal) framework for teaching and learning with inquiry tools (Kim et al., 2007)

Furthermore, 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 occurs when students use technology and are supported through scaffolds. However, since there is not much research on student-tool interaction, little is known about when student-tool interactions are meaningful, how students use them and the drawbacks in students' use of technology. 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 using tools for students who do not have difficulties and avoid cognitive overload. For example, with a web browser tool, students generally use the web resources without guide and have a tendency to find answers quickly rather than to think about the information deeply.

For this reason, according to Wallace et al. (2000), students must be supported through conceptual and procedural scaffolds embedded in the Web tool (cited in Kim et al., 2007). More research needs to be done on student-tool interaction in science classrooms.

Teacher-tool interaction emerges when the teacher selects and organizes the tools for the class. Even though tools offer a significant flexibility, teachers' tool use customization is important. It is especially crucial when teachers do not possess deep content knowledge or experience in technology integration. The inquiry tools developed by different researchers must have perspectives similar to those of the teacher. 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. Another challenge in this context concerns web-based materials in terms of their accuracy and quality despite their tremendous availability.

Teacher-Student Interaction arises when the teacher provides scaffolds like 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. To illustrate, 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. However, teachers struggled with classroom-based science inquiry difficulties in the classroom because of lack of time, resources and student management skills. Even though a teacher has several roles in a science classroom – guide, mentor, motivator, etc. – it is not clear what the teacher's role in tool use should be during the inquiry. Again, there has not been much research regarding teacher facilitation in technology-enhanced learning environment and managing a balance between technology and teacher scaffolding.

Previous studies have examined scaffolding strategies to facilitate complex activities in a technology-enhanced environment in science classrooms. One framework was developed by Shen (2010). Kim and Hannafin (2011) also investigated how peer, teacher, and technology-enhanced scaffolds influenced student inquiry. They found that students used different types of scaffolds to facilitate the inquiry and concluded that technology-enhanced scaffolds are effective when supported by clear project goals, relevant evidence, peer- and teacher-assessments and examples of knowledge articulation.

Hannafin, Land, and Oliver (1999) argued that, in technology-enhanced learning environments, scaffolds help students determine what and how to think during problem solving. This is done with hints about resources or guidance in how to use available resources and tools using bookmarks, assistants, etc. (cited in Bulu, 2008). The effects of question prompts and peer interactions in scaffolding were examined in Ge and Land's (2003) study. They found that question prompts had significantly positive effects on student problem-solving performance; however, peer interactions did not have any significance.

Technology-supported inquiry learning as an opportunity for integrating content and process learning was explored using a design framework called the Learning-for-Use (LFU) model, which provides a framework for the design of learning activities that contribute to the development of robust understanding (Edelson, 2001). The expected results were that the LFU model would enable students to master science content and process objectives more effectively. Another study investigated the effect of different types of scaffolding and their interaction in a web-based collaborative science inquiry project (Raes, in press). Teacher enhanced scaffolding, technology-enhanced scaffolding and the two combined were compared. The findings supported the notion of multiple scaffolding as an approach to enhance domain-specific knowledge and metacognitive awareness during online information problem solving (IPS).

As previously mentioned, according to the Kim et al.'s (2007) framework there has not been much research on student-tool interaction, teachers' interaction with tool, teacher facilitation in technology-enhanced learning environment and managing a balance between technology and teacher scaffolding. Little is known about when student-tool interactions are meaningful, how students use them and the drawbacks in students' use of technology, the role of the teacher in scaffolding students' scientific argumentation. Moreover, there is a gap in research in Turkey in scaffolding argumentation in technology-enhanced learning environments. For this reason, this research is based on an analysis of the effect of various scaffolds on middle school students' scientific argumentation in Turkey. The researcher will also examine the synergetic relationship between technology-based scaffolds and teacher scaffolds and attempt to understand how they interact and contribute to the argumentation abilities of students as well as how students use scaffolds to construct arguments in Web-based inquiry science in a student-centered inquiry-oriented technology-enhanced learning environment. Finally, the researcher will propose a set of explicit guidelines and strategies for designing such.

CHAPTER 3

METHODOLOGY

This chapter outlines and describes the methodology that was used in conducting the research;

(1) to test microcontext dimension,
(2) to analyze its interactions with *Kim et al.'s (2007) pedagogical framework*.

Likewise, being the subject matter of the research,

(3) how to design scaffolding embedded in a technology-enhanced learning environment to facilitate students' learning and argumentation skills and
(4) the distribution of scaffolds between teacher and technology.

3.1 Research Questions

Even though a pedagogical framework is presented for guiding the design of student-centered inquiry-oriented technology-enhanced learning environments, this framework can open further discussion and instead of fully influenced by, its microcontext dimension can only partially intersect with the other two in reality (Kim et al., 2007). Moreover few researchers have examined approaches to balancing technology and teacher scaffolding, research findings provide little guidance as to teacher facilitation of student- centered inquiry in technology-rich classrooms and studies examining tool use during classes have rarely been examined in similar classroom settings (Kim et al., 2007). Thus, the purpose of the study was to investigate the microcontext dimension of this framework and to analyze the student-tool, teacher-student and teacher-tool interactions. In this respect, first the effect of various scaffolds on middle school students' argumentation in a technology-enhanced learning environment and then the distribution of scaffolds between teacher and the technology tool were analyzed to understand how their roles are balanced in a technology-enhanced learning environment.

The study examined the following questions:

1. How do technology-based scaffolds (student journals, hints and SenseMaker) change students' scientific argumentation over time in a technology-enhanced learning environment (TELE)?
2. How do students use technology-based scaffolds and teacher scaffolds to construct scientific arguments in TELE?
    2.1 How does students' prior knowledge of science shape their use of the technology-based and teacher scaffolds?

2.2 What are the barriers to students' use of technology-based and teacher scaffolds?

3. How are the roles of teachers and technological tool balanced to scaffold students' scientific argumentation in TELE?

3.1 What are the roles of the teachers in scaffolding students' scientific argumentation in TELE?

3.2 What is the role of the technological tool in scaffolding students' scientific argumentation in TELE?

3.2 Participants

The participants were a total of 41 6th grade students with an age range of 11 to 12 years in 3 classes at Bilkent Laboratory & International School (BLIS) in Ankara, Turkey. There were two teachers, one American with five years of experience, teaching a class of 16 students (11 Male & 5 Female), and one Turkish with two years of experience, teaching two classes with 12 (6 Male & 6 Female) and 13 students (6 Male & 7 Female) respectively. The students were able to use computers, with computer skills sufficient for the purposes of this study. The demographic data includes and is limited to age and sex in this study.

BLIS 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 such a dense research study.

3.3 Materials

WISE (The Web-Based Inquiry Science Environment), a free online environment of the University of California at Berkeley (UCB) and supported by the National Science Foundation, was used in the study. WISE provides students from grades 5-12 with different science modules. In WISE modules, students work on exciting inquiry projects with topics such as global climate change, population genetics, hybrid cars and recycling. Furthermore, WISE environment guides students through information pages that provide content, “notes”, “hints”, and discussion tools, etc. (http://www.wise.berkeley.edu/pages/intro/wiseFlashIntro.php).

Promoting knowledge integration with science projects (in other words, connecting existing and new ideas, restructuring the ideas and adding further experiences from the real world) improves students’ understanding of science. The researcher used WISE in this study because WISE offers both proven technological tools and a flexibly adaptive environment (Linn et al., 2003, p. 535). With the help of its knowledge representation argumentation tool SenseMaker, students are able to construct arguments that involve evidence, claims and other components of Toulmin’s Model of Argumentation. Linn et al. (2003) also stated that students get the opportunity to gain a deeper and more comprehensive understanding of inquiry when they participate in WISE projects and teachers become more competent in guiding inquiry using WISE projects.

For this study, the unit “Light: Particle or Wave?" was designed for 6th grade students on a physics chapter about “Light” as a WISE module. The science department preferred implementing the study on this unit since students had had difficulty in understanding it in previous years. They indicated that “Light” was a difficult topic especially for this age group and maybe technology could have supported students’ learning in this unit. The objectives of the unit are presented in Appendix A. In WISE, the researcher designed the lesson and activities according to the teacher’s directions to facilitate students’ understanding of the nature of “Light” as depicted in the chapter. The teacher conducted and directed the design and content of the WISE module on “Light”. Each activity was designed according to the goals stated in Appendix A. 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.

Students were expected to complete a number of investigations (activities) throughout the “Light” unit. These helped students to grasp the key learning goals, including both target science content and the construction of scientific argumentation. The activities and goals, which designed for classroom practice, are given in Table 3.0.1

Table 3.0.1
Activities, Learning Goals, & Classroom Practices & Experiments

Activities	***Learning Goal***	***Classroom Practice & Experiment***
Activity 1 – Warm-up *Appendix B* (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 learnt 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 & Lateral Inversion (6 periods – Week 2)	Students will be able to identify and explain types of reflection.	The reflection & 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 & 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.

Table 3.0.1
Activities, Learning Goals, & Classroom Practices & Experiments (Continued)

Activity 5 – What a Colourful World: Rainbows and Spectra (4 periods – Week 3 & 4)	Students will be able to understand the concepts of colour and colour reflection and absorption**.**	The colour reflection & 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 C) (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.
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.

Throughout the unit, students had multiple opportunities to construct scientific arguments that include claims, grounds, warrants, backing for evidence as well as rebuttal and personally relevant conceptual ideas. It is likely that they restructured and communicated their understanding and learned from each other by using the technological tool SenseMaker. Bell and Linn (2000) argued that the SenseMaker elements (evidence dots and claim frames) work well with middle and high school students.

At the end, students prepared and participated in a classroom debate. They presented an argument on "how light is made up…" by providing as many reasons as they can to justify their position and evidence to support their reasons. Making the scientific debate visible to students contributed to students' science concept.

Consequently, with the WISE project students were able to identify their own ideas by discussing with peers, responding to prompts or constructing arguments. They could also consult their teachers, search for alternatives, revisit their work and add new parts. They were also able to integrate their knowledge from the experiments that they had conducted on "Light". Students were able to link their existing and new ideas through this Project, which provided sustainable activities. The "Light" project helped students understand that science inquiry involves argumentation and debate, and students had a better understanding of evidence, argument and debate.

Different types of scaffolds were embedded in WISE environment. Those scaffolds were designed based on the previous records. Then the researcher met with the thesis advisor to explain those scaffold treatments. Some of them were revised with the recommendations of the thesis advisor. Students were supported with SenseMaker as domain generic, with student journals, hints, sentence starters and question prompts in the student journals and SenseMaker as domain-specific scaffolds.

The types of scaffolds in the form of prompts used in the WISE module were in the following order;

(1) Students Journals: Students wrote their answers with the help of sentence starters and question prompts in these journals.
(2) Hints: Throughout the activities hints were delivered.
(3) SenseMaker: Students first constructed their arguments as a sub-argumentation in which the question was different for each topic and then as a main argumentation in which the question was the same for each activity.

As specific scaffolds, student journals served to enable students to revisit the same text and edit it with new ideas over time, sentence starters, question prompts and hints served to enable them to focus their inquiry and probe for connections. Both helped students to understand the content. As a generic scaffold, the features of SenseMaker helped students to understand the general framework for scientific argumentation: claims, grounds, warrants, backing, and rebuttal.

In SenseMaker students generated a scientific claim based on evidence. Students were asked to provide justifications and create arguments supported by grounds, warrants, backing and rebuttal and indicate them with their initials (C: claim, G: ground, W: warrant, B: backing, R: rebuttal). By doing this, students reviewed evidence from the Internet, described and grouped the evidence using frames in the SenseMaker argument, where each item of evidence for arguments was represented by a dot and linked to its Internet location. In this way, students were able to organize evidence into claims.

Students were exposed to scaffolds several times during the project. The first activity, the Warm-Up, did not provide any scaffolding since this was only pre-test and presented introductory information about science argumentation pattern with examples. In addition, the scaffolds in the form of hints, questions for student journals, SenseMaker and the main driving question "Is light made up of particles or is light like a wave?” were all suggested and prepared by teacher. These are given in Table 3.0.2 below.

Table 3.0.2
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 & 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?	

Table 3.0.2
Types of Scaffolds (StudentJournal, Hint, SenseMaker) (Continued)

Activity 4 – Different Surfaces & 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?*
	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 & 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?	

3.3.1 Pilot Studies

Two pilot studies were conducted with 3 classes, each with 18-19 students, during the spring semester in the year 2009-2010. In order to carry this out, first permission was obtained from the school administration. As a result of a meeting with the school director, they were willing to conduct a research study in their school. Meetings were organized with the 6th grade science teacher and he was briefed about the study. Each week a meeting with the science teacher was planned and the teacher was consulted on the development of the content of the study. At that point, the school was in a period of adaptation to the Ministry of Education's curriculum. According to the curriculum, the unit "Light" was to be taught to grade 6 students. Due to this, the researcher had the opportunity to conduct two pilot studies in the school.

The science teacher and the researcher conducted pilot studies together and both were present in all stages of the studies. Both pilot studies were videotaped. Students were encouraged to participate fully in the study. At the end of the pilot studies, it was observed that students were eager to debate and participate in the study. The teacher and students expressed their feelings by saying that the study was interesting and instructive with a diversity of resources. Since the unit was very challenging especially for this age group, the "Light" unit was selected as the project topic with the recommendation of science department to facilitate the process.

3.3.1.1 Pilot Study 1

The first pilot study was conducted from March 22 to mid April 2010 in the Bilkent Laboratory & International School and fifty-one grade 7 students participated in the study. The problems observed during the first pilot study were noted by the researcher and were altered and improved.

In the first pilot study, after planning and designing the inquiry tools to be implemented in class, the researcher observed that the teacher was hesitant about his role and how he would carry out the lesson. Should he teach the whole lesson or should he be a facilitator? The researcher suggested that he should be a facilitator, so he left students to learn on their own by following the inquiry map. At that point, the researcher realized that students were not quite certain what to do. Therefore, the teacher became actively involved with the students and guided them. In fact, the teacher had designed some guidelines for getting started in using WISE, but it was not sufficient. The teacher and the researcher subsequently decided to design explicit guidelines on WISE, like giving information about claims, grounds, warrants, backing and rebuttal with clear examples. Later, the researcher realized that students did not use the inquiry tools as the teacher had intended. Multiple factors need to be considered when using inquiry tools. For this reason, the teacher and the researcher decided to design guidelines on how students would use the inquiry map effectively and thought that an argument had to include at least three items of evidence for support. The teacher and the researcher further observed students' independent and collaborative inquiry methods, how they used tools and their perceptions of learning through scaffolds; as a result, decided to provide alternative sets of questions to prompt students. There was no doubt that there were several points in the design that needed revision and adjustment in accordance with students' needs, interests and perceptions of learning.

3.3.1.2 Pilot study 2

Before the study, a second pilot study was conducted from May 24 to 4th of June in the same school, and this time fifty-six grade 6 students participated. The changes made were utilized. The problems observed during this study were also noted by the researcher and were changed and improved at the end of the study.

In the second pilot study, even though several points in the design were reconsidered and adjusted according to students' needs, interests and perceptions of learning along with the teacher recommendations, some problems remained. The teacher still felt the need to be more effective in teacher student interaction since students kept asking questions about what to do and how to do it. The teacher's guidelines for getting started in using WISE worked well this time. Designing explicit guidelines for students when working on WISE had better results but was not satisfactory enough for this age group. For this reason, this information was given in a table to be more effective. The study was held within a more restricted time span than before. This resulted in students' tending to skip some sections. Some other students still had problems using inquiry tools properly.

The changes made after the two pilot studies can be summarized as a revision of the WISE environment. A unique format was designed for all activities and steps. The text was given in a table with dark green borders on a green background and images were 2.40 by 3.20 inches. Videos were saved & embedded in web pages and published. The Toulmin's scientific argumentation pattern was added as a graph with an example from the literature (Jiménez-Aleixandre et al., 2000). All student journals were revised and videos were embedded as separate steps. The class debate was divided into two parts: debate preparation and the debate itself. Six brainstorming steps including all the questions in the students' journals were planned. In those steps, students were required to submit their positions as well as their rationale. Experiment pages were created for each experiment. WiseData was created for the experiments. All student journals and hints were designed using open-ended questions as domain specific scaffolds. In each activity, two SenseMaker questions (one being the main debate question) were asked as domain general scaffolds. With reference to the list given in the literature, the teacher prepared student journal questions and hints. The Teacher's Manual was prepared and revised. The studies had been planned to last two weeks each, but the first one lasted approximately four weeks. While the second study was conducted in two weeks, it was clear that the actual study should be planned to last for at least three weeks.

3.4 Research Design

This research looked at how technology-based scaffolds change students' scientific argumentation when learning about the unit, the interaction between the teacher and the technological tool to support scientific argumentation in technology-enhanced learning environment and how students use scaffolds. Thus, it had a design-based research and observational case study design type of qualitative approach since the focus was on a particular organization and its aspect such school classroom and some activity in that classroom. The school in which the research was conducted had been selected with a convenience type of sampling due to the accessibility.

The complexity of the settings, multiple interacting paths, and the new possibilities of emerging technologies are reasons for adopting a design-based research 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) 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".

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, is another reason for adopting a design-based research. 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 & Hannafin, 2005).

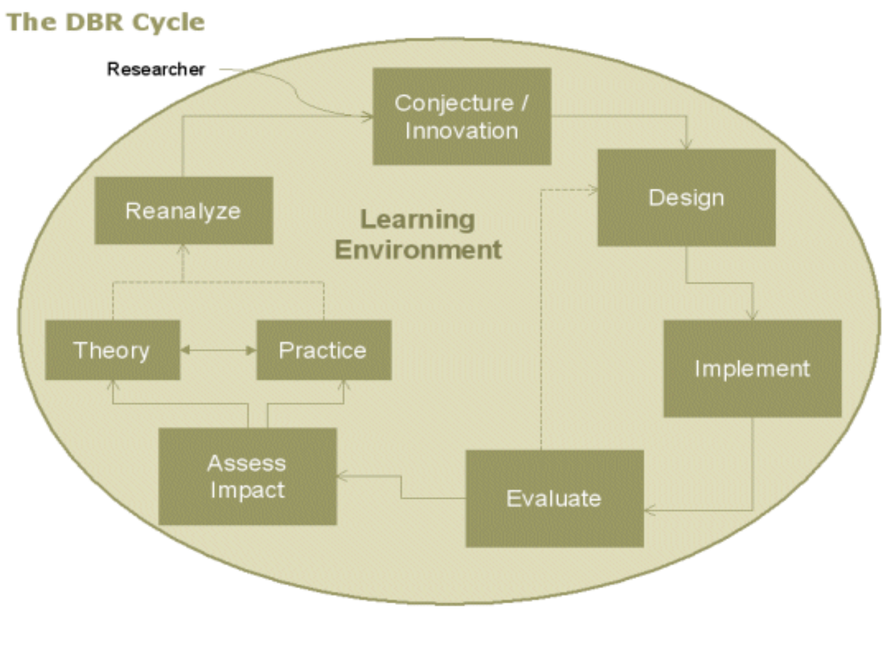

Figure 3.0.1 Design-based Research Cycle

Design-based research is characterized by an iterative cycle of design, enactment or implementation, analysis, and design (DBRC, 2003 cited in Wang & Hannafin, 2005). For example, in Sandoval and Reiser's design-based research 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 & 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 used widely earlier in Web-based inquiry science environment (WISE) and knowledge integration environment (KIE; Linn, Clark, and Slotta, 2003; Bell & Linn, 2000), biology guided inquiry learning environment (Sandoval & Reiser, 2004), etc.

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.

Micro context (classroom) involves three types of interactions:

(1) Student-tool interaction when students find and solve meaningful problems with technology tools. According to Kim et al (2007), little is known about *student-tool interaction, which* is how students use tools. Thus, individual strategies and research are needed to examine school context and teacher characteristics relevant to student-tool interaction.

(2) Teacher-tool interaction, when the teacher selects and organizes the tools. In technology-enhanced learning environments, teachers may change the use of inquiry tools according to the perceptions of students' needs and interests, teacher interests, teaching and learning styles or specific classroom needs relevant to *teacher-tool interaction*.

(3) Teacher-student interaction when teacher provides scaffolds such as hints and questions for students. Little is known about teacher facilitation in technology-enhanced classrooms (Kim et al, 2007). Kim et al. (2007) stated that many students have difficulties and need their teacher's guidance in tool use. Technology in a science class increases student motivation, but it is also important to scaffold tool-based inquiry activities effectively. In technology-enhanced learning environments teacher scaffolds exist either through question prompts or monitoring students' learning processes and monitoring students' activities by asking questions about their progress. Teacher interviews, videotaping and field notes revealed that monitoring, short and extended content interactions and social exchanges are core *teacher-student interactions*.

3.5 Procedure

Following approval of the application to the Middle East Technical University Human Subjects Ethics Committee on the 3rd of February, meetings were organized with the school director and the middle school principal in February. They were informed for the second time about the project and its aim in detail (the first one had been held before the beginning of the year to obtain permission to conduct the study). The middle school principal was also informed about the parents' and students' consent forms; before starting the study, the students and their parents were requested to sign student and parent consent forms (Appendix H). In these forms, parents and students were given some introductory information about the project, and the students were informed that their participation would not be related in any way to their grades and all their responses would be strictly confidential.

Another meeting was organized with a computer technician. He was informed about the need for a computer lab and the technical requirements for the implementation of the project. Laboratory reservations were made and times arranged. Meetings were also planned with the science teachers during February and they were consulted about the development of the content of the study. According to the curriculum and the recommendations of teachers, the design of a WISE environment was completed during February and March. The topic "eye" was removed, a "refraction" experiment and a hint were added, "refraction" and "different surfaces" were merged into one activity and some changes in the order of steps in the inquiry map were made.

Prior to the study, training and a manual for the teachers were provided (Appendix G). This included some information about the project and the activities, WISE (Web-based Inquiry Science Environment) and some recommendations for encouraging students' use of evidence to support their claims such as "How do you know?" "What is your evidence for..?" and "What reasons do you have..?". Teachers were also familiarized with Toulmin's Argumentation Pattern for exploring applications in their classes. Lesson materials with a set of activities that would encourage students to write their arguments were distributed to the teachers (Erduran et al., 2004) along with a rationale stating why scientific argumentation is important, what scientific argumentation is and some strategies that teachers can use to help their students throughout the unit. Some of these strategies are defining scientific argumentation, modeling scientific argumentation by using hypothetical examples, connecting students' prior knowledge to everyday examples and providing students with feedback. These strategies coach students on how to improve their argumentation. The underlying goal of the lesson was to help students make sense and be able to reason.

The study was conducted in 6th grade science classes for twenty-two periods from April 18th to May12th – a four-week period. Students participated in eight activities. The sequence was generally as follows: the teacher introduced the basic concepts about the experiment initially. Then, the task was outlined. Lastly, learners were asked to summarize their findings for each experiment in experiment pages and, if necessary, to create a data table.

For the first activity, a pre-test was given to understand students' prior knowledge. For the next activities, students took notes in their student journals that include questions and sentence starters like: "I think that…" after being informed about the topic. They gathered information on the Internet and were asked to reflect upon issues that came up during the activity. Hints followed student journals. Students then constructed their arguments and edited the arguments using a graphic representation, SenseMaker. Students were also asked to state their opinions and create a final argument in SenseMaker about the debate issue: "***Light: Particle or a Wave***?"

In activities 6 and 7, students started their debate tasks by stating their personal positions (Appendix C) and they thus acquired an understanding of the evidence. Students were then asked to explain their arguments using data and evidence and lastly explain how science in class applies to their own lives. Students were encouraged to develop evidence from their own lives and refine an argument for one theory or the other in brainstorming sessions. After discussing in small groups, students reached a consensus. Next, a whole-class discussion was held. Group presentations and ideas were shared. The main task was presenting arguments. Designing and using knowledge, integration through argumentation and debate encouraged students to link their ideas and experiences and finally generalize their knowledge. During the project, students worked in groups and collaborated on their argument construction. For the debate, students were urged to prepare questions, reflect on others' ideas and reply to others' questions.

After the activities concluded, students were awarded with certificate of participation and cookies (Appendix F). Interviews with two teachers and thirteen students were conducted during the four weeks from the 17th of May to the 10th of June. Each interview lasted from 10 to 30 minutes. For grade 6.1 five students, for grades 6.2 and grade 6.3 four students were interviewed respectively. High profile and low profile students were selected in pairs.

3.6 Data Collection, Sources & Measurement

This dissertation research acknowledges the real tensions that exist in any qualitative research endeavor. The researcher alone was the analyzer and interpreter of data and used sources of multilevel data collection to employ in this study. Technology-based scaffold treatments were assigned to all three classes and students' argumentation scores were compared to measure the effects of technology-based scaffold treatments on students' scientific argumentation. Students' interactions with the learning environment were also studied in order to understand how students engaged in the activities. Consequently, in order to measure how the roles of teacher and technology-based scaffolds are balanced to support students' scientific argumentation in technology-enhanced learning environment and to understand how students use technology and teacher scaffolds, videotaped recordings, observation reports and interviews were analyzed across twenty-two periods during the four week "Light" unit.

McNeill (2006) argued that when more than a single teacher lectures three classes, there will be other influences since teachers' beliefs regarding student learning play an important role in science (Keys & Bryan, 2001). Moreover, their practices for supporting students in the construction of argumentation have a significant effect on students' learning (Lizotte et al., 2004). For this reason, the differences in teacher practices in supporting students' scientific argumentation were also analyzed.

These below six sources of data were used complement to support each other to the analysis and interpretation of the study. They include the following: (1) Pretest which measured the prior knowledge of the students (Appendix B), (2) Students' SenseMaker Reports, (3) Student Journals, (4) Videotaped Recordings, (5) Observation Reports, (6) Interviews. Rubrics based on Toulmin's Model of Argument (Appendix D) assessed the quality of arguments. Each is described with their rationals in using them in this study is described in detail in below.

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), document reviews (syllabus, student journals, and SenseMaker reports), videotaped recording (holistic look at process), questionnaires (feedback from a larger sample), and peer observations (feedback, triangulation). Therefore, in this study the data sources and instruments used were pretest, which measured the prior knowledge of the students (Appendix B), students' SenseMaker reports, student journals, videotaped recordings, observation reports, interviews. Rubrics (Appendix D) also assessed the quality of arguments.

Table 3.0.3
Research Questions, Data Sources & Measurement, Data Analysis

Research Question	***Data Sources & Measurement***	***Data Analysis***
1. How do technology-based scaffolds (student journals, hints and SenseMaker) change students' scientific argumentation over time in a technology-enhanced learning environment (TELE)?	Students' SenseMaker Reports Student Journals (Rubric - Toulmin's Model used to evaluate argumentation scores)	***Quantitative Analysis*** Descriptive Statistics A one-way repeated measures ANOVA
2. How do students use technology-based scaffolds and teacher scaffolds to construct scientific arguments in TELE?	Student Journals, Pre-test, SenseMaker Reports	***Quantitative Analysis*** Descriptive Statistics
2.1 How does students' prior knowledge of science shape their use of the technology-based and teacher scaffolds?	Pre-test, SenseMaker Reports	A one-way repeated measures MANCOVA
2.2 What are the barriers to students' use of technology-based and teacher scaffolds?	Videotaped Recordings, Observation Reports, Student Interviews	***Qualitative Analysis*** Constant Comparative Analysis
3. How are the roles of teachers and technological tools balanced to scaffold students' scientific argumentation in TELE? 3.1 What are the roles of the teachers in scaffolding students' scientific argumentation in TELE? 3.2 What is the role of the technological tools in scaffolding students' scientific argumentation in TELE?	Videotaped Recordings, Observation Reports, Teacher Interviews	***Qualitative Analysis*** Constant Comparative Analysis

3.6.1 Pre-test

(Appendix B)

As stated earlier, students were given a pre-test to measure their prior knowledge of the science unit "Light". High-medium-low profile students were identified to see how prior knowledge shapes different level students' use of the technology-based and teacher scaffolds.

The teacher developed the pre-test. Appendix B presents the questionnaire that includes all 13 items of the test. Learning goal 2 – students will be able to determine the properties of waves in the electromagnetic spectrum and the source of all energy – is included in questions 3, 9, 14, and 15. Learning goal 3 – students will be able to identify and explain types of reflection – is addressed in questions 10 and 13. Learning goal 4 – students will be able to understand the difference between types of surfaces – is reflected in questions 2, 4 and 5. Learning goal 5 – students will be able to understand the concepts of colour and colour reflection and absorption – was the focus of questions 6, 7, 8, 11, and 12.

3.6.2 Students' SenseMaker Reports

The scaffold treatments for SenseMaker were created and revised during the pilot studies with the help of science teachers as well as retrieved from the literature. Students' arguments constructed using SenseMaker were evaluated using the scoring rubric in Appendix D (cited in Cho & Jonassen, 2002) in order to determine the quality of argumentation based on Toulmin's model of argument (Toulmin's et al., 1984) (cited in Erduran et al., 2004).

Table 3.0.4
A Student SenseMaker Report Analysis Example

Make Your Argument Now!
What do you think, is light made up of particles or waves?

Claim: "Light travels in straight lines. It has light energy loaded particles".
Ground: "Light travels as many rays, made up of particles. But the rays have wave properties".
Warrant: 1. "Light travels in straight lines (rays)".
2. "Rays are made up of particles full of light energy. Everything is made of particles".
Backing: "It has been proved with experiments"
Rebuttal: 1. "Unless it is refracted (then it changes direction)"
2. "Unless it goes through a prism (then it breaks into its colors and more rays)"

Table 3.0.4
A Student SenseMaker Report Analysis Example (Continued)

Rubric for SenseMaker:

0 No Info
2 Weak, inaccurate or incomplete
4 Enough Info
6 Accurate, complete and relevant

The scores for this example were 6, 6, 6, 2 and 4. The total was 24.

3.6.3 Student Journals

The scaffold treatments for Student Journals were also created and revised during the pilot studies with the help of science teachers as well as retrieved from the literature. Student journals were also analyzed using the same scoring rubric in Appendix D (cited in Cho & Jonassen, 2002) to see how students used technology-based scaffolds (student journals, hints, SenseMaker since they affect each other) to construct scientific arguments in a TELE?

Table 3.0.5
A Student Journal Analysis Example

Welcome to the journal!
What do you know about light?

"Light is a type of energy. There are two types of light sources: Man made and natural. Usually light looks white or yellow, but it is actually made of different colours. We can use special glass triangles to break the white light into its separate colours. My father once said that light could only be seen inside the atmosphere. You can not see it while it is coming from the sun to earth because there is no gas".

Rubric for Student Journal:

0 No Info
2 Weak, inaccurate or incomplete
4 Enough Info
6 Accurate, complete and relevant

The score for this example was 6.

3.6.4 Videotaped Recordings

The interaction between students and the teacher in small group format as a subset of the class discussion were videotaped to capture their verbal contribution to the lesson. How students used technology-based scaffolds (student journals, hints, SenseMaker) and teacher scaffolds to construct scientific arguments in a TELE was observed and analyzed.

3.6.5 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 meaning and context of the videotaped recordings and interviews were more effective when supplemented with field notes. The observation reports brought about a better understanding of teacher strategies & role in students' argument construction (Appendix E).

3.6.6 Interviews

Interview schedule matrices were developed. In the development phase of the interview questions, the researcher first developed a draft of students' and teachers' interview schedules that included tentative questions. Then the researcher consulted with the qualitative analysis course professor to verify the questions. The interview schedules were revised three times based on the recommendations of the professor (Appendix E).

The main data for the interviews is the transcripts; therefore, interviews need to be transcribed. Open-ended questions were used. Student interviews lent to our understanding of how students use scaffolds to construct arguments in a Web-based inquiry science environment and teacher interviews helped us understand the roles of the teachers and the technological tool in scaffolding students' scientific argumentation in TELE.

3.6.7 Toulmin's model of argument

Cho and Jonassen (2002) explained that stating claim is like stating hypothesis, grounds are data stating a measurement or observation that provide evidence for a possible answer, warrant is the principle giving the reason why the grounds are for or against the possible answer (claim), backing is implying support for the argument and rebuttal is implying rejection of the argument in Toulmin's model. Therefore, the analysis was done by using a coding scheme adapted from Toulmin's model (Toulmin's et al., 1984) (cited in Cho & Jonassen, 2002), students' arguments constructed using SenseMaker were evaluated in order to determine the quality of argumentation and student journals were analyzed to see how students use technology-based scaffolds (student journals, hints, SenseMaker) to construct scientific arguments in a TELE using the scoring rubric in Appendix D based on Toulmin's model. The individual scores were calculated by adding the number of points achieved in each argumentation category (claim, ground, warrant, backing, and rebuttal) as shown in the following argumentation example from the pilot study:

Table 3.0.6
An argumentation Analysis Example according to Toulmin's Model

Question: What do you already know about light?

6	*Claim* - We think light is a form of energy that can be called electromagnetic radiation. It can be seen by the human eye (Related to proposition and clear and complete)
4	*Ground* - The energy of light is called Radiant Energy. We can only see the Radiant Energy that comes out from the sun. (Relevant but not complete)
2	*Warrant* - Every light has a different wavelength depending on the color; for example, red has the longest while violet has the shortest wavelengths. (Writer fails to make the connection)
6	*Backing* - Waves are measured in nanometers. The energy of light is called Radiant Energy. (Relevant and specific)
4	*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. (Not sufficient)
22	*Total*

3.7 Data Analysis

The data of the present study were analyzed through Toulmin's model of argument (Toulmin's et al., 1984) (cited in Cho & Jonassen, 2002) in Appendix D, a quantitative analysis - descriptive statistics, a one-way repeated measures Anova and a one-way repeated measures Mancova and a qualitative analysis - constant comparative analysis since design-based research uses mixed methods.

3.7.1 Quantitative Analysis

3.7.1.1 Descriptive Statistics

For the first and second research questions, descriptive statistics were used to explain the basic characteristics of the participants and their scores in the pre-test, SenseMakers, student journals, and experiments and surfaces questionnaire. With the help of descriptive statistics high-medium-low profile students were identified to see how prior knowledge shapes different level students' use of the technology-based and teacher scaffolds.

3.7.1.2 A one-way repeated measures Anova

A one-way repeated measures Anova was used to show the effect of technology-based scaffolds (student journals, hints and SenseMaker) in students' scientific argumentation over time in a technology-enhanced learning environment (TELE). The dependent variables were SenseMaker-Activity, SenseMaker-Debate and student journal scores whereas the independent variables were two groups; Teacher 1 (Class 1) and Teacher 2's (Class 2 – Section 2 and Class 3 – Section 3) Classes.

Statistical assumptions were;

1. Independent observations
2. Random Sampling
3. Assumption of Sphericity

3.7.1.3 A one-way repeated measures Mancova

For the research question 2.1, a one-way repeated measures Mancova was used to show how prior knowledge of students in science shaped their use of the technology-based and teacher scaffolds. The dependent variables were SenseMaker-Activity and SenseMaker-Debate scores whereas the covariate was students' pretest scores.

3.7.2 Qualitative Analysis – Constant Comparative Analysis

The researcher employed a variety of methods to elicit information such as participant observing, interviewing and document collecting (student journals, SenseMaker argumentations). Participant observation was used to gain an understanding of the research setting and the participants in the study and was used in conjunction with other methods to gain a deeper understanding of data such as perspectives and experiences of the participants and to generate trustworthiness among data.

According to Taylor and Bogdan (1998), the researcher develops concepts from the data by coding and analyzing at the same time in the constant comparative method. In this study, the researcher analyzed the data qualitatively by transcribing and scoring the video recordings, the observation reports as well as the student and teacher interviews. In this respect, the researcher continually sorted through the data collection, coding and analysis.

In this study, the Miles and Huberman approach (1994) was used to analyze the questions "How do students use technology-based scaffolds and teacher scaffolds to construct scientific arguments in TELE" and "How are the roles of teachers and technological tools balanced to scaffold students' scientific argumentation in TELE". In this approach, analysis of qualitative data involves three components- data reduction, data display and conclusion drawing and verification.

> "The areas of reducing the data into manageable units and coding information are integral part of the analysis process" (Miles & Huberman, 1994).

The first component, data reduction continued throughout the study and data was reduced through the session summary sheet and the development of coding categories. For each session of the interview, the researcher formed a table whose rows were the interview questions for each session of the interview and the researcher formed a session summary sheet for each participant and observation session to reduce the data. In these tables, the researcher took notes summarizing what the participant said related to the interview question. Therefore, the researcher had an idea regarding what issues were covered related to research questions by just looking these notes.

The second component, data display matrix, which is a table with rows and columns, is one of the main types of displaying data. In this study, the researcher prepared a checklist matrix, which included descriptions and representative quotations, with the help of summary sheets.

The third component is drawing conclusion and verification. In this study, the researcher read many times all interview, observation, video recording and summary sheets to make sense of the explanations, developed and compared each code related to the research questions. Many analytic techniques such as microanalysis, which involves careful examination and interpretation of data, (interviews, observational field notes, videos, journals and other forms of written materials) were applied. In fact, the verification of data analysis is related to validity and reliability of the study.

> "Whether the meanings you find in the qualitative data are valid, repeatable and right" (Miles & Huberman, p.245).

Coding: A coding system was developed in the study and the underlying characteristics of patterns in the classroom were observed. This coding system involved three levels of analyses as a process of analyzing data (Strauss & Corbin, 2008). As a first step (open coding), the researcher compared data and identified different categories. As second step (axial coding), data were pieced together in a new way. The researcher continued to compare the data and relating subcategories to a category through the inductive and deductive thinking process. As a third step (selective coding), the researcher needed a further refinement and development with a thematic coding by validating similarities and relationships between categories to identify the core category or theme and generate concepts or a grounded theory, which is referred as theoretical sampling (Strauss & Corbin, 2008).

According to this thematic coding, the data was coded into seven categories: Teacher Scaffolding, Technology Scaffolding, Student-Technology Interaction, Student-

Teacher Interaction, Student-Student Interaction, Student-Teacher-Technology Interaction, and Problems in Technology-Enhanced Learning Environment, which were investigated according to the Kim et al. (2007)'s framework (Figure 2.0.2) to guide teaching and learning in technology-enhanced science classes.

3.8 Trustworthiness of the Study

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

3.8.1 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.

3.8.2 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.

3.8.3 Ethics

The participants were not harmed physically or psychologically during the study and the participants were given informed consent forms, parent consent forms, and debriefing forms (Appendix H). The confidentiality of the study was also kept since the researcher was the only one who evaluated the answers of the participants and the transcripts of the records. The data obtained were used only for scientific purposes.

3.9 Assumptions of the Study

The school where the research was conducted had been selected with a convenience type of sampling due to the accessibility. Therefore, it was assumed that the participants were a sample group from which a lot could be learned regarding the technology and teacher scaffolds in TELE. Ones of the major data sources of the study were interviews and each participant was interviewed face to face during his/her free time. Therefore, it was assumed that interviews were conducted under standard conditions. Another major data source was the videotaped recordings. Therefore, it was assumed that the participants' SenseMaker argumentation, the pre-test, the student journals and the interview responses as well as the debates were adversely affected by being recorded. It was also assumed that participants responded questions sincerely. To ensure this, the participants were told that they would not being assessed during any of the sessions.

3.10 Limitations of the Study

The participants of the study were students in BLIS in Turkey, which has a different student profile than other Turkish schools. BLIS is not a traditional institution, but rather a model school that aims to reflect the latest educational practices from IBPYP, IGCSE and IBDP and to prepare their students for success in leading universities throughout the world. Therefore, the results of the study may only be generalized to students of other international schools that have similar missions.

Since the major part of the study was a qualitative research study, data collection and data analysis procedure may be limited by the researcher's background. Since the same teacher was not involved in both the pilot studies and the actual study, teacher reluctance limited students' generation of appropriate arguments. Another limitation was that videotaping 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.

Summary

In this chapter, the researcher described methodological approaches used to guide the study design, data collection, sources, measurement and data analysis. The practical issues described in this chapter have been combined with the theoretical framework described in chapter 2, which guided the design and data collection of the study. Eventually in the study, technology-based scaffold treatments in WISE (The Web-Based Inquiry Science Environment) were assigned to all three classes, a total of 41 6^{th} grade students with an age range of 11 to 12 years at Bilkent Laboratory & International School (BLIS) in Ankara, Turkey.

The researcher used six sources of data to complement each other in the analysis and interpretation of the study: (1) Pretest to measure the prior knowledge of the students (Appendix B), (2) Students' SenseMaker Reports, (3) Student Journals, (4) Videotaped Recordings, (5) Observation Reports, (6) Interviews. Rubrics based on Toulmin's Model of Argument (Appendix D) were used to assess the quality of arguments. The students' argumentation scores were compared to measure the effect of technology-based scaffold treatments on students' scientific argumentation. The students' interactions with the learning environment were also studied to understand how students engaged in the activities. The measure how the roles of teacher and technology-based scaffolds are balanced to support students' scientific argumentation in technology-enhanced learning environment and to understand how students used technology and teacher scaffolds, videotaped recordings, observation reports and interviews were analyzed across twenty-two periods during the four week "Light" unit. The data of the present study were analyzed through a quantitative analysis - descriptive statistics, a one-way repeated measures Anova and a one-way repeated measures Mancova and a qualitative analysis - constant comparative analysis. The study had a design-based research and observational case study design type of qualitative approach.

CHAPTER 4

RESULTS

In this chapter, the data analyses address three research questions regarding: 1) the change of technology-based scaffolds (student journals, hints and SenseMaker) on students' scientific argumentation over time in a technology-enhanced learning environment (TELE), 2) students' use technology-based scaffolds and teacher scaffolds to construct scientific arguments in TELE and the relationship of technology-based and teacher scaffolds with prior knowledge, 3) the roles of teachers and technology tool in scaffolding students' scientific argumentation in TELE. In this respect, the researcher combines the various data sources such as students' pretests, student journals, SenseMaker reports, experiments & surfaces questionnaires, videotape recordings, observation reports and teachers' and students' interviews discussed in Chapter 5 to address each of these questions. Both a quantitative analysis - descriptive statistics, a one-way repeated measures Anova and a one-way repeated measures Mancova and a qualitative analysis - constant comparative analysis were conducted since design-based research uses mixed methods.

4.1 Students' Scientific Argumentations over time

The researcher first examined the research question 1 "How do technology-based scaffolds (student journals, hints and SenseMaker) change students' scientific argumentation over time in a technology-enhanced learning environment (TELE)?" For this reason, the researcher analyzed students' SenseMaker reports – for both activity & debate questions and student journals and conducted a quantitative one-way repeated measures Anova to show the change of technology-based scaffolds on students' scientific argumentations over time in a technology-enhanced learning environment (TELE). Descriptive statistics were also used to explain the basic characteristics of the participants. The researcher evaluated students' arguments constructed using SenseMaker in order to determine the quality of argumentation and analyzed student journals using the scoring rubric in Appendix D based on Toulmin's model. The individual scores were calculated by adding the number of points achieved in each argumentation category (claim, ground, warrant, backing, and rebuttal).

4.1.1 Students' SenseMaker Reports Analysis

4.1.1.1 Activity questions analysis

There were three samples and the samples comprised 41 participants: Class 1 (Teacher 1's Class), Class 2 (Teacher 2's section 2 Class), and Class 3 (Teacher 2's section 3 Class). The participants were fairly well distributed in three classes ($n1 = 16$, $n2 = 12$, $n3 = 13$ respectively).

Table 4.0.1 shows the means and standard deviations of students' SenseMaker scores in two groups measured six times. The means were higher and the standard deviations were lower in Group 2.

Table 4.0.1
Descriptive Statistics of Students' SenseMaker Scores by Group measured six times

	Group 1		Group 2	
Age group	*M*	*SD*	*M*	*SD*
SMaker 2	9,37	7,82	16,32	9,06
SMaker 3	11,00	9,12	15,36	6,77
SMaker 4	15,25	9,17	15,92	6,54
SMaker 5	12,75	9,14	15,36	8,78
SMaker 6	14,87	9,95	15,20	7,32
SMaker 7	10,62	9,87	15,04	8,24

The Mauchly's Test of Sphericity (0.749 for Group 1 and 0.059 for Group 2) shows that the assumption was not violated (p>.05). In Table 4.0.2 and Table 4.0.3, it can be seen that the multivariate test was significant for the SenseMaker effect in Group 1 (Wilks' lambda is 0.042) p<.05 but was not significant for the SenseMaker effect in Group 2 (Wilks' lambda is 0.895) p>.05. The eta square index indicated that the percentage of the variance accounted for 0.607, which indicates a medium effect.

Table 4.0.2
Multivariate Tests for Students' SenseMaker scores for Group 1

	Value	*F*	Hypothesis *df*	Error *df*	*p*	Partial Eta Squared
Pillai's trace	,60	3,39	5,00	11,00	,04	,60
Wilks' lambda	,39	3,39	5,00	11,00	,04	,60
Hotelling's trace	1,54	3,39	5,00	11,00	,04	,60
Roy's largest root	1,54	3,39	5,00	11,00	,04	,60

Table 4.0.3
Multivariate Tests for Students' SenseMaker scores for Group 2

Effect		Value	*F*	Hypothesis *df*	Error *df*	*p*	Partial Eta Squared
Smaker	Pillai's Trace	,07	,31	5,00	20,00	,89	,07
	Wilks' Lambda	,92	,31	5,00	20,00	,89	,07
	Hotelling's Trace	,08	,31	5,00	20,00	,89	,07
	Roy's Largest Root	,08	,31	5,00	20,00	,89	,07

Table 4.0.4 presents the follow-up tests, which show there was a quadratic increase in the students' SenseMaker scores in Group 1 over time since $p<.05$. Figure 4.0.1 shows that these increases were in SenseMaker 2, 3, and 5 for Group 1. Figure 4.0.2 shows that the increase was in SenseMaker 3 for Group 2. This can also be seen in the pairwise comparisons of the means.

Table 4.0.4
FOLLOW-UP TEST for Students' Six SenseMaker scores for Group 1

Source	SMaker	Type III Sum of Squares	*df*	Mean Square	*F*	*p*	Partial Eta Squared
Smaker	Linear	54,03	1	54,03	1,79	,20	,10
	Quadratic	273,24	1	273,24	7,12	,01	,32
	Cubic	10,51	1	10,51	,52	,47	,03
	Order 4	1,50	1	1,50	,04	,83	,00
	Order 5	118,08	1	118,08	5,03	,04	,25
Error (SMaker)	Linear	452,88	15	30,19			
	Quadratic	575,09	15	38,33			
	Cubic	298,62	15	19,90			
	Order 4	511,49	15	34,09			
	Order 5	351,87	15	23,45			

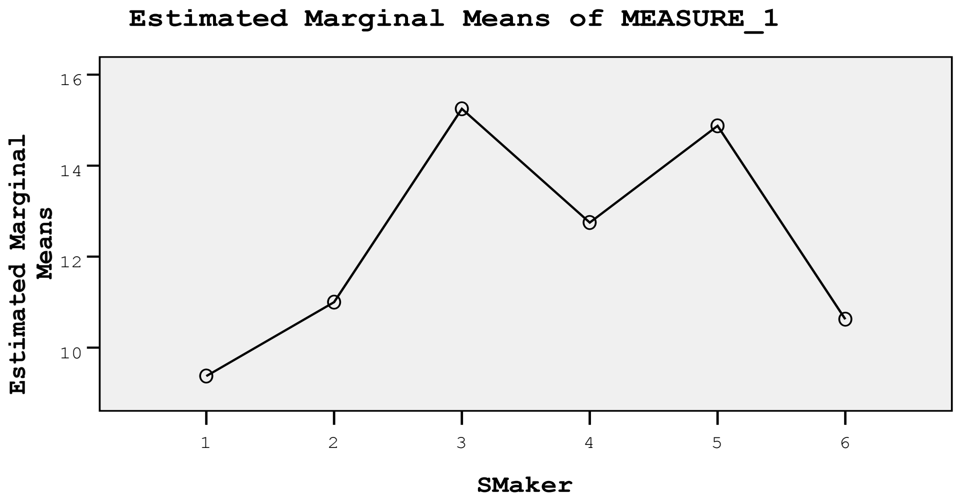

Figure 4.0.1 A Plot of the Means of six SenseMaker Scores for Group 1

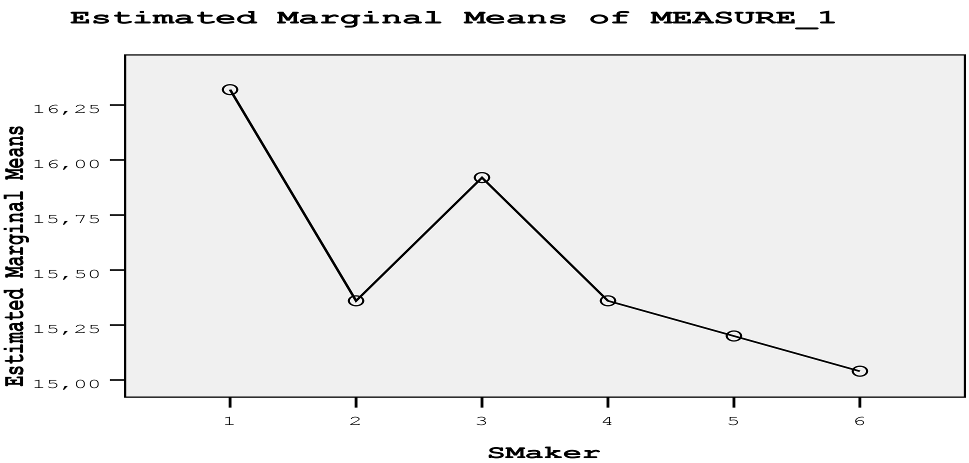

Figure 4.0.2 A Plot of the Means of six SenseMaker Scores for Group 2

As a summary, the researcher conducted a one-way repeated measures ANOVA to evaluate students' SenseMaker activity questions scores by Groups. The within-subjects factors were SenseMaker scores with six levels. The SenseMaker effect was tested using the multivariate criterion of Wilks' Lambda. Even though the means were higher in Group 2 than in Group 1, the SenseMaker effect was significant for Group 1, *p=0.042* but noninsignificant for Group 2, *p=0.895.*

Follow-up polynomial contrasts indicated a significant quadratic effect in the students' SenseMaker scores for Group 1, $F(1,15) = 7.127$, $p< .05$, partial $\eta^2 = .322$ with the means increasing over time. It should be noted that the significant trend was due to the increases in SenseMaker 2, 3, and 5. These results suggest that technology-based scaffolds (student journals, hints and SenseMaker) especially influenced scientific argumentations for activity questions over time in Group 1.

4.1.1.2 Debate question analysis

Table 4.0.5 presents descriptive statistics, means and standard deviations, of students' SenseMaker scores in Teacher 1's Class and Teacher 2's Class (both sections) for the debate question measured five times. The means were higher in Teacher 2's section 2 and 3 Classes.

Table 4.0.5
Descriptive Statistics of Students' SenseMaker Scores by Group measured five times

	Group 1		Group 2	
Age group	*M*	*SD*	*M*	*SD*
Smaker 1	12,25	5,05	17,60	6,97
Smaker 3	7,75	8,60	15,28	7,70
Smaker 5	9,00	9,79	14,72	7,54
Smaker 7	9,75	10,40	13,76	7,24
Smaker 8	1,37	5,50	13,20	9,66

The Mauchly's Test of Sphericity (0.480 for Group 1 and 0.045 for Group 2) shows that assumption was not violated (p>.05) for Group 1. It can be seen in Tables 4.0.6 and 4.7 that the multivariate test was significant for SenseMaker effects in Group 1 (Wilks' lambda is 0.006) p<.05 but not significant for SenseMaker effects in Group 2 (Wilks' lambda is 0.061) p>.05. The eta square index shows that the percentage of the variance accounted for 0.678, indicating a medium effect.

Table 4.0.6
Multivariate Tests for Students' SenseMaker scores for Group 1

Effect		Value	*F*	Hypothesis *df*	Error *df*	*p*	Partial Eta Squared
Smaker	Pillai's Trace	,67	6,30	4,00	12,00	,01	,67
	Wilks' Lambda	,32	6,30	4,00	12,00	,01	,67
	Hotelling's Trace	2,10	6,30	4,00	12,00	,01	,67
	Roy's Largest Root	2,10	6,30	4,00	12,00	,01	,67

Table 4.0.7
Multivariate Tests for Students' SenseMaker scores for Group 2

Effect		Value	*F*	Hypothesis *df*	Error *df*	*p*	Partial Eta Squared
Smaker	Pillai's Trace	,33	2,65	4,00	21,00	,06	,33
	Wilks' Lambda	,66	2,65	4,00	21,00	,06	,33
	Hotelling's Trace	,50	2,65	4,00	21,00	,06	,33
	Roy's Largest Root	,50	2,65	4,00	21,00	,06	,33

Table 4.0.8 presents the follow-up tests, which show that there were linear and cubic increases in the students' SenseMaker scores in Group 1 over time since $p<.05$. Figure 4.0.3 shows that these increases were in SenseMaker 3 and 4 for Group 1 and Figure 4.0.4 shows that there were no increases for Group 2. The eta square index indicated that the percentage of the variance accounted for 0.646, an indication of a medium effect.

Table 4.0.8
FOLLOW-UP TEST for Students' Five SenseMaker scores for Group 1

Source	SMaker	Type III Sum of Squares	*df*	Mean Square	*F*	*p*	Partial Eta Squared
Smaker	Linear	624,10	1	624,10	27,41	,00	,64
	Quadratic	77,78	1	77,78	1,12	,30	,07
	Cubic	354,02	1	354,02	8,26	,01	,35
	Order 4	1,28	1	1,28	,05	,81	,01
Error (Smaker)	Linear	341,50	15	22,76			
	Quadratic	1037,07	15	69,13			
	Cubic	642,37	15	42,82			
	Order 4	357,05	15	23,80			

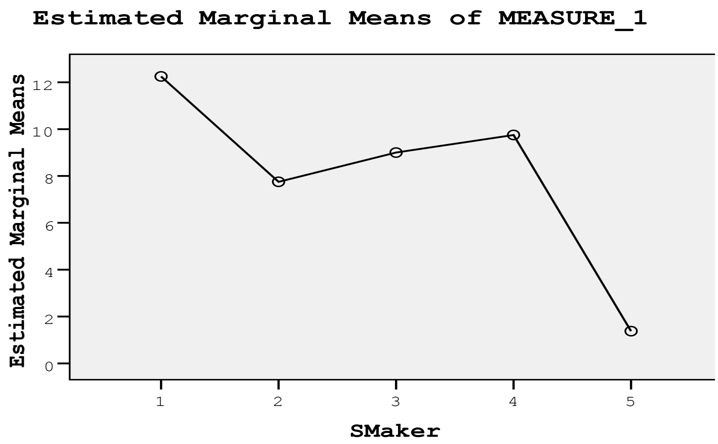

Figure 4.0.3 A Plot of the Means of five SenseMaker Scores for Group 1

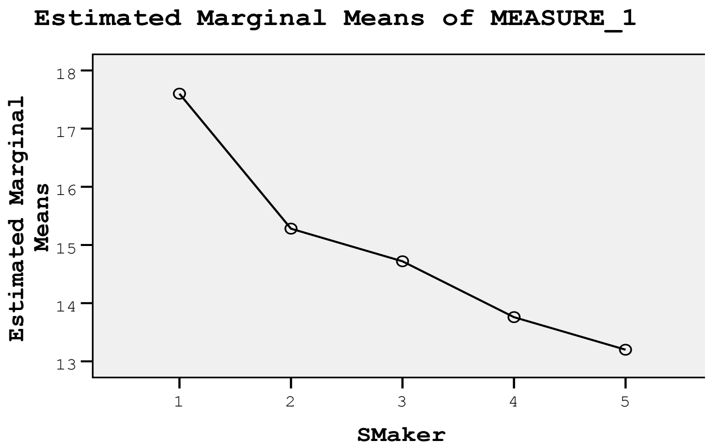

Figure 4.0.4 A Plot of Means of five SenseMaker Scores for Group 2

As a summary, the researcher conducted a one-way repeated measures ANOVA to evaluate students' SenseMaker debate question scores by Group. The within-subjects factors were SenseMaker scores at five levels. The SenseMaker effect was tested using the multivariate criterion of Wilks' Lambda. Even though the means were higher in Group 2 than in Group 1, the SenseMaker effect was significant for Group 1, p=0.006 but not significant for Group 2, p=0.061.

Follow-up polynomial contrasts indicated a significant linear and cubic effect in the students' SenseMaker scores for Group 1, $F(1, 15) = 27.413$, $p< .05$, partial $\eta^2 = .646$ with the means increasing over time. It should be noted that the significant trend was due to the increases in SenseMaker 3 and 4. These results suggest that technology-based scaffolds (student journals, hints and SenseMaker) were influential on students' scientific argumentation for debate questions as well as over time in Group 1.

4.1.2 Student Journals Analysis

Table 4.0.9 presents descriptive statistics, means and standard deviations, of students' Student Journal scores in two groups measured seven times. The means were close to each other but higher in Group 2.

Table 4.0.9
Descriptive Statistics of Students' Student Journal Scores by Groups measured seven times

	Group 1		Group 2	
Age group	*M*	*SD*	*M*	*SD*
SJournal1	5,25	1,23	4,96	1,30
SJournal2	3,12	2,41	4,24	1,45
SJournal3	2,75	1,77	4,24	1,05
SJournal4	2,87	2,06	3,44	1,68
SJournal5	3,25	2,04	3,84	1,72
SJournal6	3,00	2,06	4,64	1,25
SJournal7	2,50	2,00	3,44	1,87

Mauchly's Test of Sphericity (0.009 for Group 1 and 0.080 for Group 2) shows that the assumption was not violated ($p>.05$) in Group 2. Table 4.0.10 and Table 4.0.11 show that the multivariate test was significant for the Student Journal effect in Group 1 (Wilks' lambda is 0.002) $p<.05$ and Group 2 (Wilks' lambda is 0.029) $p<.05$. The eta square index indicated that the percentage of the variance accounted for 0.838, which indicates a large effect for Group 1 and 0.490, which indicates a medium effect for Group 2.

Table 4.0.10
Multivariate Tests for Students' Student Journal scores for Group 1

Effect		Value	*F*	Hypothesis *df*	Error *df*	*p*	Partial Eta Squared
SJournal	Pillai's Trace	,838	8,59	6,00	10,00	,002	,838
	Wilks' Lambda	,16	8,59	6,00	10,00	,01	,83
	Hotelling's Trace	5,15	8,59	6,00	10,00	,01	,83
	Roy's Largest Root	5,15	8,59	6,00	10,00	,01	,83
SJournal * Classes	Pillai's Trace	,00	.	,00	,00	.	.
	Wilks' Lambda	1,00	.	,00	12,50	.	.
	Hotelling's Trace	,00	.	,00	2,00	.	.
	Roy's Largest Root	,00	,00	6,00	9,00	1,00	,00

Table 4.0.11
Multivariate Tests for Students' Student Journal scores for Group 2

Effect		Value	*F*	Hypothesis *df*	Error *df*	*P*	Partial Eta Squared
SJournal	Pillai's Trace	,49	3,04	6,00	19,00	,02	,49
	Wilks' Lambda	,51	3,04	6,00	19,00	,02	,49
	Hotelling's Trace	,96	3,04	6,00	19,00	,02	,49
	Roy'sLargest Root	,96	3,04	6,00	19,00	,02	,49
SJournal * Classes	Pillai's Trace	,00	.	,00	,00	.	.
	Wilks' Lambda	1,00	.	,00	21,50	.	.
	Hotelling's Trace	,00	.	,00	2,00	.	.
	Roy'sLargest Root	,00	,00	6,00	18,00	1,00	,00

Table 4.0.12 presents the follow-up tests, which show that there were linear, quadratic and cubic increases in the students' Student Journal scores in Group 1 over time since

p<.05. Figure 4.0.5 shows that these increases were in Student Journals 4 and 5 for Group 1. The eta square index indicated a medium effect.

Table 4.0.12
FOLLOW-UP TEST for Students' Student Journal scores for Group 1

Source	SJournal	Type III Sum of Squares	*df*	Mean Square	*F*	*p*	Partial Eta Squared
SJournal	Linear	36,57	1	36,57	21,09	,00	,58
	Quadratic	16,29	1	16,29	7,82	,01	,34
	Cubic	26,04	1	26,04	32,66	,00	,68
	Order 4	1,36	1	1,36	1,10	,30	,06
	Order 5	,01	1	,01	,01	,92	,00
	Order 6	,21	1	,21	,12	,73	,00
SJournal * Classes	Linear	,00	0	.	.	.	,00
	Quadratic	,00	0	.	.	.	,00
	Cubic	,00	0	.	.	.	,00
	Order 4	,00	0	.	.	.	,00
	Order 5	,00	0	.	.	.	,00
	Order 6	,00	0	.	.	.	,00
Error (SJournal)	Linear	26,00	15	1,73			
	Quadratic	31,22	15	2,08			
	Cubic	11,95	15	,79			
	Order 4	18,50	15	1,23			
	Order 5	17,41	15	1,16			
	Order 6	25,82	15	1,72			

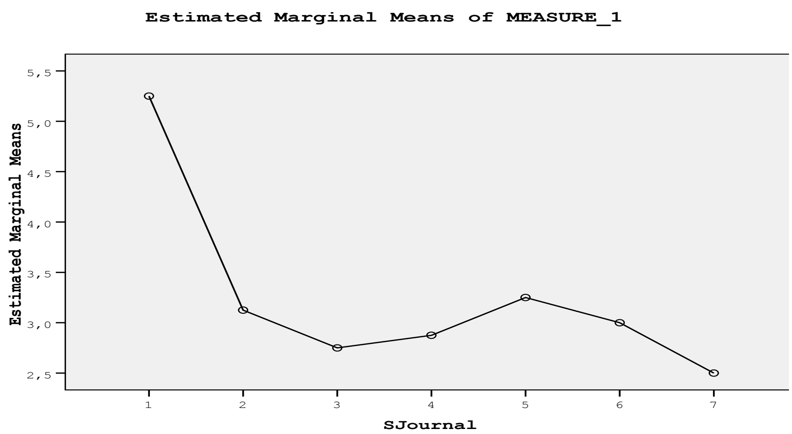

Figure 4.0.5 A Plot of the Means of Student Journal Scores for Group 1

Table 4.0.13 presents the follow-up tests, which show that there were linear and cubic increases in the students' Student Journal scores in Group 2 over time since p<.05. Figure 4.0.6 shows that these increases were in Student Journals 5 and 6 for Group 2. The eta square index indicated a small effect.

Table 4.0.13
FOLLOW-UP TEST for Students' Student Journal scores for Group 2

Source	SJournal	Type III Sum of Squares	*df*	Mean Square	*F*	*p*	Partial Eta Squared
SJournal	Linear	15,45	1	15,45	8,95	,01	,27
	Quadratic	4,76	1	4,76	2,13	,15	,08
	Cubic	9,62	1	9,62	8,98	,01	,27
	Order 4	11,02	1	11,02	6,64	,01	,21
	Order 5	7,80	1	7,80	6,24	,02	,20
	Order 6	1,53	1	1,53	1,21	,28	,04
SJournal * Classes	Linear	,00	0	.	.	.	,00
	Quadratic	,00	0	.	.	.	,00
	Cubic	,00	0	.	.	.	,00
	Order 4	,00	0	.	.	.	,00
	Order 5	,00	0	.	.	.	,00
	Order 6	,00	0	.	.	.	,00
Error (SJournal)	Linear	41,40	24	1,72			
	Quadratic	53,61	24	2,23			
	Cubic	25,70	24	1,07			
	Order 4	39,80	24	1,65			
	Order 5	30,00	24	1,25			
	Order 6	30,11	24	1,25			

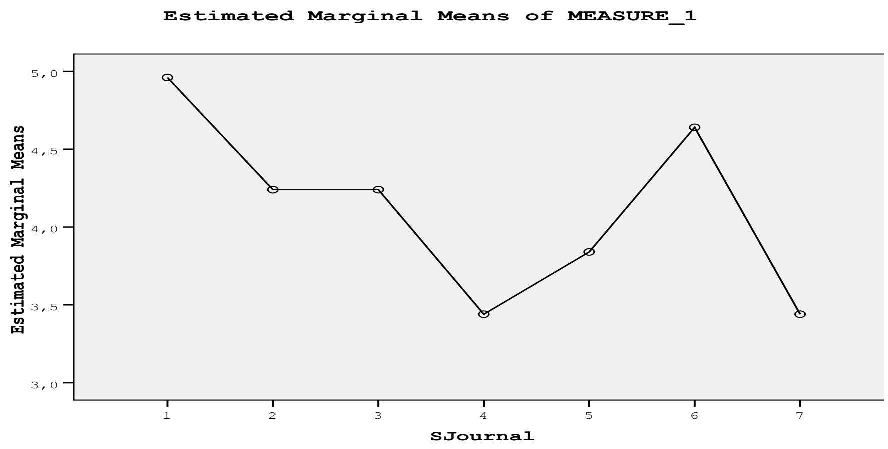

Figure 4.0.6 A Plot of Means of Student Journal Scores for Group 2

As a summary, the researcher conducted a one-way within-subjects repeated measures ANOVA to evaluate students' Student Journal scores by Groups. The within-subjects factors were Student Journal scores for seven levels. The Student Journal effect was tested using the multivariate criterion of Wilks' Lambda. The Student Journal effect was significant, p=0.002 for Group 1 (even though the assumption was violated) and 0.029 for Group 2, p<.05. The eta square index indicated that the percentage of the variance accounted for 0.838, which shows a large effect for Group 1 and 0.490, a medium effect for Group 2.

The follow-up polynomial contrasts indicated a significant linear, quadratic, and cubic increases in the students' Student Journal scores in Group 1 with the means increasing over time, $F(1, 15)$ = 21.099, 7.829, and 32,666, p< .05. The eta square index showed that the percentage of the variance accounted between 0.3 and 0.6, which indicates a medium effect. The follow-up tests also showed that there were linear and cubic increases in the students' Student Journal scores in Group 2 over time, $F(1, 24)$ = 8.956, 2.131, and 8.988, p< .05. The eta square index indicated that the percentage of the variance accounted for between 0.09 and 0.27, which means there was a small effect. These results suggest that technology-based scaffolds (student journals, hints and SenseMaker) influenced students' Student Journal scores over time in both groups. Overall, the effect of technology-based scaffolds (student journals, hints and SenseMaker) was significant on students' scientific argumentations over time in a technology-enhanced learning environment (TELE). Then the researcher is interested in how students used those scaffolds to construct scientific arguments in TELE and if there is a relationship between students' prior knowledge and their SenseMaker scores.

4.2 The Effect of Prior Knowledge

The researcher examined the research question 2 “How do students use technology-based scaffolds and teacher scaffolds to construct scientific arguments in TELE?”, 2.1 “How does students’ prior knowledge of science shape their use of the technology-based and teacher scaffolds”. For research question 2, the researcher analyzed the pretest, student journals and SenseMaker reports, used descriptive statistics to explain the basic characteristic and scores and identified high-medium-low profile students to show how prior knowledge shapes different level students’ use of the technology-based and teacher scaffolds. During the study, students also completed experiments & surfaces questionnaires. The researcher also examined these questionnaires and provided only descriptive statistics to explain the basic characteristics and scores. For research question 2.1, the researcher analyzed students’ pretests and SenseMaker reports – for both activity & debate questions and conducted a quantitative one-way repeated measures Mancova to show if there is a relationship between students’ prior knowledge and their SenseMaker scores.

4.2.1 Pretest Analysis

There were three samples consisting of 41 participants: Class 1 (Teacher 1’s Class), Class 2 (Teacher 2’s section 2 Class), and Class 3 (Teacher 2’s section 3 Class). The participants were well distributed in three classes (n_1 = 16, n_2 = 12, n_3 = 13 respectively). Table 4.0.14 presents descriptive statistics of students’ pretest scores in two groups.

Table 4.0.14
Descriptive Statistics of Students’ Test Scores by Group

	Group 1		Group 2	
Age group	*M*	*SD*	*M*	*SD*
PreTest	6,31	1,62	5,68	1,88

Table 4.0.15 presents the pair comparisons that show students’ profiles, SenseMaker, pretest, and student journal scores in pairs.

Table 4.0.15
Pairs

Group 1 Teacher1's Section1 Class		*SenseMaker*	*Pretest*	*S Journal*
	Student5 - Low Student4 -High	118, incomplete, improved 132, consistent, not improved, all rebuttals	15% 54%	24 34
	Student1 - Med Student3 - High	178, well improved little inconsistency, 8 rebuttals 160, improved little inconsistency,0rebuttal	38% 54%	28 32
	Student2 - High	168, improved only in second arg, 3 rebuttals	54%	34
Group 2 Teacher2's Section2& Section3 Classes				
	Student7 - Med Student9 - Med	180, slightly improved in both, 0 rebuttal 164, inconsistent not improved, 2 rebuttals	31% 38%	36 30
	Studen6 - Low Student8 - Med	200, well but not improved, 0 rebuttal 162, pretty well improved in both	23% 38%	26 14
	Student10- Low Student11-High	54, incomplete, 0 rebuttal 150, not consistent, 3 rebuttal	23% 62%	24 26
	Student12-High Student13-High	246, well done and improved, 5 rebuttals 236, not very consistent, 3 rebuttals	54% 62%	40 38

4.2.2 Experiments & Surfaces Questionnaire Analysis

Table 4.0.16 presents descriptive statistics of students' experiments and surfaces questionnaire scores in both Groups: Group 1 (M=19.5625, SD=9.33073), Group 2 (M=26.4400, SD=5.99361). The means were higher and the standard deviations lower in Group 2.

Table 4.0.16
Descriptive Statistics of Students' Experiments and Surfaces Questionnaire Scores by Groups

Groups	*M*	*SD*	*N*
1,00	19,56	9,33	16
2,00	26,44	5,99	25
Total	23,75	8,10	41

4.2.3 Student Pretest and SenseMaker Scores Analysis

4.2.3.1 Activity questions analysis

The homogeneity-of-regression (slope) assumption evaluates the interaction between the covariate and the factor (independent variable) in the prediction of the dependent variable. A significant interaction between the covariate and the factor suggests that the differences in the dependent variable among groups vary as a function of the covariate and the results from a MANCOVA are not meaningful. The results show that the interaction (groups*pretest) was not significant, $p>.05$ (except SenseMaker 2), so a MANCOVA analysis can be conducted. Levene's Test of Equality Error Variances shows that the underlying assumption of homogeneity of variance for MANCOVA has been met, $p>.05$ (except SMaker3).

Table 4.0.17 presents the relationship between the covariate (pretest) and the dependent variables (SenseMaker scores) for Group 1, controlling for the factor which shows this relationship was significant only for SenseMaker 2, F (1,14) = 6.818, p<0.05. Therefore, there was no relationship between the covariate (pretest) and the dependent variables (SenseMaker scores) except for SenseMaker 2 in Group 1. The eta square index showed that the percentage of the variance accounted for 0.328, which indicates a small effect.

Table 4.0.17
Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	*df*	Mean Square	*F*	*p*	Partial Eta Squared
Corrected Model	SMaker2	300,57	1	300,57	6,81	, 02	, 32
	SMaker3	107,13	1	107,13	1,31	,27	,08
	SMaker4	163,29	1	163,29	2,07	,17	,12
	SMaker5	48,53	1	48,53	,56	,46	,03
	SMaker6	105,08	1	105,08	1,06	,32	,07
	SMaker7	107,54	1	107,54	1,11	,31	,07
Intercept	SMaker2	669,53	1	669,53	15,18	,01	,52
	SMaker3	427,01	1	427,01	5,24	,03	,27
	SMaker4	735,70	1	735,70	9,36	,01	,40

Table 4.0.17
Tests of Between-Subjects Effects (Continued)

	SMaker5	363,66	1	363,66	4,22	,05	,23
	SMaker6	590,90	1	590,91	5,98	,02	,29
	SMaker7	412,96	1	412,96	4,26	,05	,23
Pretest	SMaker2	300,57	1	300,57	6,81	,02	,32
	SMaker3	107,13	1	107,13	1,31	,27	,08
	SMaker4	163,29	1	163,29	2,07	,17	,12
	SMaker5	48,53	1	48,53	,56	,46	,03
	SMaker6	105,08	1	105,08	1,06	,32	,07
	SMaker7	107,54	1	107,54	1,11	,31	,07
Classes	SMaker2	,00	0	.	.	.	,00
	SMaker3	,00	0	.	.	.	,00
	SMaker4	,00	0	.	.	.	,00
	SMaker5	,00	0	.	.	.	,00
	SMaker6	,00	0	.	.	.	,00
	SMaker7	,00	0	.	.	.	,00
Error	SMaker2	617,17	14	44,08			
	SMaker3	1140,86	14	81,49			
	SMaker4	1099,70	14	78,55			
	SMaker5	1206,46	14	86,17			
	SMaker6	1382,66	14	98,76			
	SMaker7	1354,20	14	96,72			
Total	SMaker2	2324,00	16				
	SMaker3	3184,00	16				
	SMaker4	4984,00	16				
	SMaker5	3856,00	16				
	SMaker6	5028,00	16				
	SMaker7	3268,00	16				
Corrected Total	SMaker2	917,75	15				
	SMaker3	1248,00	15				
	SMaker4	1263,00	15				
	SMaker5	1255,00	15				
	SMaker6	1487,75	15				
	SMaker7	1461,75	15				

Table 4.0.18 presents the relationship between covariate (pretest) and the dependent variables (SenseMaker scores) for Group 2, controlling for the factor which shows that this relationship was not significant, $p>0.05$. Therefore, there was no relationship between the covariate (pretest) and the dependent variables (SenseMaker scores) in Group 2.

Table 4.0.18
Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	*df*	Mean Square	*F*	*p*	Partial Eta Squared
Corrected Model	SMaker2	109,12(a)	1	109,12	1,34	,25	,05
	SMaker3	,30(b)	1	,30	,01	,93	,00
	SMaker4	7,52(c)	1	7,52	,17	,68	,01
	SMaker5	27,96(d)	1	27,96	,35	,55	,01
	SMaker6	53,48(e)	1	53,48	,99	,32	,04
	SMaker7	61,21(f)	1	61,21	,89	,35	,03
Intercept	SMaker2	234,73	1	234,73	2,89	,10	,11
	SMaker3	590,27	1	590,27	12,32	,01	,34
	SMaker4	485,17	1	485,17	10,93	,01	,32
	SMaker5	351,20	1	351,20	4,42	,04	,16
	SMaker6	274,46	1	274,46	5,11	,03	,18
	SMaker7	250,71	1	250,71	3,66	,06	,13
Pretest	SMaker2	109,12	1	109,12	1,34	,25	,05
	SMaker3	,30	1	,30	,01	,93	,00
	SMaker4	7,52	1	7,52	,17	,68	,01
	SMaker5	27,96	1	27,96	,35	,55	,01
	SMaker6	53,48	1	53,48	,99	,32	,04
	SMaker7	61,21	1	61,21	,89	,35	,03
Classes	SMaker2	,00	0	.	.	.	,00
	SMaker3	,00	0	.	.	.	,00
	SMaker4	,00	0	.	.	.	,00
	SMaker5	,00	0	.	.	.	,00
	SMaker6	,00	0	.	.	.	,00
	SMaker7	,00	0	.	.	.	,00
Error	SMaker2	1864,31	23	81,05			
	SMaker3	1101,45	23	47,88			
	SMaker4	1020,31	23	44,36			
	SMaker5	1825,79	23	79,38			
	SMaker6	1234,51	23	53,67			
	SMaker7	1571,74	23	68,33			
Total	SMaker2	8632,00	25				
	SMaker3	7000,00	25				
	SMaker4	7364,00	25				
	SMaker5	7752,00	25				

Table 4.0.18
Tests of Between-Subjects Effects (Continued)

	SMaker6	7064,00	25
	SMaker7	7288,00	25
Corrected Total	SMaker2	1973,44	24
	SMaker3	1101,76	24
	SMaker4	1027,84	24
	SMaker5	1853,76	24
	SMaker6	1288,00	24
	SMaker7	1632,96	24

4.2.3.2 Debate question analysis

The homogeneity-of-regression (slope) assumption evaluates the interaction between the covariate and the factor (independent variable) in the prediction of the dependent variable. A significant interaction between the covariate and the factor suggests that the differences in the dependent variables among groups vary as a function of the covariate and the results from a MANCOVA are not meaningful. The results show that the interaction (groups*pretest) was not significant, p>.05, so a MANCOVA analysis can be conducted. Levene's Test of Equality Error Variances, which shows the underlying assumption of homogeneity of variance for MANCOVA has been met, *p>.05* (except SMaker7 and 8).

Table 4.0.19 presents the relationship between the covariate (pretest) and the dependent variables (SenseMaker-Debate scores) for Group 1, controlling for the factor which shows that this relationship was not significant, $p>0.05$. Therefore, there was no relationship between the covariate (pretest) and the dependent variables (SenseMaker-Debate scores) in Group 1.

Table 4.0.19
Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	*df*	Mean Square	*F*	*p*	Partial Eta Squared
Corrected Model	SMaker1	47,43	1	47,43	1,97	,18	,12
	SMaker3	60,26	1	60,26	,80	,38	,05
	SMaker5	3,06	1	3,06	,03	,86	,01
	SMaker7	15,53	1	15,53	,13	,71	,01
	SMaker8	5,80	1	5,80	,18	,67	,01
Intercept	SMaker1	342,61	1	342,61	14,29	,01	,50
	SMaker3	225,46	1	225,46	3,01	,10	,17
	SMaker5	48,84	1	48,84	,47	,50	,03

Table 4.0.19
Tests of Between-Subjects Effects (Continued)

	SMaker7	175,23	1	175,23	1,52	,23	,09
	SMaker8	1,02	1	1,02	,03	,86	,01
Pretest	SMaker1	47,43	1	47,43	1,97	,18	,12
	SMaker3	60,26	1	60,26	,80	,38	,05
	SMaker5	3,06	1	3,06	,03	,86	,01
	SMaker7	15,53	1	15,53	,13	,71	,01
	SMaker8	5,80	1	5,80	,18	,67	,01
Classes	SMaker1	,00	0	.	.	.	,00
	SMaker3	,00	0	.	.	.	,00
	SMaker5	,00	0	.	.	.	,00
	SMaker7	,00	0	.	.	.	,00
	SMaker8	,00	0	.	.	.	,00
Error	SMaker1	335,56	14	23,96			
	SMaker3	1050,73	14	75,05			
	SMaker5	1436,93	14	102,63			
	SMaker7	1607,46	14	114,81			
	SMaker8	447,94	14	31,99			
Total	SMaker1	2784,00	16				
	SMaker3	2072,00	16				
	SMaker5	2736,00	16				
	SMaker7	3144,00	16				
	SMaker8	484,00	16				
Corrected Total	SMaker1	383,00	15				
	SMaker3	1111,00	15				
	SMaker5	1440,00	15				
	SMaker7	1623,00	15				
	SMaker8	453,75	15				

Table 4.0.20 gives the relationship between the covariate (pretest) and the dependent variables (SenseMaker-Debate scores) for Group 2, controlling for the factor which shows that this relationship was not significant, $p > 0.05$. Therefore, there was no relationship between the covariate (pretest) and the dependent variables (SenseMaker-Debate scores) in Group 2.

Table 4.0.20
Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	*df*	Mean Square	*F*	*p*	Partial Eta Squared
Corrected Model	SMaker1	30,20	1	30,20	,61	,44	,02

Table 4.0.20
Tests of Between-Subjects Effects (Continued)

	SMaker3	5,78	1	5,78	,09	,76	,01
	SMaker5	56,95	1	56,95	1,00	,32	,04
	SMaker7	15,23	1	15,23	,28	,60	,01
	SMaker8	140,59	1	140,59	1,54	,22	,06
Intercept	SMaker1	484,40	1	484,40	9,79	,01	,29
	SMaker3	456,13	1	456,13	7,40	,01	,24
	SMaker5	243,42	1	243,42	4,27	,05	,15
	SMaker7	309,10	1	309,10	5,71	,02	,19
	SMaker8	83,74	1	83,74	,91	,34	,03
Pretest	SMaker1	30,20	1	30,20	,61	,44	,02
	SMaker3	5,78	1	5,78	,09	,76	,01
	SMaker5	56,95	1	56,95	1,00	,32	,04
	SMaker7	15,23	1	15,23	,28	,60	,01
	SMaker8	140,59	1	140,59	1,54	,22	,06
Classes	SMaker1	,00	0	.	.	.	,00
	SMaker3	,00	0	.	.	.	,00
	SMaker5	,00	0	.	.	.	,00
	SMaker7	,00	0	.	.	.	,00
	SMaker8	,00	0	.	.	.	,00
Error	SMaker1	1137,79	23	49,46			
	SMaker3	1417,25	23	61,62			
	SMaker5	1310,08	23	56,96			
	SMaker7	1243,32	23	54,05			
	SMaker8	2099,40	23	91,27			
Total	SMaker1	8912,00	25				
	SMaker3	7260,00	25				
	SMaker5	6784,00	25				
	SMaker7	5992,00	25				
	SMaker8	6596,00	25				

As a summary, a one-way within-subjects repeated measures MANCOVA was conducted to evaluate the relationship between the covariate (pretest) and the dependent variables (SenseMaker activity and debate questions scores), controlling for the factor (classes) which shows that this relationship was not significant, $p>.05$.

Therefore, there was no relationship between the covariate (pretest) and the dependent variables (SenseMaker and SenseMaker-Debate scores).

All of these results suggest that technology-based scaffolds (student journals, hints and SenseMaker) influenced and improved students' scientific argumentation for both activity and debate questions over time in Group 1 and their Student Journal scores in both groups. The results also suggest that students' prior knowledge of science did not have any effect on their use of the technology-based and teacher scaffolds.

4.3 Support in TELE – Role of Teacher and Technology

The researcher examined the research questions 2 "How do students use technology-based scaffolds and teacher scaffolds to construct scientific arguments in TELE?", 2.2 "What are the barriers to students' use of technology-based and teacher scaffolds?", 3 "How are the roles of teachers and technological tool balanced to scaffold students' scientific argumentation in TELE?", 3.1 "What are the roles of the teachers in scaffolding students' scientific argumentation in TELE?", 3.2 "What is the role of the technological tool in scaffolding students' scientific argumentation in TELE?". For this reason, the researcher first analyzed various data sources separately such as videotape recordings, observation reports, student & teacher interviews to support to complement each other and conducted a qualitative constant comparative analysis. The researcher then reached out a conclusion by combining all of these analyses.

4.3.1 Videotape Recordings Analysis

4.3.1.1 Computer & lab classes

A videotape recorder was used to record the classroom interaction. The classroom setting, the human setting, and the scheduling patterns were all observed. A coding system was developed and in this way the underlying characteristics of patterns in the classroom were observed.

As shown in Table 4.0.21, according to the coding system seven categories were analyzed: Teacher Scaffolding, Technology Scaffolding, Student-Technology Interaction, Student-Teacher Interaction, Peer Interaction (Student-Student Interaction), Student-Teacher-Technology Interaction, and Problems in Technology-Enhanced Learning Environment. In each category, the evidences (in quotations) were woven into a narrative account since the study had an observational case study design type of qualitative approach.

Table 4.0.21
Observation Schedule Categories

Theme: Teacher Scaffolding	***Theme:*** Technology Scaffolding
Codes: Introduction of SenseMaker and Wise Explanation how to construct arguments in SenseMaker Explanation how to use components of Toulmin Argumentation Pattern Explanation how to use Student Journals Support with examples Give support Give a direction Answer to students' questions Encouragement	***Codes:*** Use of Wise Use of SenseMaker Use of Student Journals Use of Inquiry Map Use of Experiment Pages Use of Video Use of Internet
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 Observations: "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 Observations:*** "The students are filling the student journals on WISE"

Table 4.0.21

Observation Schedule Categories (Continued)

Theme: Student-Technology Interaction	***Theme:*** Student-Teacher Interaction
Codes: Study in the computer Typing Study in WISE Make search in Internet Construct arguments in SenseMaker Watch Video Write in Student Journals	***Codes:*** Give some direction to students Ask-Give support to students Give explanations to students Ask-Answer questions Give explanations how to construct arguments in SenseMaker to students Give explanations how to use components of Toulmin Argumentation Pattern 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 Observations: "The students on the left side of the class are typing while looking at their notes."	***Representative Observations:*** "One student is explaining something to the teacher and the teacher talks with him."

Table 4.0.21

Observation Schedule Categories (Continued)

Theme: Peer Interaction ***Codes:*** Ask questions to each other Study in pairs Look at each others' screen Discuss between them	***Theme:*** Student-Teacher-Technology Interaction ***Codes:*** Study in the computer with the help of teacher Study in WISE with the help of teacher Making search in Internet with the help of teacher Construct arguments in SenseMaker with the help of teacher 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 Observations: "Two male students are working together on the left side of the class."	***Representative Observations:*** "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 Mulfunction of Computer	
Description: The problems were malfunctioning of Video and Computer.	
Representative Observations: "The teacher detects a problem in a student's system.	

Group 1:

In the code of Teacher Scaffolding, enabling students to study on their own by following the inquiry map in WISE, leaving the initiative to students until some strategic questions emerge were important aims. When such questions arose, the teacher generally asked the researcher for help in explaining the meaning of Toulminian components with examples. These were emphasized with the representative observations given below:

> "The teacher comes to the right of the class and monitors students in the class", "The teacher goes to help to a student and tells him that the warrant should be a scientific fact or a truth", "When the student asks something showing the screen, the teacher says "maybe she knows better than me" referring to the researcher", "A male student sitting in the middle of the class asks the teacher what "medium" is. The teacher says "Medium is anything light travels through", "the teacher gets everybody's attention saying "Everyone listen to this for a minute, your friend has a good question. When we are talking about light, what is a medium? A student who has been raising his hand answers "Anything that light goes through". The teacher says "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", "The teacher continues to help students by reminding them of what they learned about light", "The teacher monitors students and asks if they are OK and if they are finished. Then she explains to them what to do next", "The teacher says to the class: "Listen, OK. I noticed that 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, make sure that you understand it before you turn your lab in to me. I want your labs to have good explanations. So let me ask you, who can tell me roughly what they think refraction is? She goes to the board with a marker and starts to draw while explaining. "So that's the idea behind refraction. Light bends when it gets to a new medium, a new substance and angle because one side of the wave slows down instead of the other side of the wave. Does that make more sense"?

In the code of Technology scaffolding, the areas examined were working with WISE and SenseMaker tool, writing in student journals, reading hints, writing into experiment pages and watching videos. These were emphasized in the representative observations below:

> "The video talks about lights travelling through water. Some students listen while most of them keep working with peers, asking

> other students questions and wandering around. The video is still on".

In the code of Student-Technology Interaction, some of the points addressed were studying using computers and WISE, writing arguments in SenseMaker, writing in student journals, reading hints, watching videos. These were emphasized in the representative observations below:

> "Students are in a computer lab and they are looking at the screen", "The rest of the students are working silently and individually", "The male student who is closest to the camera has a white screen and he is writing something there. Then he goes to another page but he has two notice boxes", "Some of the students take a look to their notes and keep on typing", "The student in front of the camera has the same screen as the video with green background on the wall".

In the code of Student-Teacher Interaction, monitoring students to see if they do well and understand, asking questions, and making explanations when necessary were focused on. These were emphasized in these representative observations:

> "The teacher asks the male student with white t-shirt some questions about light and water. She explains to him the details of light going through the water and asks him why it happens that way", "So let me ask you, who can tell me roughly what they think refraction is? A student gives the answer", "A student raises his hand to speak and the teacher answers a student and collects some papers from the students who are finished".

In the code of Peer Interaction, students discussing, asking and answering questions, talking to each other, studying together, exchanging ideas and words can be seen in the following representative observations:

> "One student from the front of the class gets up to look at his friend's screen to see how he did it", "One student asks his friend in Turkish what "olay" means in English", "The female students on the left side of the class are also exchanging words", "Students are talking with each other and asking for directions", "Two male students talk on the right side of the class about how to write what they mean properly", "The students continue to work in coordination", "Most of them keep working with peers", "Other students continue to work, while some of them are helping each other", "The male student with the white t-shirt wanders around and looks at his peers work and talks with them", "One student goes to his peer with his notes to ask something. She helps him".

In the code of Student-Teacher-Technology Interaction, asking the teacher about something on the computer screen and answering students' questions about something on the computer screen can be seen in these representative observations:

> "One male student came to the teacher with his notes and asked something. Then they go to his computer together and try to understand what the issue is", "When the student asks something showing her screen teacher says "maybe she knows better than me" referring to the researcher".

In the code of Problems in technology-enhanced learning environments, some issues were the screens were sometimes frozen, video downloading took a while, and the experiment pages did not show the saved data on the screen. In addition, the technological problems, teacher's motivation and teacher's encouragement of students towards studying in WISE were considerably lower than in the other two classes.

Group 2:

In the code of Teacher Scaffolding, the areas examined were giving instruction when students are new in the topic, directing students' to focus on lesson and on specific points, organizing the class, providing clarifications, modeling in the desired behavior, motivating students, giving hints about the strategies, encouraging to make research, controlling the frustration in constructing argumentation, answering students' questions about the components of Toulmin Argumentation Pattern. These are shown in the following representative observations:

> "She explains to students how they will write each component of their arguments in the boxes", "The teacher says that with practice they will improve and it is not a problem if it is not perfect for the first time", "She gives some hints about what kind of ideas they can use. She also warns them to be careful about the difference between grounds and claims. She says that grounds are facts that they are going to use information to support claims", "She says something about making a concept map and goes to the board", "The boy with the red shirt consults the teacher about his claim. The teacher says "that is very good". "The male student in red shirt tells the teacher that it is so hard to write a backing. Teacher says, "Just try".

In the code of Technology scaffolding, the topics examined were working with WISE itself with all its components as well as the SenseMaker tool, writing in experiment pages, watching videos, using internet, searching in Google, writing in student journals, reading hints. These were emphasized in the representative observations below:

> "A female student works on a green screen and writes student journal and reads something from a small red box", "She works with the argumentation boxes in SenseMaker", "They watch the video silently. The video explains each theory and shows visuals related to each argument".

In the code of Student-Technology Interaction, studying using a computer and WISE, doing research on the Internet, writing arguments in SenseMaker, writing in student journals, reading hints and watching videos were examined. These were dealt with in the following representative observations:

> "Students look at their screens", "They continue working on WISE on their own", "Everyone writes their arguments", "A female student works on a green screen and writes student journal and reads something from a small red box", "They watch the video silently".

In the code of Student-Teacher Interaction, the areas dealt with were 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, confirming students' work in situations. These are shown in these representative observations:

> "The male student asks the teacher whether his grounds are good" and maintaining interactive learning environment."

In the code of Peer Interaction, students' talking to each other, asking questions to each other, studying together, looking to each other's screen were examined. These can be seen in the representative observations below:

> "The boy in the red t-shirt asks his friend what a warrant is", "They ask each other questions across the classroom. They work on their computers", "A male student comes and looks at his friend's screen", "Students discuss the arguments among themselves".

In the code of Student-Teacher-Technology Interaction, teacher explanation to students while looking at the computer screen, showing something to students on the computer screen, showing something to the teacher on computer screen, asking to write in student journals as well as argumentation boxes were examined. The following are representative observations:

> "The teacher comes near the boy in red. They both look at his screen. She explains something to him very quietly", "she takes the mouse from the student and starts to do something. They both look at the screen", "She explains how they will use the boxes", "An introduction to the experiment pages by the teacher", "The boy in

the red t-shirt asks the teacher whether they should write in their student journals".

In the code of Problems in technology-enhanced learning environments, some of the issues were the screens sometimes froze, video downloading took a while, and the experiment pages were not showing the saved data on the screen even though they were saved in the teacher's account. These can be seen in these representative observations:

> "A female student says that her page is frozen. The teacher says, "refresh the page", "The teacher helps another student who says that his computer is not working".

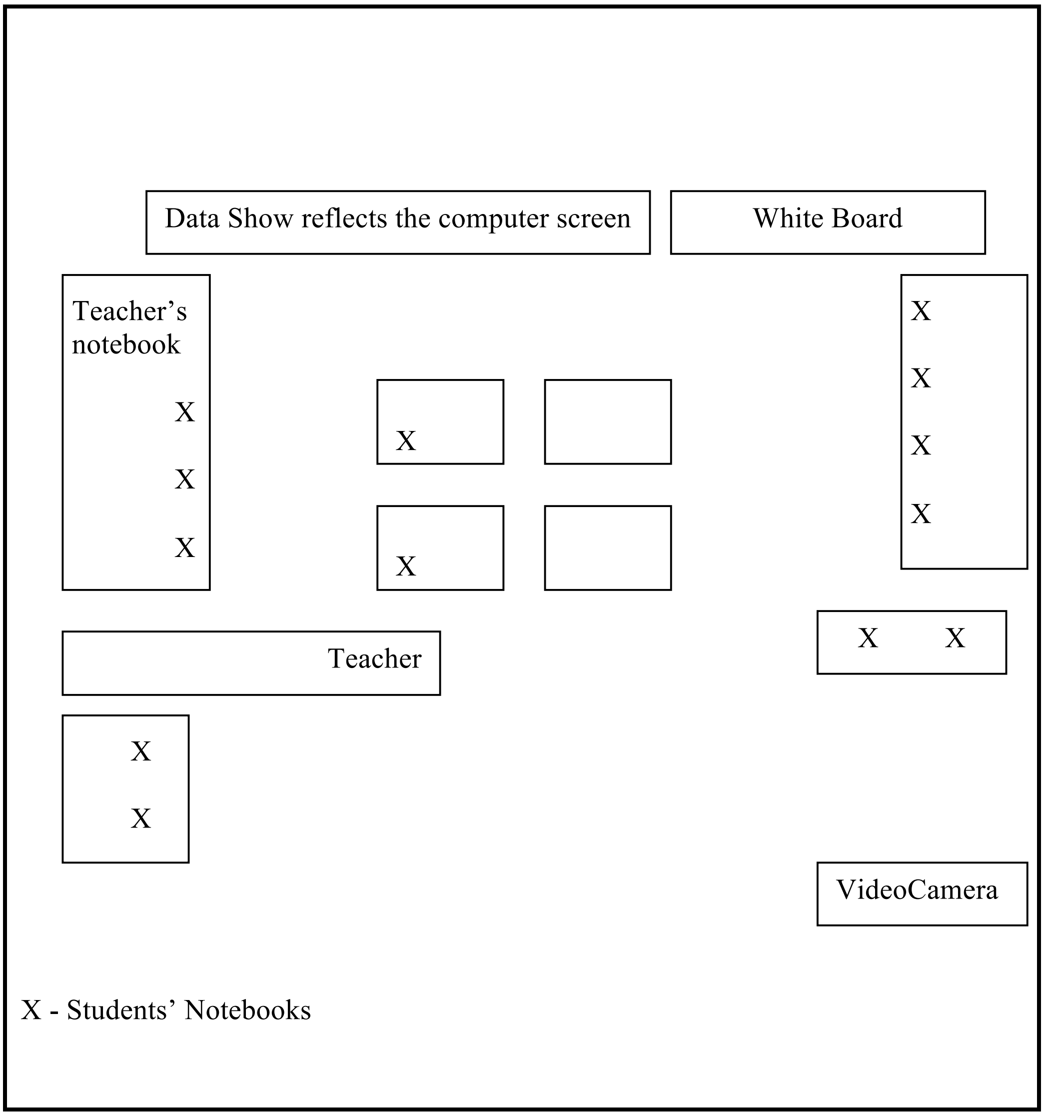

Figure 4.0.7 Classes in Computer Lab

4.3.1.2 Debates

To describe how the roles of teachers and technological tools are balance in scaffolding students' scientific argumentation in a technology-enhanced learning environment a coding system was developed and in this way the underlying characteristics of debate patterns in the classroom were observed. As shown in Table 4.0.22 according to the coding system two categories were analyzed: the role of the teacher and the role of the student.

Table 4.0.22
Observation Schedule Categories for Debate

Theme: Role of Teacher	***Theme:*** Role of Student
Codes: Explanations how to participate in debate Give explanations how to use components of Toulmin Argumentation Pattern Give some directions Encouragement Answer questions Monitor students	***Codes:*** Participate in debate Group discussions Present the opening position Construct arguments using components of Toulmin Argumentation Pattern Support with examples Ask-answer questions Peer support Chair management
Description: Teacher had a role in debate by giving some directions to students, answering questions, monitoring students and giving necessary explanations.	***Description:*** Students participated in debate by group discussions, presenting and defending their positions, constructing arguments, supporting their peers.
Representative Observations: "The teacher interrupted the chair because he needed to ask a question at this point"	***Representative Observations:*** "The student with the green shirt supported his argument by giving more examples and repeated his argument that 'light is Wave'.

Group 1:

In the code of role of teacher, the teacher role in a debate was examined. During the debate, the teacher was generally a passive listener and waited for students to determine the answer to the debate question. Moreover, the teacher only interrupted to call for silence in the class and inform students about how long they could still talk. This was emphasized in the following representative observations:

> "She is preparing the class for debate, assessing students, organizing the class setting for the debate, giving instructions for the debate, distributing debate plans and other papers, interrupting and directing students' speeches, directing the chair and giving explanations about the way in which a debate must be conducted."

In the code of role of student, how the students participated in the debate was examined. In some groups, it was observed that only some (and the same) students participated in the debate while others just listened, which was criticized by 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. This was emphasized by the representative observations below:

> "The chair is the one who generally directs and organizes the debate. He gives instructions to the other students. At the beginning of the debate, 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 takes responds. Sometimes the discussion takes longer and the chair stops the discussion and gives a turn to another member who hasn't talked too much. The explanations are generally in claim and example-evidence form but Toulminian argumentation 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 2:

In the code of role of teacher, the teacher's role in debate was examined. The teacher was active by interrupting and informing groups what they had to do. The teacher also directed the chair and gave instructions. It was also observed that the teacher often scaffolded and gave instructions to the students. This was shown in these representative observations:

> "Don't you have any questions", "answer the question from what you learned from Wise", or "it is hard to remember the names."

In the code of role of student, how students participated in debate was examined. It was observed that groups made their opening statements and explain their arguments. Students constructed their arguments in the form of Toulmin argumentation pattern. Students used warrants but not backing or rebuttal. The chair managed the debate. This was emphasized with the below representative observations:

> "Students generally make their arguments and show some evidence for their claims. This evidence is generally in the form of grounds in the Toulmin argumentation pattern. They support their ideas by giving examples and scientists' views. They also read some information from the paper they have prepared before by searching and finding from a variety of sources such as the Internet, Wise, Wikipedia and articles. When a group member asks a question, the other group first discusses altogether and a member from the group answers. When a member states a claim, the chair sometimes interrupts the group to explain the claim. Or when a group states their arguments, the other groups can present the counter argument. Groups also present their ideas by giving warrants (principles from the unit), but no backing or rebuttal were observed."

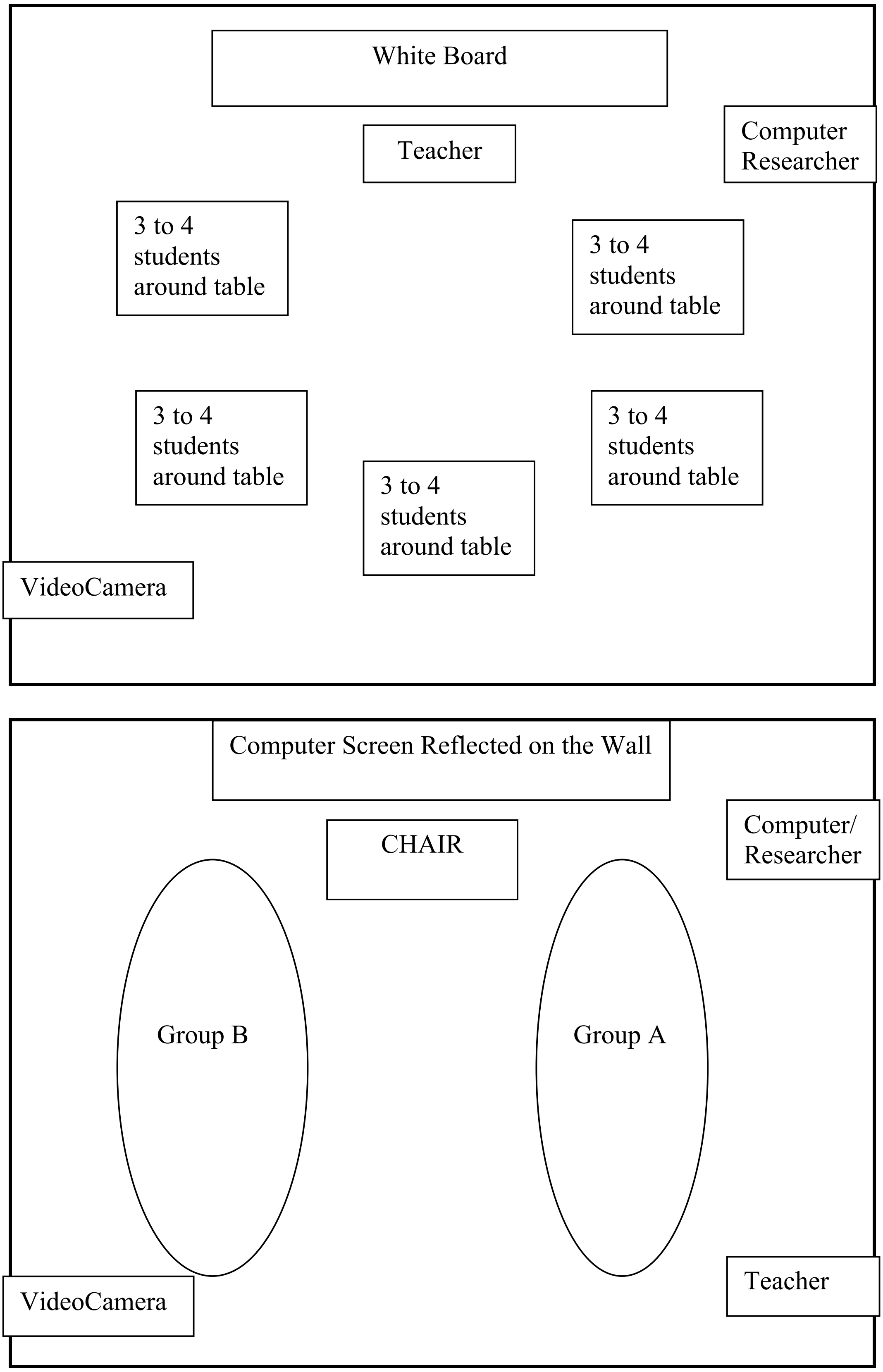

Figure 4.0.8 Classes in Computer Lab

4.3.2 Observation Reports Analysis

The meaning and context of the videotaped recordings were more effective when supplemented with field notes. Therefore, description of students and teachers, place, events, activities, and conversation were all noted down. Ideas, strategies, and reflections were also recorded. The goal of the observation reports is to bring about a better understanding of teacher strategies & their role in students' construction of arguments. As shown in Table 4.0.21, the same coding system was used in the observation reports analysis.

G*roup 1:*

In the code of Teacher Scaffolding, explaining experiments, asking and answering questions, directing students to write on their student journals and complete arguments, organizing the lab and letting students understand by themselves were observed and examined. In the code of Technology scaffolding, writing into the experiment pages, filling in student journals, constructing arguments in WISE, conducting experiments and completing tasks were observed and examined. In the code of Student-Technology Interaction, writing into the experiment pages, filling in student journals, constructing arguments in WISE were observed and examined. In the code of Student-Teacher Interaction, asking and answering questions were observed and examined. In the code of Peer Interaction, discussing and helping in pairs were observed and examined. In the code of Student-Teacher-Technology Interaction, looking at students' screen to understand if they can manage all the steps in WISE, giving explanation to students and showing them on the computer screen, showing teachers on the computer screen, asking students to write in their student journals as well as in argumentation boxes were observed and examined. In the code of Problems, the difficulties in constructing arguments with the components in technology-enhanced learning environments were observed and examined.

G*roup 2:*

In the code of Teacher Scaffolding, explaining the content, checking the progress of each student, directing students, organizing the class, helping students to conduct their experiments, asking and answering the questions, checking for the hypotheses, helping students understand the components of the argumentation pattern, facilitating, guiding, mentoring, and encouraging students were observed and examined. In the code of Technology scaffolding, writing in the experiment pages, watching videos, writing in student journals, constructing arguments in SenseMaker, submitting the brainstorming questions and searching on the Internet were observed and examined. In the code of Student-Technology Interaction, writing the results of the experiments, watching videos, writing in student journals and filling out the boxes in SenseMaker, submitting the brainstorming questions and searching internet were observed and examined. In the code of Student-Teacher Interaction, asking the teacher for help and answering students' questions were observed and examined. In the code of Peer Interaction, students' discussions of their points of view in pairs and looking at each other's screens, coming to a consensus for debate and exchanging ideas even though they were working on their own were observed and examined. In the code of Student-Teacher-Technology Interaction, taking care of each student, visiting each student's computer and checking the work, observing how students use SenseMaker and hints, constructing arguments, writing in student journals during the task and asking the teacher questions were observed and examined. In the code of Problems, the difficulty in the comprehension of the Toulmin Argumentation components – claim, ground, warrant, backing, rebuttal – were observed and examined.

4.3.3 Interview Analysis

4.3.3.1 Teachers' interview

Teacher interviews helped to clarify the roles of the teachers and technological tool in scaffolding students' scientific argumentation in TELE. How students used technology-based scaffolds (student journals, hints, SenseMaker) and teacher scaffolds to construct scientific arguments in a TELE was observed and analyzed. To this aim, as shown in Table 4.0.23 according to the coding system four categories – Teacher Scaffolding, Technology Scaffolding, Student-Teacher-Technology Interaction and Problems in Technology-Enhanced Learning Environment – were analyzed.

Table 4.0.23
Teacher Interview Schedule Categories

Theme: *Teacher Scaffolding*	***Theme:*** *Technology Scaffolding*
Codes:	***Codes:***
Give a direction	Use of SenseMaker
Give support with examples	Use of Hints
Give support by facilitating students	Use of Sentence Starters
Answer the questions	Use of Student Journals
Summarize the points	Use of Toulmin Argumentation Pattern
Give guidance	Give Enthusiasm
Build something in an appropriate time and step	
Use different methods	
Give lecture and experiments	
Description: Teacher scaffolded students by giving directions, answering questions, giving guidance and support by facilitating them, summarizing the points, using different methods and giving lecture and experiments.	***Description:*** Students were scaffolded by the technology when they used SenseMaker, Hints, Sentence Starters, Student Journals, Toulmin Model and technology gave them enthusiasm.
Representative Quotes: "You set students up to do an activity in such a way that you help them first in theory and by helping them through that they are able to do it independently afterwards."	***Representative Quotes:*** "Technology is important and very useful in helping kids get a lot of information and they can explore things on their own a lot better."

Table 4.0.23
Teacher Interview Schedule Categories (Continued)

Theme: Student-Teacher-Technology Interaction	***Theme:*** Problems in TELE
Codes: Technology support first then teacher's help then support from technology again.	***Codes:*** Narrow space in SenseMaker to construct arguments Malfunction of SenseMaker Bad organized screen Use of complicated names for components instead of easier ones Use of complicated model of argumentation instead of easier one Difficulty in finding rebuttal and topic Repeating same steps twice Using computer and science labs Too much experiments, steps, arguments Long version of WISE
Description: Teacher and technology scaffolding complemented each other respectively.	***Description:*** The problems were difficulty in topic and argumentation model as well as bad organized screen, repeated steps, too much experiments and arguments in WISE.
Representative Quotes: "In WISE, students followed everything from the technology first but when they cannot make a connection between tow steps then I helped them. Then I left them to technology again."	***Representative Quotes:*** "Kids were not familiar with and had a hard time understanding the terms in the argumentation model."

Teacher 1:

In the code of Teacher Scaffolding, the role of the teacher for scaffolding students in TELE was examined. Teacher indicated that she was not scaffolding students much by teaching argumentation or providing any help. Asking what they know, what they have seen and telling students to write it in their hypothesis were her main responsibilities. This can be seen in the following representative quotes:

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

In the code of Technology scaffolding, the role of the technology in scaffolding students in TELE was examined. It was indicated that students were scaffolded by using SenseMaker, hints, sentence starters, student journals, Toulmin argumentation pattern. This is clear in the representative quotes 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 it is linear and looks like the next step. However, student journals might help students get ideas. The inquiry map was useful but different from the way she would teach some concepts. However, students do best with the teacher's help."

In the code of Student-Teacher-Technology Interaction, how teachers and technology tool balance the roles to scaffold students' scientific argumentation in TELE was examined. Teacher indicated that she minimized her role in scaffolding students in their use of WISE. She generally left the initiative to students until some 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 question and that`s about it, I don't think that I play much role in the scaffolding part. Not in the WISE program."

In the code of Problems in TELE, the difficulty in understanding the terms of argumentation model and online teaching were indicated. The following representative quotes show this:

> "The terms "argumentation, claim, grounds, and backing" were not familiar to the students, so they had 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 variations 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."

Teacher 2:

In the code of Teacher Scaffolding, the role of the teacher in scaffolding students in TELE was examined. It was indicated that teacher scaffolded students by giving a direction, supporting with examples, giving support by facilitating students, answering the questions, summarizing the points, giving guidance, building something in an appropriate time and step, using different methods and giving lecture and experiments. These representative quotes illustrate:

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

In the code of Technology scaffolding, the role of the technology for scaffolding students in TELE was examined. It was indicated that students were scaffolded by using SenseMaker, hints, sentence starters, student journals, Toulmin argumentation pattern. This is emphasized with these representative quotes:

> "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 transport 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 the same thing again and again it would be just boring for them. But after they finished an argument, a journal come up and it was organized because as a teacher you don't need to explain every step. You explain for one time and if there is no problem they follow easily."

In the code of Student-Teacher-Technology Interaction, how teachers and technology tool balance the roles to scaffold students' scientific argumentation in TELE was examined. Teacher indicated that technology then teacher then technology scaffolded students again. 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 technology again. I think that this was a good way."

In the code of Problems in TELE, the difficulty in topic and argumentation model as well as bad organized screen, repeated steps, too much experiments and arguments in WISE were indicated. This is shown in the following representative quotes:

> "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. With several experiments, too many arguments and the difficulty of the concept made students dislike the idea of making arguments. If it were something that they observe everyday, they could write arguments more easily."

4.3.3.2 Students' interviews

Student interviews helped in understanding how students used technology-based scaffolds (student journals, hints, SenseMaker) and teacher scaffolds to construct arguments in a Web-based inquiry science environment and the roles of teachers and technology for scaffolding students' scientific argumentation in TELE. For this reason, as shown in Table 4.0.24 according to the coding system four categories – Teacher Scaffolding, Technology Scaffolding, Student-Technology-Teacher Interaction and Problems in Technology-Enhanced Learning Environment – were analyzed.

Table 4.0.24
Student Interview Schedule Categories

Theme: Teacher Scaffolding	***Theme:*** Technology Scaffolding
Codes: Explanation how to construct arguments in SenseMaker Explanation how to use components of Toulmin Argumentation Pattern Explanation how to use Student Journals Support with examples Give a direction Give a support	***Codes:*** Use of Computer Use of WISE (SenseMaker) in constructing arguments Support from WISE Use of Student Journals Use of Experiment Pages Increase Motivation
Description: Teacher scaffolded students by giving directions, giving support, explanations how to construct arguments and component of Toulmin Model as well as writing in student journals.	***Description:*** Students were scaffolded by technology by using computer, studying in WISE and SenseMaker, writing in Student Journals and experiment pages and technology increased their motivation.
Representative Quotes: "I received help mostly from the teacher. The teacher showed everything."	***Representative Quotes:*** "Student journals, hints and sentence starters are all useful in constructing scientific arguments."

Table 4.0.24
Student Interview Schedule Categories (Continued)

Theme: Student-Technology-Teacher Interaction	***Theme:*** Problems in TELE
Codes: Teacher's Help first who explained what to do in WISE then support from technology	***Codes:*** Difficulty in constructing arguments Difficulty in finding rebuttal Malfunction of Technology
Description: Students were interacted with technology and teacher by having help from teacher first then technology.	***Description***: The problems were difficulty in finding rebuttal, constructing arguments and malfunctioning of technology.
Representative Quotes: "I received teacher's help first who exhmaireo what to do in WISE and write in student journals, etc."	***Representative Quotes:*** "Finding rebuttal is hard but useful."

Group 1:

In the code of Teacher Scaffolding, the role of the teacher in scaffolding students in TELE was examined. Students indicated that they usually used WISE and when they needed help they asked their teacher's help. These representative quotes can illustrate:

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

In the code of Technology scaffolding, the role of technology in scaffolding students in TELE was examined and students indicated that they were scaffolded by technology by using computer, studying in Wise and SenseMaker, writing in Student Journals and experiment pages, hints were all useful. This can be seen in the following representative quotes:

> "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."

In the code of Student-Teacher-Technology Scaffolding, how teachers and technology tool balance the roles to scaffold students' scientific argumentation in TELE was examined and students were interacted with technology and teacher by having help from teacher when they need. This can be seen in the following representative quote:

> "The teacher she showed us ways to write in our notes, writing into student logs."

In the code of Problems in TELE, the difficulty in finding rebuttal, constructing arguments and malfunctioning of technology were indicated. This is shown with the representative quotes below:

> "With the WISE program I was like at home you know some programs don`t run java so they are not well constructed some certain programs have it. So lucky that I found another program working on my computer but I …Java takes one common download that is difficult which was the biggest technical problem I faced and not saving also the data. Coming up with a claim, coming up with a rebuttal or backing"

Group 2:

In the code of Teacher Scaffolding, the role of the teacher in scaffolding students in TELE was examined and students indicated that teacher scaffolded them by giving directions, giving support, explanations how to construct arguments and component of Toulmin Model as well as writing in student journals. This is shown in these 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."

In the code of Technology scaffolding, the role of the technology by using computer, studying in Wise and SenseMaker, writing in Student Journals, experiment pages and increased motivation was indicated. This can be seen in the representative quotes below:

> "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 had 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. I wrote what I learned in student journals and then I read what I wrote there so it helped me to revise before the test. Sentence starters were sometimes helpful in staying focused. Argumentation is like answering questions and I think that it is easier with the steps of the model. WISE was fun and educational. I was motivated because I love technology. Before WISE I had never constructed an argument. Using Internet helped me a lot in constructing arguments since I accessed many resources. The Internet does not always give the right information, so I was attentive in using the information from Internet. I don't think that I really need rebuttal and the others (warrant, ground, and backing) to construct arguments. The argumentation model, as a facilitating procedure, might be important, but I think that to write a few facts would be enough. 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."

In the code of Student-Teacher-Technology Scaffolding, how teachers and technology tool balance the roles to scaffold students' scientific argumentation in TELE was examined and students indicated that they were interacted with technology and teacher by having help from teacher first then technology. This can be seen in the following representative quote:

> "I received my teacher's help who explained us what to do. She also explained what to do in WISE and write in student journals, etc. Ms. Sıla helped us. She told us what to do and WISE also said like now do this stuff...now write something in your journal...so we received teacher guidance and guidance for WISE such as the journals. "

In the code of Problems in TELE, the difficulty in finding rebuttal, constructing arguments and malfunctioning of technology were indicated. This is shown in the following representative quotes:

> "I had difficulty in understanding the components of the argumentation model with its unfamiliar terms. When writing the student journals, I needed support. When constructing arguments, I experienced difficulty since it was hard to defend my point of view. It was difficult for me to find a rebuttal, which was confusing and makes it harder. I had difficulty in finding backing for some warrants. I think that warrants and backings were enough. Finding facts was the main barrier for me when using technology in constructing arguments. The problem I had in working with the technological tool was that I was unable to save what I wrote. The computer was freezing and I was forgetting the order of the steps. I had some technological problems like the Internet connection was lost. I think that the SenseMaker tool needs to have a better design and adjustments. The reason was that the grey thing was not going under and it was so thin that my claims cannot fit into it, so my arguments were ruined and I had to do them again. My suggestion is that the arguments should be written in MS-Word then upload in Wise"

4.4 Summary of Findings

4.4.1 Quantitative Analysis Findings

Technology-based scaffolds (student journals, hints and SenseMaker) influenced and improved students' scientific argumentation for both activity and debate questions over time in Group 1 and their Student Journal scores in both groups in a technology-enhanced learning environment (TELE). The results also suggest that students' prior knowledge of science did not have any effect on their use of the technology-based and teacher scaffolds.

4.4.2 Qualitative Analysis Findings

4.4.2.1 Students' Use of Scaffolds to construct Argumentation

As indicated in the quotations of the previous section, videotape recordings, observation reports and student interviews showed that students received help and support mostly from their teacher, which helped them to learn and improve their argumentations. In interviews students indicated that they were also supported by technology-based scaffolds, argumentation model and debate in constructing arguments. As domain- specific scaffolds, student journals, hints, sentence starters and question prompts in student journals and SenseMaker helped them to learn argumentation. Student journals also helped them to revise all the knowledge they had. With sentence starters they were more focused. Even though they were generally comfortable in using technology, using a new tool, WISE, required teacher explanations. As a domain-generic scaffold, SenseMaker was a useful tool for constructing arguments. They pointed out that to make a digital argumentation instead of writing an argumentation was more fun and educative.

According to students' interviews, it was easier to construct arguments with the Toulminian argumentation model and the use of the components like grounds and backing. They stated that argumentation model is like a formula; it gives the main thing to you and makes easier. Some students indicated that scientific argumentation model helped them to organize their answers in a more scientific way. When constructing argumentation they first searched the topic and then asked to teacher while working on WISE. They planned the argumentation process as ground as a fact, warrant as reason, backing as second reason, which strengthens warrant. Those steps forced them to think about. They developed their own way such as having some sorts of facts or something to claim that they think that is right, then tell it to the opposite side and see if they can get to a conclusion or to think about something to support and choose something learnt in science class. In spite of the difficulty learning the model, practicing it with different examples made it easier and they enjoyed it. Choosing interesting facts for ground and backing is easy for them because of the labs. They indicated that rebuttal helped them to look the main idea from different sides. Working with a group was also fun for them when constructing arguments. According to students, the ideal way of learning to construct argumentation is to ask a question, research about it, make a discussion, make a rebuttal to look from the different side and having help mostly from teacher. They indicated that they also benefited from their friends' support.

In debates, students generally interacted well with the teacher and among themselves. They supported their claims with evidences and their ideas by giving examples and scientists' views. The explanations were generally in claim and example-evidence form but Toulminian argumentation components were also involved in some of the arguments such as ground, backing, and even warrant but no rebuttal. When a group member asked a question, the other group first discussed altogether and a member from the group took the word and answered the question. When a member stated a claim, the chair sometimes interrupted the group to explain their claim. Or when a group stated their arguments, the other groups also presented the counterargument. It was observed grounds, backings and warrants but not any rebuttal.

4.4.2.2 The Barrier to Students' Use of Scaffolds

Videotape recordings and observation reports showed that students had some technological problems like lost of Internet connection, the computer was freezing, downloading the necessary equipment (Java) for using Wise and SenseMaker tool was not saving properly and gone. Moreover SenseMaker tool needs to have a better design and adjustments. The reason was that grey line was not going under and it was so thin that their claims could not fit into. So their arguments were ruined. Therefore students' suggestion was that the arguments must be written in Ms-Word then upload in Wise so that people can see it. Another observed problem was Group 1 teacher's low motivation and encouragement towards the project.

Students' interviews showed that WISE was a new learning environment for them; they had problems in understanding to follow the inquiry map and use SenseMaker tool to construct arguments. Moreover, in the interviews teachers indicated that there were too much argumentation to construct during the unit. Students also indicated that since there were too much scaffolds they felt bored sometimes especially when they did not need them. In interviews, students also indicated that constructing arguments were really difficult especially at the beginning and finding facts was the main barrier for them. Students had difficulty in understanding the components of Argumentation model with unfamiliar terms. They did not include rebuttals in their argumentations most of the time because they were not be able to find any after writing backing and warrant.

4.4.2.3 Teacher Role in Scaffolding Argumentation

According to videotape recordings and observation reports, teacher role was important in the class. Both were, as facilitators, knowledgeable of the skills and strategies for effective learning. Their responsibilities generally included recruiting the student's interest, reducing the degrees of freedom by simplifying the task, modeling and highlighting the features of the task, maintaining direction in the class, demonstrating ideal solutions, providing hints and questions that helped the students to reflect and controlling the frustration. This is also supported with the students' interviews.

Teacher interviews suggested that two teachers behaved differently; one was very active by giving support in each stage and informing students what they have to do while the other preferred to leave students to follow the instructions from Wise on their own unless they had some strategic questions. The actual pattern of Group 2 teacher's was as follows; teacher helped students to draw their attention to the topic and the strategies, discussed them at the beginning of the class and modeled them to make them explicit and provided students with both individual and full class feedback during unit whereas Group 1 teacher was minimizing her role in showing methods for constructing arguments. Then the responsibility is gradually transferred to the students. When students understood the strategies and the goal of the task, it was easier for them to complete the task. As students became more competent, they behaved as leader and helped each other. Both the quality and quantity of support are varied based on the needs of students. As students became more competent, support is faded.

Moreover, as instruction progresses the teacher was aware of her students' progresses and the change in their capabilities as well as she had the knowledge of the task. The interaction between the knowledge of the task and the awareness in the change of students' capabilities generated an effective instruction even though the degree differs according to the teachers' styles of teaching. Based on students' changing knowledge and skills, teacher constantly provided support in this dynamic but complex learning environment. Support was not only for different students at different levels but also for the same student over a period of time. Teacher provided several types of support such as making explanations, providing clarifications, inviting students to study, modeling the desired behavior and providing feedback. In the previous classes before debate, teacher gave instructions from WISE project about how they would be prepared for the debate like making research, stating their positions, finding some supporting evidences as well as counterarguments, presenting facts, making presentations, and thinking about the other group's perspective and reaching out a conclusion.

4.4.2.4 Technology Role in Scaffolding Argumentation

As students worked in the "Light" project in WISE, technology helped them with sentence starters and question prompts in student journals and technological tool, SenseMaker, in the process of constructing arguments. Hints, WISE-inquiry map, student journals and SenseMaker questions are all prepared according to the change in students' level of knowledge. Students indicated in the interviews that technology facilitated this process by reading the information pages in WISE and use of mouse instead of pencil and eraser. It was also indicated that students used student journals as keeping everything they learnt to use them later and think about this information as a fact when constructing argumentation. Hints and SenseMaker were useful tools to construct argument. Student believed that WISE, as a whole, made them very organized. With WISE, they were able to follow the topic easily since there were many opportunities such as student journals, inquiry map, and the other things. Another great opportunity was to search the Internet while being in the project. Videotape recordings and observation reports supported this result as the technology even facilitated constructing argumentation better than teacher in some cases.

4.4.2.5 Distributed Scaffolding - Synergy

All the results of the videotape recording analysis supported by observation reports suggest that learning took place in an interactive environment in which the teachers, students and the technology all have roles in the process. Students tried to include almost all components of Toulmin Argumentation Pattern such as claims, grounds, backing, and warrants. However, rebuttal was only seen in a few of the arguments. Domain-specific and domain-generic scaffolds were

Teacher role was important in the class, but students were also active participants in the instruction. The interaction between the two was an important factor in the effectiveness of the instruction in the classroom. The teacher was aware of the students' progress with an ongoing assessment of the students' understanding and the students played an important role in those interactions.

Scaffolding is not restricted to just the interactions between teacher and student. Environment itself is also being used as a scaffold. In this dynamic learning environment in which a variety of interactions occur scaffolding is also provided in technological tools and peer interactions. Instead of the teacher having to work with each student, support is provided with technology tool so that students can interact with it on their own, move forward in the inquiry process leaving the teacher available for students who need more help and peers could help each other. The more knowledgeable peers contributed by providing help and clarification as well as directions to their peers, whereas less knowledgeable ones contributed by asking questions. Both also provided motivation, thus encouraging each other to think.

Despite the difficulty of the "Light" topic, all the difficulties in constructing arguments and students' being new to that kind of technology-enhanced learning environment, both teacher and students interpreted the scaffolding in a positive way in the interviews and indicated that they interacted well with them using the technology tool, WISE-inquiry map and sentence starters, which contributed them to make a strong debate.

Since each student had a different application of the same model in SenseMaker tool accordingly with the context and they were supported by student journals and hints, which provide additional support for argumentation, domain-specific scaffolds were important and synergetic. Since the features of SenseMaker enabled students to understand the same general framework for scientific argumentation; claim, grounds, warrant, backing, and rebuttal domain-generic scaffold was redundant (Tabak, 2004). In the study, teacher support was also synergistic with the scaffolds provided by the tool, which resulted in greater student learning in terms of the ability to write scientific arguments. It was clear that without the strong interaction and harmony between teacher support and the technology scaffolds, there wouldn't be a synergetic relationship to promote students' learning and ability to construct coherent arguments.

4.4.3 Overall Findings - Combining Quantitative & Qualitative Analysis

The data analyses addressed three research questions regarding: 1) the change of technology-based scaffolds (student journals, hints and SenseMaker) on students' scientific argumentation over time in a technology-enhanced learning environment (TELE), 2) students' use technology-based scaffolds and teacher scaffolds to construct scientific arguments in TELE and the relationship of technology-based and teacher scaffolds with prior knowledge, 3) the roles of teachers and technology tool in scaffolding students' scientific argumentation in TELE. In this respect, the researcher combined the various data sources and a quantitative and a qualitative analysis were conducted since design-based research uses mixed methods.

Overall, the findings were as follows;

1. Technology-based scaffolds (student journals, hints and SenseMaker) improved students' scientific argumentations over time in Group 1 and their Student Journal scores in both groups in a technology-enhanced learning environment (TELE).
2. Students' prior knowledge of science did not have any effect on their use of the technology-based and teacher scaffolds.
3. Since Group 1 teacher did not scaffold their students, technology-based scaffolds were the reason of Group 1's improvement in constructing arguments.
4. Learning science content did improve learning constructing argumentation.
5. The reason of decrease in some of SenseMaker and student journal scores was the difficulty of the content.
6. The reason of improvement in the SenseMaker scores was domain-specific scaffolds.
7. The reason Group 2 did not have any improvements in constructing arguments was that the students were already good in writing argumentations at the beginning of the project (SenseMaker scores were high at the beginning).
8. The reason Group 2 abilities were strong to write argumentations at the beginning of the project was that the support from teacher and from each other was strong from the beginning so that technology-based scaffolds ineffective.
9. Students generally used warrants and backings, rebuttal was only seen in a few argumentations.
10. Since each student had a different application of the same model in SenseMaker tool accordingly with the context and they were supported by student journals and hints, which provide additional support for argumentation, domain-specific scaffolds were important and synergetic.
11. Since the features of SenseMaker enabled students to understand the same general framework for scientific argumentation; claim, grounds, warrant, backing, and rebuttal domain-generic scaffold was redundant (Tabak, 2004).
12. Teacher support was also synergistic with the scaffolds provided by the tool, which resulted in greater student learning in terms of the ability to write scientific arguments.

CHAPTER 5

DISCUSSIONS

This chapter presents discussions drawn from the findings of the study and suggestions for future work. The researcher revisits the three research questions regarding: 1) the change of technology-based scaffolds (student journals, hints and SenseMaker) on students' scientific argumentation over time in a technology-enhanced learning environment (TELE), 2) students' use of technology-based scaffolds and teacher scaffolds to construct scientific arguments in a TELE and the relationship of technology-based and teacher scaffolds with prior knowledge, 3) the roles of teachers and technological tools in scaffolding students' scientific argumentation in a TELE in order to elaborate on the findings and provide direction for future work.

5.1 Discussions

The researcher discusses the findings and their implications for the effect of technology-based scaffolds over time in constructing argumentations, the effect of prior knowledge, students' use of scaffolds to construct argumentation, barriers to students' use of scaffolds, the role of the teacher and technology in scaffolding argumentation, distributed scaffolding – synergy and the verification of Kim et al.'s framework. Like many questions in educational research, these questions do not have easy answers. For this reason, the purpose of the study was to investigate the microcontext dimension of Kim et al.'s (2007) framework and to analyze the student-tool, teacher-student, and teacher-tool interactions. The effect of various scaffolds on middle school students' argumentation in a technology-enhanced learning environment and the distribution of scaffolds between teacher and the technological tool were also analyzed to understand how their roles can be balanced in a technology-enhanced learning environment. The researcher describes these and their implications for the field. Finally, the researcher will propose a set of explicit guidelines and strategies for designing such environments and possible directions for future research.

5.1.1 Scientific Argumentation over time

In the study, the arguments students put forth using SenseMaker were evaluated in two groups; first with different SenseMaker questions for each activity, and second with the same "debate" question for each activity. The results showed that technology-based scaffolds (student journals, hints and SenseMaker) improved students' scientific argumentations over time. Specifically, for the activity questions, the means were higher for Group 2 compared to Group 1 whereas the significant trend was in Group 1 due to the increases in SenseMaker 2,3 and 5. For debate questions, the means were higher again in Group 2 than in Group 1, and the SenseMaker effect was significant for Group 1 with increases in SenseMaker 3 and 4. The SenseMaker scores were high for Group 2 initially.

Students were scaffolded with activity and debate questions in terms of domain-specific scaffolds. The activity questions differed according to the context of each activity. The context was congruent with the learning goals of the unit. Students were however scaffolded with the same debate question at the end of each activity. The results showed that Group 1 students significantly improved in both types of questions. It seems that they especially increased their SenseMaker scores in the middle of the unit. Even when they had lower means, the effect of the technology-based scaffolds could be stated as significant for Group 1 since their teacher did not scaffold them in constructing argumentation. These results also showed that the reason underlying the improvement in the SenseMaker scores were domain-specific scaffolds since the general framework of the argumentation model in SenseMaker tool remained constant as a domain-general scaffold throughout the curriculum unit. In other words, the domain-general scaffold only supported students in terms of the general framework of the components of the argumentation model, and did not add support in terms of quality of arguments.

The scaffolds did not influence Group 2 because their SenseMaker scores were high enough at the beginning of the unit, which showed that they were already constructing strong argumentations. Moreover, their teacher and their peers provided strong support at the beginning of the unit. The results also showed that Group 2 decreased their SenseMaker debate question scores during the unit. The researcher expected that the students would increase their scores during the unit with the same debate question, which was observed for Group 1. Group 2's results revealed once again their abilities to construct strong argumentations at the beginning of the unit and that the repetitive questions decreased their motivation, leaving them unable to add any value to their debate question argumentations. This result also disproves that learning scientific content did not positively effect their learning constructing argumentation, since Group 1 showed significant improvement in the debate questions as well. Thus, it can be concluded that the decrease in some of the SenseMaker and student journal scores in Group 1 was due to the difficulty of the content.

These results suggested that students had developed their SenseMaker scores in constructing arguments with claims, grounds, backing, warrants, and when generating arguments, they gained insight by differentiating between the ground, warrants, and backings as in Toulmin's framework, in some cases more sophisticated arguments using rebuttals. Students generally linked their claim and ground with warrants and backings, but rebuttal was only seen in a few of argumentations. A number of studies have investigated Toulmin's Argument Pattern and found that in terms of the quality of argumentation and reasoning, whether the claim is justified, whether there is a link between claim and grounds such as warrants, whether a rebuttal exists and whether grounds are strengthened with backings are all important considerations. For example, Erduran et al. (2004) collaborated with middle school science teachers to develop instructional activities to make argumentation a component of instruction and used Toulmin's Argument Pattern in their study and asserted that students' ability to construct strong rebuttals is significant for teaching argumentation (Erduran et al., 2008). Therefore, the quality of the argument was evaluated based on the presence or absence of rebuttals. Consequently, in their study they considered evidence-based rebuttal as a high level of argumentation, whereas irrelevant counter argumentation lacking evidence was low-level argumentation. In this study, the rebuttal component of all argumentations was completed by only 1 student in Group 2, who was a high profile student. Therefore, in future, the researcher would like to analyze how to improve students' use of rebuttals since the results showed that students rarely used the rebuttal component in their arguments in this study.

These results were supported by the research of Dawson and Venville (2010), which found that students improved significantly in the complexity and quality of their arguments, rational informal reasoning, and the conceptual understanding of genetics; Jimenez-Aleixandre et al. (2000), which found that students developed a variety of arguments with a pre-dominance of claims, in some cases more sophisticated ones using backings, justifications, or warrants using Toulmin Argumentation Pattern; and Sampson and Clark (2008), which found that many of the frameworks describe the structure of an argument in terms of claims and justification. The diversity of perspectives provided insight to students in generating arguments in science education. Likewise Onyancha and Anderson (2010) used a modified version of Toulmin's (1958) model of argument analysis to examine the elements of grounds, warrant and backing that students used to support their claims and found that high profile students tend to construct arguments according to the scientific principles, while low profile students tend to construct arguments according to their personal beliefs to support their claims.

The analysis of the Student Journals also showed that the effect of technology-based scaffolds (hints, sentence starters, question prompts in student journals) was significant for both groups. Students developed their Student Journal scores, with the means increasing over time. They developed their ability to write in their journals and benefited from the use of hints, sentence starters and question prompts, which ultimately led the students to generate coherent arguments. Specifically, the eta square index indicated that the percentage of the variance accounted for 0.838, which shows a large effect for Group 1, and 0.490, a medium effect for Group 2. In addition to this, the means of the students' experiments and surfaces questionnaire scores for Group 2 were also higher compared to those of Group 1, indicating that Group 2 outperformed and outlearned Group 1 in terms of the science content. Overall, the effect of technology-based scaffolds (student journals, hints and SenseMaker) was significant on students' scientific argumentations over time in a technology-enhanced learning environment (TELE).

These results were also supported by the research of Cho and Jonassen (2002), which found that providing students with online argumentation scaffolds during group problem-solving activities increased the generation of arguments; Belland (2010), which found a significant effect of technology-based argumentation scaffolds on middle school students' argumentation ability during a problem-based learning unit; Land and Zembal-Saul (2003), which found technology-based scaffolds to be useful in supporting explanations and prompts and questions were provided to individual or small groups; Hannafin, Land, and Oliver (1999), which found that in technology-enhanced learning environments, scaffolds support students on what and how to think during problem solving through hints to resources or suggestions, guidance on how to use available resources and tools with bookmarks, assistants, etc. (cited in Bulu, 2008); Ge and Land (2003), which found that question prompts had significantly positive effects on student problem-solving performance; Bell and Davis (2000), which found that scaffolding in the form of prompts and hints for supporting argumentation actually helped students' knowledge integration in a technology-enhanced learning environment (Mildred study).

5.1.2 Students' Use of Scaffolds to Construct Argumentation

Students' pretest results were evaluated to see how prior knowledge shaped different level students' use of the technology-based and teacher scaffolds, high-medium-low profile students were identified and the analysis showed that there was no relationship between pretest scores and the students' SenseMaker scores in both groups. However, this result was in contradiction with Von Aufschnaiter et.al.'s (2007) study, which investigated junior high school students' processes of argumentation and cognitive development, showing that students draw on their prior knowledge and experiences. Lee and Songer's (2004) study also illustrated that high ability students used and benefited more from the explanation scaffolds compared to low ability students.

Throughout the whole process, students faced many challenges. Videotape recordings and observation reports showed that students also had some technological problems like Internet connectivity problems, frozen computer screens, downloading the necessary software (Java) for WISE and SenseMaker tool was not saving properly. Moreover SenseMaker tool needs to have a better design and adjustments. Another observed problem was Group 1 teacher's low motivation and encouragement towards the project. Students' interviews showed that WISE was a new learning environment for them; they had problems in understanding to follow the inquiry map and use SenseMaker tool to construct arguments. Moreover, in the interviews teachers indicated that there were too much argumentation to construct during the unit. Students also indicated that since there were too much scaffolds they felt bored sometimes especially when they did not need them. Students had difficulty in understanding the components of Argumentation model with unfamiliar terms. Constructing arguments were really difficult for them especially at the beginning and finding facts was the main barrier for them. They did not include rebuttals in their argumentations most of the time because they were not be able to find any after writing backing and warrant.

During their interviews, the teachers also pointed out some problems in students' construction of arguments; first, the long sentences that students wrote did not fit into the SenseMaker screen when writing their arguments; second, some technological problems in using the tool led students to lose their motivation; third, the difficulty of the "Light" topic; fourth, the language which was also a challenge for students since English was not their native language; and lastly, with several experiments and many arguments, and the difficulty of the concept, the idea of making arguments was not easy for the students, especially in this age of group. Moreover, both teachers agreed that students need more familiar terms from their daily life instead of "grounds, backing, and warrant". Due to the several challenges that students face in such a complex learning environment, support in TELE was important.

5.1.3 Support in TELE - Role of Teacher and Technology

Learning took place in an interactive and dynamic environment in which a variety of interactions occurred – students, teachers and the technology all had roles in the process. The students were active participants of the instruction, teachers were facilitators and knowledgeable about the skills and strategies for effective learning even though there were significant differences between the teachers' teaching practices; one was very active by giving support in each stage and informing students about what they have to do while the other preferred to leave students to follow the instructions from Wise on their own unless they had some strategic questions.

5.1.3.1 Teacher Role in Scaffolding Argumentation

Wood, Bruner, and Ross (1976) defined scaffolding as the process in which a child solves a problem or achieves a goal, which is beyond his unassisted efforts. Therefore, adult assistance is essential to enable the child to complete a task that is within the child's range of competence (p.90). 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 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).

In view of this, the researcher's argument is that teacher is the most important element of such a multi-dimensional technology-enhanced learning environment. According to videotape recordings and observation reports, teacher role was important in the class. Both were, as facilitators, knowledgeable of the skills and strategies for effective learning. Their responsibilities generally included recruiting the student's interest, reducing the degrees of freedom by simplifying the task, modeling and highlighting the features of the task, maintaining direction in the class, demonstrating ideal solutions, providing hints and questions that helped the students to reflect and controlling the frustration. This is also supported with the students' interviews. Teacher interviews suggested that two teachers behaved differently; one was very active by giving support in each stage and informing students what they have to do while the other preferred to leave students to follow the instructions from

Wise on their own unless they had some strategic questions. Group 2 teacher's teacher helped students to draw their attention to the topic and the strategies, discussed them at the beginning of the class and modeled them to make them explicit and provided students with both individual and full class feedback during unit whereas Group 1 teacher minimized her role in showing methods for constructing arguments. Then the responsibility is gradually transferred to the students. When students understood the strategies and the goal of the task, it was easier for them to complete the task. As students became more competent, they behaved as leader and helped each other. Both the quality and quantity of support are varied based on the needs of students. As students became more competent, support is faded.

Moreover, as instruction progresses the teacher was aware of her students' progresses and the change in their capabilities as well as she had the knowledge of the task. The interaction between the knowledge of the task and the awareness in the change of students' capabilities generated an effective instruction even though the degree differs according to the teachers' styles of teaching. Based on students' changing knowledge and skills, teacher constantly provided support in this dynamic but complex learning environment. Support was not only for different students at different levels but also for the same student over a period of time. Teacher provided several types of support such as making explanations, providing clarifications, inviting students to study, modeling the desired behavior and providing feedback. In the previous classes before debate, teacher gave instructions from WISE project about how they would be prepared for the debate like making research, stating their positions, finding some supporting evidences as well as counterarguments, presenting facts, making presentations, and thinking about the other group's perspective and reaching out a conclusion. However if teacher is not comfortable in using technology then it would be challenging for the teacher as Group 1 teacher indicated.

5.1.3.2 Technology Role in Scaffolding Argumentation

During the study, Group 2 students received help and support mostly from their teacher, which helped them to learn and improve their argumentations. According to Vygotsky's (1978) internalization, cognitive processes first occur on an interpsychological plane and then move on to an intrapsychological plane. 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, helps the learner to accomplish a task otherwise not possible. In interviews students indicated that they were also supported by technology-based scaffolds, argumentation model and debate in constructing arguments. As domain- specific scaffolds, student journals, hints, sentence starters and question prompts in student journals and SenseMaker helped them to learn argumentation. Students used student journals as keeping everything they learnt to use them later and think about this information as a fact when constructing argumentation. With sentence starters they were more focused. As a domain-generic scaffold, SenseMaker was a useful tool for constructing arguments. They pointed out that to make a digital argumentation instead of writing an argumentation was more fun and educative. With WISE, they were able to follow the topic easily since there were many opportunities such as inquiry map and information pages. Another great opportunity was to search the Internet while being in the project in spite of Teacher 1 stated that she did not think using technology was good for teaching concepts even though it might be good for constructing arguments, doing research and debating. According to students' interviews, it was easier to construct arguments with the Toulminian argumentation model and the use of the components like grounds and backing. They stated that argumentation model is like a formula; it gives the main thing to you and makes easier. The steps forced them to think about. They developed their own way such as having some sorts of facts or something to claim that they think that is right, then tell it to the opposite side and see if they can get to a conclusion or to think about something to support and choose something learnt in science class. In spite of the difficulty learning the model, practicing it with different examples made it easier and they enjoyed it. Choosing interesting facts for ground and backing is easy for them because of the labs. They indicated that rebuttal helped them to look the main idea from different sides. According to students, the ideal way of learning to construct argumentation is to ask a question, research about it, make a discussion, make a rebuttal to look from the different side and having help mostly from teacher.

All these results were supported by the research carried out by Kim and Hannafin (2011), which focused on how peer, teacher, and technology-enhanced scaffolds influence student inquiry and found that technology-enhanced scaffolds are effective when supported by clear project goals, relevant evidence, peer- and teacher-assessments and exemplars of knowledge articulation; Land and Zembal-Saul's (2003) investigation, in which students who were supported by technology-based scaffolds in Progress Portfolio were more successful when their instructors helped them; Puntambekar and Kolodner (2005)'s research, which found that technology-based scaffolds that are used as active supports 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.

5.1.4 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 researcher will discuss the rationales of this argument and suggest a set of explicit guidelines and strategies for designing such environments in the last section.

The learning of argumentation and other epistemological practices are involved in constructivist science class goals and are grounded in social constructivist views of learning (Jimenez-Aleixandre, 2008). Classroom discourse involves interaction between students and the teacher, teaching, reasoning and the construction of scientific knowledge. It is organized as a sort of cognitive apprenticeship, which requires students to support their claims with evidence. The main issues to be considered when designing constructivist learning environments with the goal of supporting the argumentation role of the students are the role of the teacher, the curriculum, the assessment, metacognition and communication (Jimenez-Aleixandre, 2008). In this respect, the task must be scaffolded and the level of the students must be understood within their own ZPDs for successfully designed scaffolding in classrooms (Puntambekar and Kolodner, 2005). In building scaffolds in complex learning environments, there are multiple ZPDs that designers have to take into consideration. Scaffolding can take the form of environments and resources as well as take place between individuals. The classroom synergy, the dynamic between the participants and tools and fading, the removal of tools when students no longer need them are the key aspects that must be considered (Puntambekar & Hübscher (2005).

The need for support was distributed throughout diverse tools in the learning environment such as instructional materials, technological tools (templates and prompts embedded in tools), and teacher interventions, which were described by Puntambekar and Kolodner (2005) as "distributed scaffolding". Tabak (2004) discussed three patterns in distributed scaffolding: *Differentiated scaffolding,* which is combining multiple forms of supports provided through different means to address several diverse learning needs. Since this study focused only on supporting students' scientific argumentation, there was no differentiated scaffolding. *Redundant scaffolding,* which refers to different types of supports that target the same need at different points in time. In this study, students were provided domain-specific and domain-generic scaffolds. They were supported by student journals and hints as domain-specific, and by SenseMaker as domain generic scaffolding. As generic scaffolds, the features of SenseMaker enabled the students to understand the general framework for scientific argumentation; the claim, grounds, warrant, backing, and rebuttal. Students were exposed to these scaffolds several times during the project. Therefore, these generic scaffolds were redundant scaffolding. Finally, *Synergetic scaffolding,* which is multiple, co-occurring and interacting support, addressed the same need. In the study, 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. The teacher of Group 2 was very active in providing support at each stage and 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. Domain-specific scaffolds were also synergetic since they provided additional support for the students to improve their abilities to construct argumentation compared to domain-generic scaffolds, which only helped students to understand the general framework of argumentation model. Students improved their argumentation scores using SenseMaker as well as their scores in constructing arguments with claims, grounds, backing, warrants and in some cases rebuttals. It was clear that without the strong interaction and balance between teacher support and the technology scaffolds, there would not have been a synergetic relationship to promote student learning nor improve student ability to construct arguments. The three types of interaction and the micro level factors from Kim et al.'s (2007) framework that must be carefully analyzed were:

Student-tool interaction is when students solve meaningful problems using technology and are supported by scaffolds. In this study, technology increased the students' motivation in science. Even though there were many barriers like 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 regarding 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 in the argumentation model, which could not have been done without in-depth thought. As generic scaffolds, the features of SenseMaker enabled students to understand the general framework for scientific argumentation; 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. Another barrier 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. 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.

Teacher-tool interaction is when the teacher selects and organizes the tools in the class. As Kim et al. (2007) argued, the teacher's tool use customization is important especially when teachers do not have experience in technology integration. In the study, teachers were not experienced in using and integrating the content into WISE. Kim et al. (2007) argued that the inquiry tools developed by the researcher must have similar perspectives with those of the teacher. In the study, the teachers and the researcher worked together to integrate them. The study was conducted over a two-year period with pilot studies, 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 it was not her own work. In the teacher's interaction with tool, the teacher's role was very important. Teacher reluctance in integrating technology and implementing a new innovation in the classroom was big a drawback in this sense. 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.

Teacher-student interaction is when the teacher provides scaffolds such as hints and questions for the student. In the study, 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. It 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 in the Group 2 teacher's class.

The results are supported by the research done by Sharma and Hannafin (2007), which also found that scaffolds must be integrated, considering various synergetic tools such as curricular materials, resources and teachers in dynamic environments; and 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, and even though a tool offers significant flexibility, the teacher's tool use customization is important; Albe (2008), who explored how students elaborated arguments on a socio-scientific controversy in small group discussions and found that students' social interactions significantly influenced the patterns of argumentation within the group discussions but were in contradiction of the research of Ge and Land (2003), which found that peer interactions did not have any significance in scaffolding.

As previously mentioned, according to the Kim et al.'s (2007) framework there has not been much research on student-tool interaction, teachers' interaction with tools, teacher facilitation in technology-enhanced learning environment and managing a balance between technology and teacher scaffolding. Little is known about when student-tool interactions are meaningful, how students use them and the drawbacks in students' use of technology, the role of the teacher in scaffolding students' scientific argumentation. Moreover, there is a gap in research in Turkey in scaffolding argumentation in technology-enhanced learning environments. For this reason, the researcher examined the synergetic relationship between technology-based scaffolds and teacher scaffolds and proposed a set of explicit guidelines and strategies for designing such environments.

5.2 Scaffolding Argumentation Framework in TELE

The results showed that technology-based scaffolds were emphasized in improving students' scientific argumentations in Group 1. However, the researcher's argument is that even though technology creates opportunities and motivates students, the improvements in the learner abilities in constructing arguments rely on the instructional practices that the teacher implements. As mentioned before, the teacher is the sole planner and organizer of the teaching. The Group 2 SenseMaker argumentation scores were initially high because their teacher scaffolded them very intensely, enabling the students to construct strong arguments at the beginning. Therefore it is necessary to consider technology with all the aspects of the classroom context; the curricular activities embedded in the tool, teacher support, the teacher's structuring of and guidance during the entire class hour. In the classroom, it is important how students interact with technology and the teacher. It is also important how teacher presents the instruction, making it difficult or easy. Therefore, the teacher must manage and prepare technology appropriately.

In the study, Group 2 teacher was helping her students in each stage of the instruction. She was very dynamic and she was interacting with the technology and filling the gaps when needed. At the end her students had high scores even in their first SenseMaker argumentation scores. The results also showed that the reason for the decrease in the SenseMaker and student journal scores were the difficulty level of the science content. Therefore, to improve students' ability to construct arguments, they need to learn the science content. Students need to be supported with domain-specific scaffolds in order to learn the science content, and this support needs to be present until the students have learned the science content. In the study, there were several activities that were consistent with each learning goal. In each of them, the students had domain-specific scaffolds such as hints, sentence starters, question prompts in student journals and SenseMaker, which helped the students to focus on science content. They learned the content and at the end, they were able to construct argumentation. In Group 2, since they were able to construct strong arguments at the beginning, the results did not show significant improvements. The other reason for the lack of significant improvement is that they were scaffolded with the same general framework constantly, which did not add any value to them since it eventually became repetitive and redundant. In other words, since the features of SenseMaker enabled students to understand the same general framework for scientific argumentation; claim, grounds, warrant, backing, and rebuttal, domain-generic scaffold was redundant (Tabak, 2004). Also, since each student had a different application of the same model in SenseMaker according to the context and they were supported by student journals and hints, which provided additional support for argumentation, domain-specific scaffolds were important and synergetic. Here a question arises regarding whether domain-generic scaffolding needs to be faded whereas domain-specific scaffolding does not need to be faded as a topic for future study.

Therefore, how the teacher structures the instruction to improve students' abilities in constructing argumentation in TELE and how the teacher interacts with the technology is crucial. The question of how the teacher and technology balance and complement each other remains even though the Group 2 teacher practice was a good example for this balance. When the opportunities that technology offers are the same for all students, teacher practice becomes important, as the researcher has argued. Instructional Development (ID) models help the teacher to think and plan the instruction. The teacher needs to select the subject before planning the activities. Therefore, the existing practice needs to be analyzed and questioned first before integrating technology into the learning environment. Then the teacher can identify the difficulty and challenge and formulate the solution. The design of the instruction, developing the instructional materials, implementation using the materials and strategies and evaluating the adequacy of the instruction are the next steps in ID models. In Reiser and Dick's model (1996), the identification of goals and objectives, planning instructional activities, choosing instructional media, developing assessment tools, implementing instruction and revising instruction are the key principles (cited in Lim, In Press).

Therefore, the researcher has formulated and proposes a set of design guidelines and strategies about how the teacher must structure and interact with the technology and students in a technology-enhanced learning environment in Table 5.0.1 The aim is to overcome the complexities and help teachers to plan their practices in order to facilitate the structuring of a technology-enhanced learning environment.

Table 5.0.1
Scaffolding Argumentation Framework in TELE

Scaffolding Guidelines	**Scaffolding Strategies**
Microcontext Component: Teacher-Tool Interaction	Strategy 1a: Question the existing practice
Guideline 1: Plan the instruction	Strategy 1b: Identify the challenge
	Strategy 1c: Formulate a solution
Guideline 2: Select Media & Materials	Strategy 2a: Choose the media congruent with learning goals
	Strategy 2b: Prepare science content congruent with learning goals and debate
	Strategy 2c: Prepare domain-specific and generic scaffolds
Guideline 3: Develop Assessment Tools	Strategy 3a: Prepare a pretest to evaluate the existing knowledge
	Strategy 3b: Prepare questions to evaluate new content knowledge
	Strategy 3c: Prepare questions to evaluate argumentations
Guideline 4: Implement Instruction	Strategy 4a: Implement new practice and structure
	Strategy 4b: Use new pattern of interaction and debate
Guideline 5: Revise Instruction	Strategy 5a: Revise the new practice and structure
	Strategy 5b: Reexamine new pattern of interaction and debate
Microcontext Component: Teacher-Student Interaction	Strategy 1a: Analyze students' needs
Guideline 1: Need Analysis	Strategy 1b: Identify the problem
	Strategy 1c: Formulate a solution
Guideline 2: Implement the new solution	Strategy 2a: Reduce the complexity and decompose the tasks
	Strategy 2b: Increase the motivation
Guideline 3: Revise the new solution	Strategy 3a: Revise the new structure
	Strategy 3b: Revise the new pattern of interaction

Table 5.0.1
Scaffolding Argumentation Framework in TELE (Continued)

Microcontext Component: Tool-Student Interaction	Strategy 1a: Analyze students' needs
Guideline 1: Need Analysis	Strategy 1b: Identify the problem
	Strategy 1c: Formulate a solution
Guideline 2: Implement the new solution	Strategy 2a: Reduce the complexity
	Strategy 2b: Increase the motivation
Guideline 3: Revise the new solution	Strategy 3a: Revise the new structure
	Strategy 3b: Revise the new pattern of interaction

To overcome the complexities and help teachers to plan their practices in order to facilitate the structuring of a technology-enhanced learning environment, the researcher describes these guidelines by reviewing these complexities for the field as follows:

Microcontext Component: Teacher-Tool Interaction

Description: Teacher support is synergistic with the scaffolds provided by the tool, which resulted in greater student learning in terms of the ability to write scientific arguments. For this reason, the teacher's role is important for planning and organizing the instruction. The teacher scaffolds the learning environment by integrating technology to construct scientific argumentation by planning the instruction, selecting media & materials, developing assessment tools, implementing instruction and revising the instruction. Learning argumentation relies on learning the science content, which is possible with the teacher, domain-specific and domain-generic scaffolds. How the teacher presents the instruction and makes it explicit to the students is important. The way the teacher defines, models argumentation, provides individual and full-class feedback, connects it to everyday discourse, adapts the instruction based on students' prior knowledge all shape the instruction.

Guideline 1: Plan the instruction - Question the existing practice, identify the challenge and formulate a solution.
Guideline 2: Select Media & Materials - Choose the media congruent with learning goals, prepare science content congruent with learning goals and debate and prepare the domain-specific and generic scaffolds.
Guideline 3: Develop Assessment Tools - Prepare a pretest to evaluate the existing knowledge, prepare the questions to evaluate new content knowledge and prepare the questions to evaluate argumentations.
Guideline 4: Implement the Instruction - Implement new practice and structure and use new pattern of interaction and debate.
Guideline 5: Revise the Instruction - Revise the new practice and structure and reexamine new pattern of interaction and debate.

Microcontext Component: Teacher-Student Interaction

Description: Student interaction with the teacher through asking and answering questions, having explanations on how to construct arguments and use the components of model as well as write in student journals, having a direction and being encouraged by their teachers is possible. The needs analysis must be conducted, and so that problem areas can be identified and a solution be formulated. If there is any difficulty in comprehension, then the complexity must be reduced by decomposing the tasks into parts and increasing student motivation. Lastly, a new solution and new interaction pattern must then be revised. Students also need to listen to their teachers and their peers carefully and understand the subject.

Guideline 1: Needs Analysis - Analyze students' needs, identify the problem and formulate a solution.
Guideline 2: Implement the new solution - Reduce the complexity and decompose the tasks and increase the motivation.
Guideline 3: Revise the new solution - Revise the new structure and revise the new pattern of interaction.

Microcontext Component: Tool-Student Interaction

Description: Technology scaffolds students through computer work, online searches, various tools and videos. In this respect, the way students interact with technology and student ownership in using technology is important. The study showed that technology-based scaffolds help students to improve their abilities to construct argumentation. In fact, tools are helping students to focus on a more challenging part of the task to improve their skills for constructing argumentation. During the study, even though students rarely used rebuttals, domain-generic scaffolds forced students to use all of the components of the argumentation model. For this reason, a needs analysis must be conducted once again to see what kind of challenges students face in using technology and a solution must be formulated. Then a new solution and new interaction pattern must be implemented and finally revised.

Guideline 1: Needs Analysis - Analyze students' needs, identify the problem and formulate a solution.
Guideline 2: Implement the new solution - Reduce the complexity and increase the motivation.
Guideline 3: Revise the new solution - Revise the new structure and revise the new pattern of interaction.

5.3 Future Work

This study showed that the teacher's role was as significant as that of technology in improving students' argument construction skills. The interaction between technology and teacher scaffolding was not an easy task, and considering all the factors it was actually quite a difficult process. For this reason, the researcher would like to examine more closely how to balance technology and teacher scaffolding since both are inevitable in a technology-enhanced learning environment in future. I would also like to analyze how to improve students' use of rebuttals since the results showed that students rarely used the rebuttal component in their arguments in this study.

5.4 Conclusions

As previously mentioned, according to the Kim et al.'s (2007) framework, there has not been much research on student-tool interaction, teachers' interaction with tools, teacher facilitation in technology-enhanced learning environment and managing a balance between technology and teacher scaffolding. Little is known about when student-tool interactions are meaningful, how students use them and the drawbacks in students' use of technology, the role of the teacher in scaffolding students' scientific argumentation. Moreover, there is a gap in research in Turkey in scaffolding argumentation in technology-enhanced learning environments. For this reason, this research is based on an analysis of the effect of various scaffolds on middle school students' scientific argumentation in Turkey. The researcher also examined the synergetic relationship between technology-based scaffolds and teacher scaffolds and attempted to understand how they interact and contribute to the argumentation abilities of students as well as how students use scaffolds to construct arguments in Web-based inquiry science in a student-centered inquiry-oriented technology-enhanced learning environment. Finally, the researcher suggested a set of explicit guidelines and strategies for designing such environments.

Puntambekar and Kolodner (2005) argued 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. In this respect, this study showed that the roles of the teacher and technology, the interactions between student-tool, student-teacher and teacher-tool must be analyzed, and scaffolding must be designed carefully in a technology-enhanced learning environment to facilitate students' learning and argumentation skills as indicated by Kim et al.'s (2007) framework. The results also 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 the claim, ground, backing, warrants, and in some cases, more sophisticated ones using rebuttals as in Toulmin's framework. Peer interactions were also significant in scaffolding.

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APPENDIX A. 6TH GRADE SCIENCE LIGHT CURRICULUM

Behavioral objectives	Topic	Methodologies/Strategies
Identify and explain types of reflection Describe how light interacts with different types of surfaces. Understand how beams of coloured light can be added to form new colours Understand the ways light is reflected on different coloured objects	Light	Through labs and activities, students will identify and explain types of reflection Through labs and activities, students will describe how light refracts through different media. Through labs and activities, students will describe the concepts of colour and colour reflection and absorption

APPENDIX B. PRE-TEST

(1) The bending of a beam of light when it passes obliquely from one medium to another is known as _______.

Reflection
Refraction
Dispersion
Deviation

(2) Objects that allow light to pass through them are _______.

Focused
Absorbed
Transparent
Opaque

(3) Which of these can you see?

X Rays
Visible Light
Gamma Rays
Radio

(4) Which of the below is opaque?

air
frosted glass
alcohol
gold

(5) Which of the below is translucent?

air
alcohol
frosted glass
tea

(6) If red ray is passed through a piece of red plastic (a red filter), what colour will you see?

green
red
blue

violet

(7) If white light ray is passed through a piece of red plastic (a red filter), what colour will you see?

green
red
blue
white

(8) If a white light ray hits a yellow object (made of red and green), which light would be reflected and the object would look?

white
red
green
yellow

(9) Which of the below is not what a green plant need to make glucose?

Oxygen
Light
Water
Minerals

(10) What is the Law of Reflection?

The angle of the incident ray is bigger than the angle of the reflected ray
The angle of the incident ray is smaller than the angle of the reflected ray
The angle of the incident ray is the same as the angle of the reflected ray
None of Above

(11) When a white light is split up into different colours by a Glass Prism, which of the below is refracted the least?

Blue
Green
Violet
Red

(12) Which of the below is not one of the primary colours.

Green
Red
Blue

Yellow

(13) Which of the below is correct?

The image appears to be greater distance behind the mirror as the object is in front of the mirror

The image appears to be smaller distance behind the mirror as the object is in front of the mirror

The image appears to be the same distance behind the mirror as the object is in front of the mirror

None of the Above

APPENDIX C. THE DEBATE

You will begin your debate activities by stating your personal positions. You will be creating an argument that explains “Light: Particle or a Wave?”. You then will explore and develop an understanding of the evidence. You are required to explain your arguments using data and evidence. Based on the evidence presented in your argument, you should prepare to argue whether light is made up of particles or behaves like wave. You are also encouraged to develop evidence from your own lives and refine an argument for one theory or the other. Those first will be discussed in small groups and you are asked to come to some consensus. Then a whole-class discussion will be held, Group presentations and ideas will be shared with the rest of class by responding questions from the other students and the teacher. The main task will be presenting arguments.

Your teacher will give you a worksheet to use as you prepare for the debate. Here’s what you need to do for your presentation:

(1) Make an opening statement about your position. You should state your position and the arguments you will be proposing.
(2) Present your argument. Include convincing evidence to support your position.
(3) Try to imagine that you are on the opposing side of the debate and think of some questions that they may ask you. Your classmates will challenge your position by asking you questions that you will have to respond to.
(4) You should have a final conclusive argument/statement about your position.

A good presentation will
• be well-organized and clearly presented.
• have a good understanding of both sides of the issue.
• have plenty of evidence to back up claims being made.
• be convincing to the audience (your classmates) and the judge (your teacher)

Good Luck!

Retrieved from WISE: “Global Climate Change: Who’s to Blame?” project.

THE DEBATE PLAN

Name of the Student:

(1) What is your opening statement?
Who will present it? ______________________

(2) What is your argument (position on the issue)?
Who will present it? ______________________

(3) What evidence will you present to support your argument?

(4) Who will present it? ______________________

(5) Write down two questions that the audience may ask you.

(6) Write down two questions that you have for the opposing argument.

(7) Write down your final argument.
Who will present it? ______________________

Retrieved from WISE: “Global Climate Change: Who’s to Blame?” project.

THE DEBATE NOTES

Your teacher has told you what your role is as an audience member. Now, you must pay close attention to all of the issues raised in the debate.

For each group that presents, take notes about the position that they are arguing for. Make notes about the evidence that they present. Write at least two challenging questions for them. Remember, they are trying to convince you to agree with their position.

Name of the Student:

Group Position:

Group Members	Evidence Presented	Challenging Questions
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Retrieved from WISE: “Global Climate Change: Who’s to Blame?” project.

APPENDIX D. QUALITY CRITERIA

Quality of argumentation in student essays

Claims

6 The writer states generalizations that are related to the proposition and which are clear and complete.
4 The writer states generalizations that are related to the propositions, but the assertions are not complete.
Enough information is available to figure out the writer's intent, but much is left to the reader to determine.
2 The writer makes generalizations that are related to the proposition, but the assertions lack specificity or offer unclear referents. The writer leaves much for the reader to infer in order to determine the effect of the claim.
0 No claim related to the proposition or unclear assertions.

Grounds

6 The supporting data are compete, accurate, and relevant to the claim.
4 The data offered are relevant but not complete. The writer leaves much for the reader to infer from the data. The writer may have offered the data without the complete citation, which would allow the reader to determine the reliability of the data as evidence. The writer may offer data, which are not complete enough to allow the reader to determine their significance.
2 The data or evidence are weak, inaccurate, or incomplete. E.g. a) an attempt at using a general principle without establishing the truth of the principle; b) the use of examples from personal experience, which are not generalizable; c) the citation of data when no source is identified; and d) the use of obviously biased or outdated material.
0 No supporting data are offered or the data are not related to the claim.

Warrants

6 The writer explains the data in such a way that it is clear how they support the claim.
4 The writer explains the data in some way, but the explanation is not linked specifically to the claim.
2 The writer recognizes a need to connect the data to the claim and states some elaboration of data, but the writer fails to make the connection. Or most rules and principles are not valid or relevant.
0 No rules and principles are offered.

Backings

6 The writer states correct, relevant, and specific sources of warrants.
4 The writer states correct, relevant sources of warrants but the sources are very general, not specific.
2 The writer states incorrect, irrelevant sources of warrants.
0 No sources of warrants are given

Rebuttals

6 The writer states complete and systematic identification of constraints of solutions.
4 The writer identifies constraints of solutions but the constraints are not sufficient.
2 The writer offers few constraints of solutions but the constraints are not elaborated.
0 No recognition of constraints of solutions.

Note. Based on Toulmin's model of argument (Toulmin, Rieke, & Janik, 1984).

Cited in Cho & Jonassen (2002)

APPENDIX E. INTERVIEW SCHEDULES

TEACHER INTERVIEW SCHEDULE

School **Date and Time (start – stop) Interviewer**

INTRODUCTION

As a PhD student in Middle East Technical University – The Computer Education and Instructional Technology Department I am conducting a study titled "Supporting Middle School Students Learning And Scientific Argumentation In Technology-Enhanced Learning Environments: Distribution Of Scaffolds". The aim of my study is to analyze the effects of technology-based scaffolds in the Web-based Inquiry Science Education (WISE) on Grade 6 students' learning and scientific argumentation. I'm interviewing science teachers and my hope is to understand how do teachers and technology tool complement roles to scaffold students' scientific argumentation in technology-enhanced learning environment. I hope my findings will make significant contributions to the determination of the effects of technology-based scaffolds in the Web-based Inquiry Science Education (WISE) on students' scientific argumentation.

- What you say to me is completely confidential. We don't pass on anything people tell us. And we don't use names of individuals in anything we write.
- Any further questions I can answer?
- I'd like to tape our conversation, Is it OK with you? And you are free for the next half an hour, right?

BACKGROUND QUESTIONS
Lets start with some questions about the teaching experiences you had before.

Q1a. For how long have you been teacher?
Q1b. For how long have you been teacher in this school?
Q2a. Have you ever used a technology tool in your science classes? If yes can you explain?
Q2b. Have you ever used a technology tool in constructing scientific argumentation in your science classes? If yes can you explain?

QUESTIONS ABOUT CONTENT AND PROCESS

Q1. Describe how you teach to construct scientific argumentation to your students?
    Q1.1 Are they researching in the textbook? In the class?
Q2. Describe your role when students construct scientific argumentation?

PROMPT: Helper
Facilitator
Instructor which one?

Q3. What kind of help you provide to your students when they construct scientific argumentation?

Q4. Describe the role of technology tool when students construct scientific argumentation?

Q5. What kind of help do you think that technology tool provide in students' constructing of scientific argumentation?

PROMPT: Hints
Sentence Starters
Student Journals
Teacher guidance

Q6. What does scientific argumentation mean to you?

Q6.1 What does scientific argumentation model mean to you?

Q6.2 Can you give an example for scientific argumentation?

Q6.3 Can you give an example for scientific argumentation model?

Q7. What does scaffolding mean to you?

Q7.1 Can you give an example for scaffolding?

Q8. How do you feel about using technology tool in constructing scientific argumentation? Does technology help students in constructing scientific argumentation? If yes explain?

Q9. Do you feel (think?) that technology-based scaffolds help students in constructing scientific argumentation? How?

Q9.1 In this position how do you define your role as a teacher?

Q9.2 What do you feel (think) about constructing scientific argumentation with an argumentation model through scaffolds

Q9.3 What do you feel (think) about including rebuttal when constructing argumentation through scaffolds?

Q10. How you and technology tool complement roles to scaffold students' scientific argumentation in technology-enhanced learning environment?

Q10.1 What do you think about our last year's study when we used the technology tool?

Q11. In your mind, what is the ideal way of learning to construct argumentation?

PROMPT: How should it be done?
How should be the role of the teacher?
How should be the role of the technology tool?

Q11.1 How should it be done with light then? The role of the teacher?

Q11.2 So We should start with the experiments?

Do you want to add something?

Thank You.

STUDENT INTERVIEW SCHEDULE

School **Date and Time (start – stop) Interviewer**

INTRODUCTION

As a PhD student in Middle East Technical University – The Computer Education and Instructional Technology Department I am conducting a study titled "Supporting Middle School Students Learning And Scientific Argumentation In Technology-Enhanced Learning Environments: Distribution Of Scaffolds". The aim of my study is to analyze the effects of technology-based scaffolds in the Web-based Inquiry Science Education (WISE) on Grade 6 students' learning and scientific argumentation. I'm interviewing grade 6 students and my hope is to understand their perceptions of learning through scaffolds as well as barriers to learning when they interact with the technology tool. I hope my findings will make significant contributions to the determination of the effects of technology-based scaffolds in the Web-based Inquiry Science Education (WISE) on students' scientific argumentation.

- What you say to me is completely confidential. We don't pass on anything people tell us. And we don't use names of individuals in anything we write.
- Any further questions I can answer?
- I'd like to tape our conversation, Is it OK with you? And you are free for the next half an hour, right?

BACKGROUND QUESTIONS
Lets start with some questions about the experience you had before about scientific argumentation in your class.

1a. Tell me about yourself as a student?
1b. What motivates you in science classes?
2a. Have you ever used technology in science? How?
2b. Have you ever constructed argument in science? How?

QUESTIONS ABOUT CONTENT AND PROCESS

1. Describe the process you go through as you construct scientific argumentation? How do you construct scientific argumentation?
   1.1. What do you experience when you construct scientific argumentation?
2. Describe how you are comfortable with using a technology tool?
   2.1. How much experience you had with a technology tool?
3. What kind of help have you received in using technology tool in science class?
4. What kind of help do you need when you use technology tool in constructing scientific argumentation?

PROMPT: Hints
Sentence Starters
Student Journals
Teacher guidance

5. What problems you encounter when you use technology tool in constructing scientific argumentations?
6. What does scientific argumentation mean to you?
   6.1. What does scientific argumentation model mean to you?

PROMPT: Claim, Evidence

   6.2. Can you give an example for scientific argumentation?
7. What does scaffolding mean to you?

PROMPT: Support

   7.1. Can you give an example for scaffolding?
8. How did you feel when you first are required to construct scientific argumentation?

PROMPT: In terms of subject matter
In terms of argumentation model
In terms of the outcomes wanted from you
In terms of using a technology tool

9. How do you feel about using technology tool in constructing scientific argumentation? Does technology help in constructing scientific argumentation? If yes explain.
10. Do you feel (think) that technology-based scaffolds help constructing scientific argumentation? How?
    10.1. What do you feel (think) about constructing scientific argumentation with an argumentation model through scaffolds?

PROMPT: Claim, Evidence

    10.2. What do you feel (think) about including rebuttal when constructing argumentation through scaffolds?

PROMPT: Counterargument

11. In your mind, what is the ideal way of learning to construct argumentation?
    11.1. How should it be done?

Thank You.

APPENDIX F. OBSERVATION SCHEDULE

Purpose

The purpose of this observation is to describe how do teachers and technology tool complement roles to scaffold students' scientific argumentation in technology-enhanced learning environment. The dynamic learning environment and the interaction process between technology tool and teacher will be systematically examined. The following research questions will provide a guideline for observation:

(1) What are the roles of the teachers to scaffold students' scientific argumentation in technology-enhanced learning environment?
(2) What is the role of the technology tool to scaffold students' scientific argumentation in technology-enhanced learning environment?
(3) How do students interact with the teacher and the technology tool in constructing scientific argumentation?
(4) How do students participate in the debate?
(5) What limits or encourage students to construct scientific argumentation in technology-enhanced learning environment?
(6) How do the teacher and students interpret scaffolding in constructing scientific argumentation in technology-enhanced learning environment?

Data Collection

A science classroom will be observed for three sessions to explore interaction patterns between students, teacher and technology tool. A videotape recorder will be used to record the classroom interaction. Data will be collected on 2 aspects of the classroom environment:

(1) Context: information about the physical setting (mapping the layout of seats, tables and other objects in the classroom), the human setting (description of characteristics of students and the teacher), and the scheduling patterns (timeline for periods and scheduling of activities during the classroom period)
(2) Classroom discussion: interaction patterns between the teacher, students and technology tool.

Coding System for Field Notes

In creating a system to organize the field notes, the main purpose is to find the underlying characteristics of debate patterns in the classroom observed. The coding categories below will be used in order to classify field notes and the transcribed data in the light of research questions. Additional coding categories will be added if necessary.

Teacher's interactive activities
- Facilitating
- Directing
- Responding
- Framing
- Controlling
- Restating
- Clarifying, etc.

Students' interactive activities
- Question asking
- Answering
- Debating
- Describing
- Constructing argumentation

Technology tool scaffolding
- Hints
- Sentence Starters
- Student Journal
- SenseMaker

These descriptive codes will allow the researcher to pull out key activities of the teacher, students and technology tool in the classroom. After coding the field notes according to these categories, they will be grouped in clusters. Grouping these categories into smaller number of overarching constructs will help the researcher reduce large number of codes into small analytical units. These units will then be used to analyze debate patterns in the classroom. Some of the initial analytical units might be similar to the following:

Setting-context

Debate structures
- Patterns
- Procedures

Meanings, perspectives

APPENDIX G. CERTIFICATE OF PARTICIPATION

Certificate of

Participation

This is to certify that

____

has successfully completed the
WISE "Light: Particle or Wave" Project

Ms. Sıla Severim / Ms. Christina Levyssohn
Instructors

This ______*Day of* ______________ ______

____
Signature

Researcher: Mrs. Hale Üstünel
Middle East Technical University

MS. CHRISTINA'S CLASS

APPENDIX H. TEACHER'S MANUAL

WELCOME TO WISE

WISE (the web-based inquiry science environment) is a simple yet powerful learning environment where students examine real world evidence and analyze current scientific controversies. The curriculum projects are designed to meet standards and complement the science curriculum, and grade 5-12 students will find them exciting and engaging. A web browser is all they need to take notes, discuss theories, and organize their arguments!

Getting started- A Guide to WISE

Consent form will be signed by students
Students' registration – Student Portal
Set the notebook, the data show and speakers if needed
Log on
Select the study
Skip the choose partner and click the enter the project button (but they actually choose a partner and cooperate with them but do not share the computers).
If students lose their path during the project then they need to click index button and select the appropriate activity and step. But normally they will follow the steps in each activity in the inquiry map and click on "go the next activity button" in below of the inquiry map when all steps end.
Finally when they finish, they click the exit button.

To track student work and unleash the full power of WISE, students must be registered correctly in the WISE system. While this is not a difficult task, there are several points where it's possible to go astray, so it's very important to read these instructions ahead of time.

Computer Lab

We suggest you have enough computers so that no more than two students are sharing each computer. This is to maximize learning and involvement.
Each computer must meet the Technical Requirements for WISE.
Your students will need to visit two addresses-
The Student Registration Page at *http://wise.berkeley.edu/pages/newStudent.php* where students will register for WISE accounts.
The Student Portal at *http://wise.berkeley.edu/student* where students will log into WISE each day.

Either your students will need to type in the above URLs *exactly* each time they need to reach either page, or you can set up bookmarks on each computer to make the process easier.

Registering Students

Every student in the classroom should register and get an account, *even if more than one student are sharing each computer.* If several students are sharing a computer, they should take turns going through the registration process. They will have a chance to indicate that they are sharing a computer when they enter a WISE project.
To register, the student should either type the address *http://wise.berkeley.edu/pages/newStudent.php* in the URL bar of the web browser, or select the "Student Registration" bookmark if you created it.

Students should enter:
Their full name
The class period (usually a number)
A password (this will be entered twice to double-check)
A "Student Registration Code" - your students should enter your student registration code, which is WHCQMM at the moment. If this changes, the researcher will inform you. This lets WISE know to connect the students to your list of current students. Your code will never change, unless you request a new one.

After entering all the information and clicking on "Register", students will receive a username. This, combined with their password, will allow access to WISE.
Note: Each student should be very careful to remember his/her username and password. Should a student forget, do not have the student re-register for WISE. You can use the Teacher's PET to recover this information.

Running a project

To reach the WISE Student Portal, students must type in the address *http://wise.berkeley.edu/student*, or select the "WISE Student Portal" bookmark (if you created one).

Your students will be prompted for their username (i.e. "janicew" or "dwightj") and password from the registration process (*Note: This is the student's password, not the Teacher Registration Code*). If several students are sharing a computer, it doesn't matter which one logs in.

The project you have selected will appear as a link on the student portal page. Have your students click on it to go to the project.
The first time a student enters a project, he/she will be prompted to join a group.

Since the student will be using a computer alone, then he/she should click on "Don't set up a group, I'm working alone".

Every day of the project run, the students will:
Visit the student portal and log in.
Click on the project name to go to the last completed step in the project.
You can view, print, and grade your students' work by selecting Grade Student Work from the Management menu.

Common Classroom Difficulties

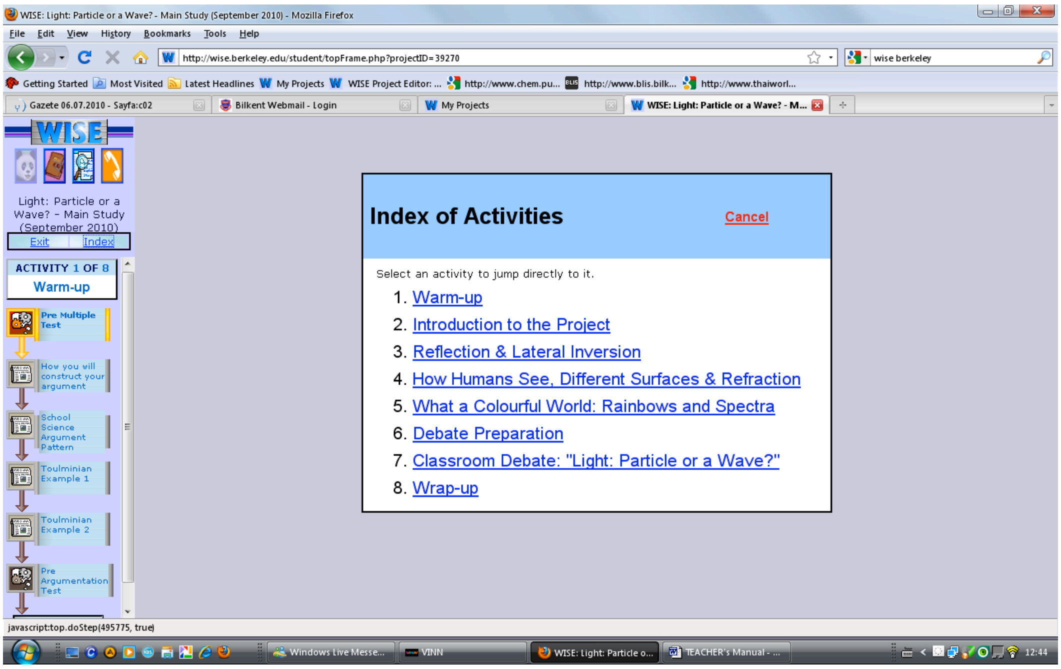
If students forget their username and/or password (if a student always gets "Authorization Failed" errors when trying to log in, this is probably the problem), do not have the students register again. You can use the Teacher's PET to look up the student username, and assign a new password to the student (you can do both using the View your students option in the Management menu).

If you are having your students type the URLs to the student registration and portal pages, the URLs must be typed *exactly* as they appear in this guide.
On the other hand, if you wish to create bookmarks, your school computer lab may not allow them to be created without the lab manager's assistance, or there may be so many bookmarks that your created bookmarks are difficult to find in the list. If you have these sorts of difficulties, talk to your lab manager or technical support staff to find a solution that fits your computer lab's needs.
If your students need to change groups in the middle of a project, they will need to select "Change" next to the names of their group members in the Student Portal. Detached group members will lose their work on the project, so it is best to do this very early in a project if it must be done.

Activities

Warm-up - 2 periods
Introduction to project - 2 periods
Reflection & Lateral Inversion - 6 periods
Different Surfaces & Refraction - 4 periods
What a Colourful World: Rainbows and Spectra - 4 periods
Debate Preparation - 2 periods
Classroom Debate: “Light: Particle or a Wave?”- 1.5 periods

7 activities –
21.5 periods (3 to 4 weeks) of time
Each week there are 6 periods.



PART 1: Introducing Wise

The WISE is a free online learning environment supported by the National Science Foundation. In Wise modules, students work on exciting inquiry projects on topics such as global climate change, population genetics, hybrid cars, and recycling. Students learn about and respond to contemporary scientific controversies through designing, debating and critiquing solutions, all on the WISE system.

Students do most WISE activities on a computer, using a web browser. Special WISE software guides students through evidence and information pages that provide content, “notes”, “hints”, and discussion tools that encourage students to reflect and collaborate, and other tools for data visualization, causal modeling, simulations and assessment.

PART 2: WISE in the classroom

Interaction and collaboration are the keys to making WISE successful. Students work on WISE modules in pairs. Close collaboration encourages students to share their ideas and support each other. WISE modules are built to facilitate deep interactions among students and between students and the teacher. This approach gives students a chance to express themselves, share ideas, and encourages constructive social interactions.

Teachers are also meant to play an interactive role in WISE modules. As students work in pairs, the teacher is free to circulate around the room, going over each pair’s progress and discussing ideas. The teacher also frequently regroups the class to discuss findings, questions, and issues that arise during the project.

Finally, WISE modules are usually designed to take approximately one week of class time and are meant to be integrated into the existing science class curriculum.

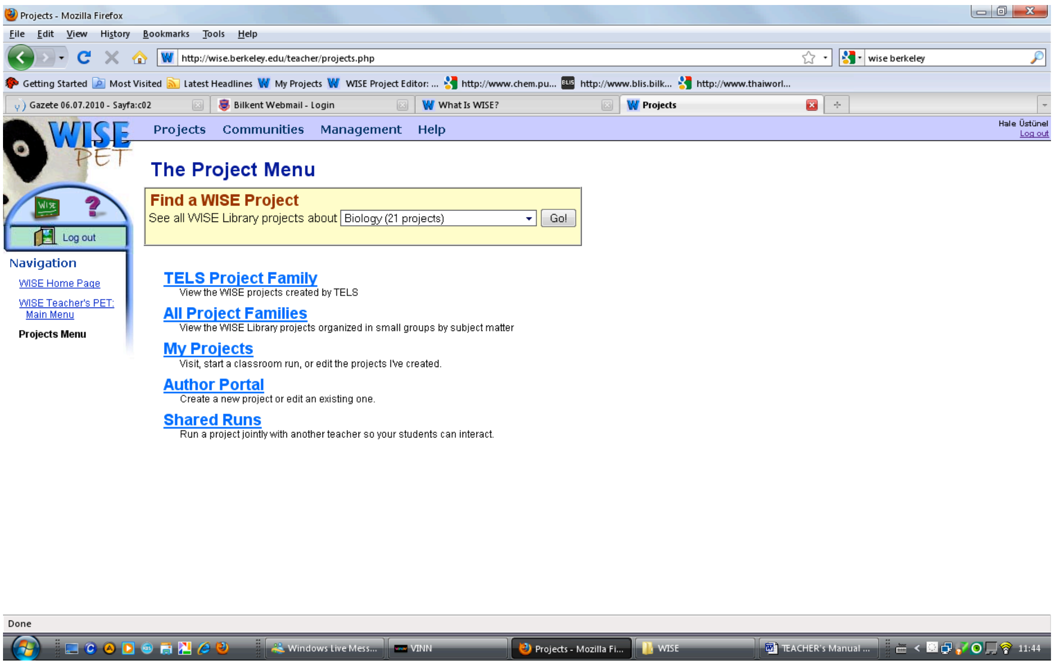
PART 3: WISE and TELS

Technology enhanced learning in Science (TELS) center is a National Science Foundation funded consortium of 7 universities, a non-profit educational organization, and several school districts around the country.
TELS creates science curriculum modules that are based on the WISE platform. TELS curricula fulfill local and national standards for middle school or high school science classrooms.

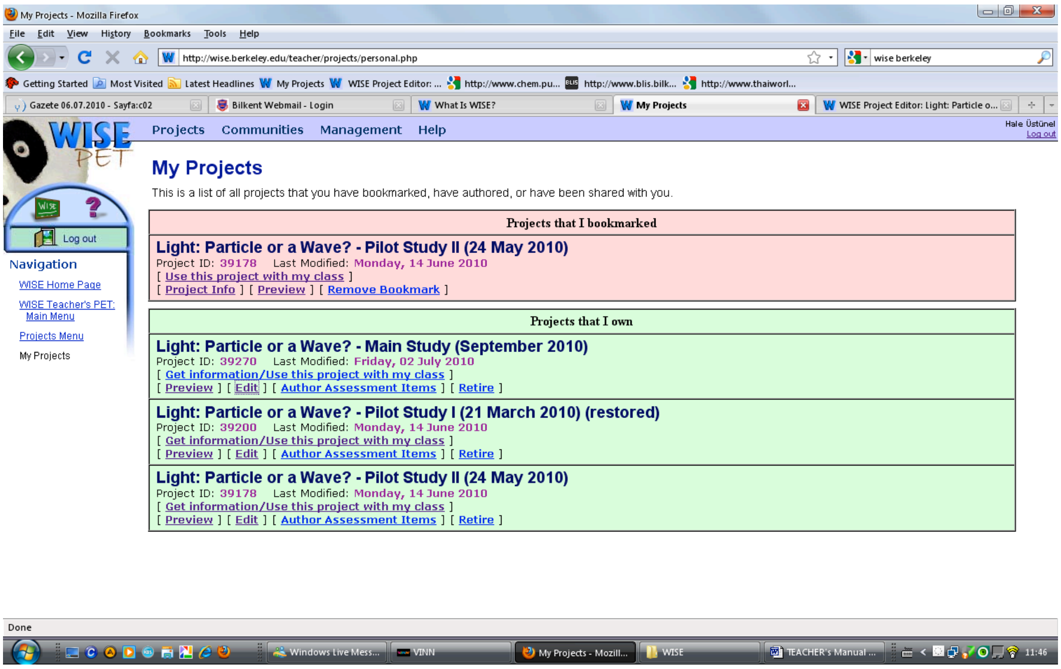
PART 4: The Teacher's Role in WISE

The teacher's primary role in any WISE module is to facilitate. Teachers should play an active role throughout the project, occasionally bringing the class together for discussions and also circulating around the room, interacting with small groups of students.

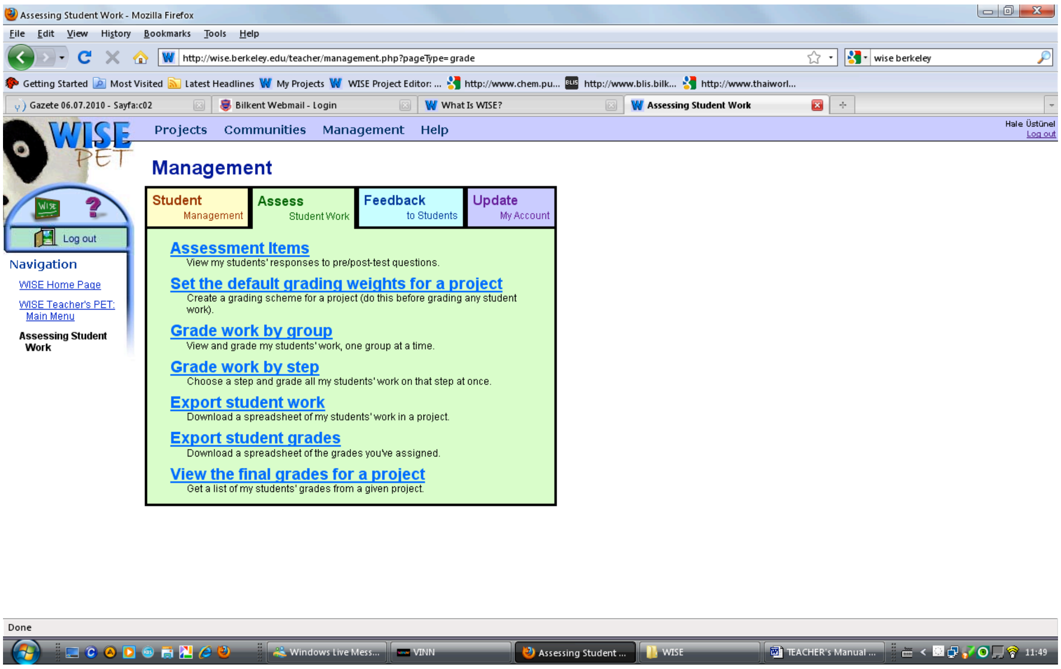
The teacher's PET (Portal and Educator's Toolbox) helps teachers successfully use WISE modules in their classroom.
Features include the *Project Library,*



Project Editor (where you can customize existing projects and even create new ones),



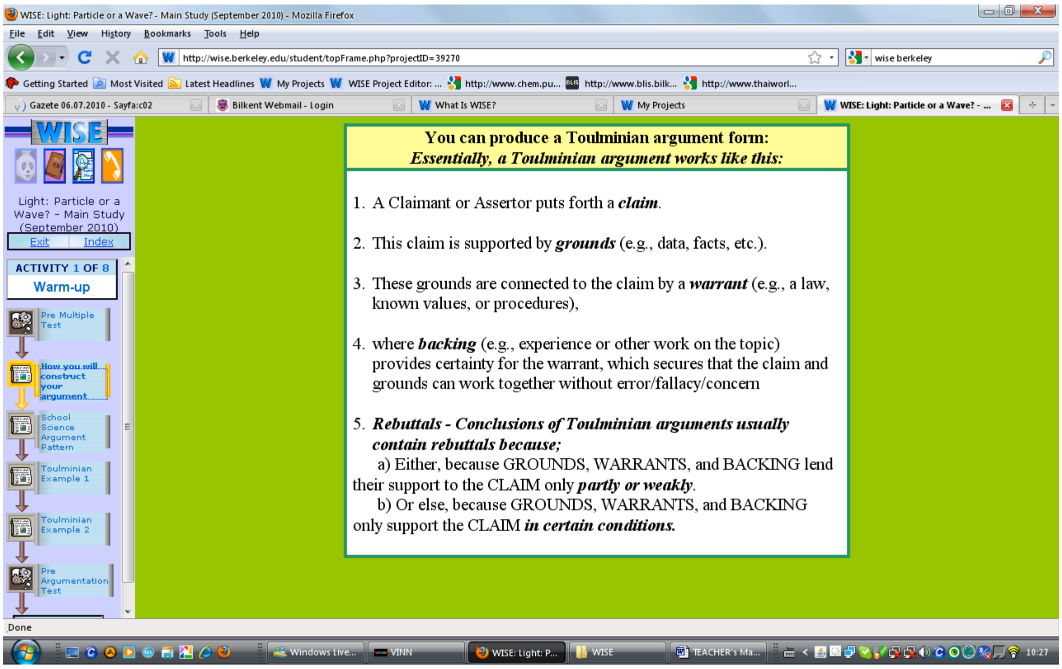
Management Tools (where you can view and assess student work and provide feedback), and online supports.



PART 5: The WISE Inquiry Environment

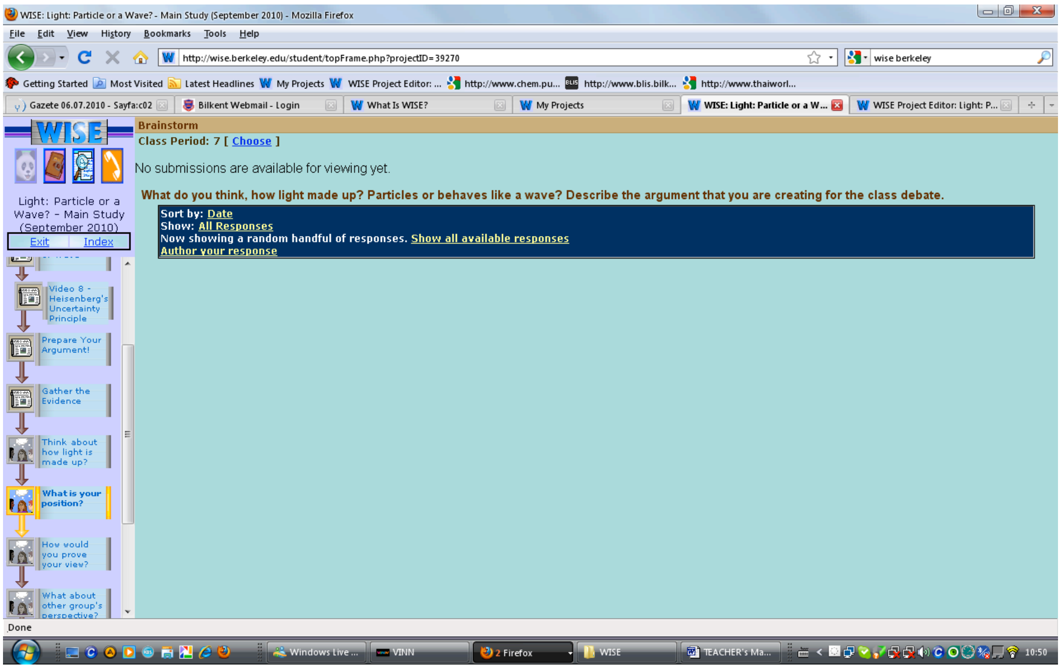
Tels modules are designed to support students as they explore current science controversies and design solutions to scientific problems. Tels modules take advantage of current web resources, data visualization and modeling tools and other features that support students' process of inquiry, including reflection notes and online discussion with classmates. WISE/Tels modules are divided into activities and steps;

The inquiry map scaffolds students' learning and guides their understanding.

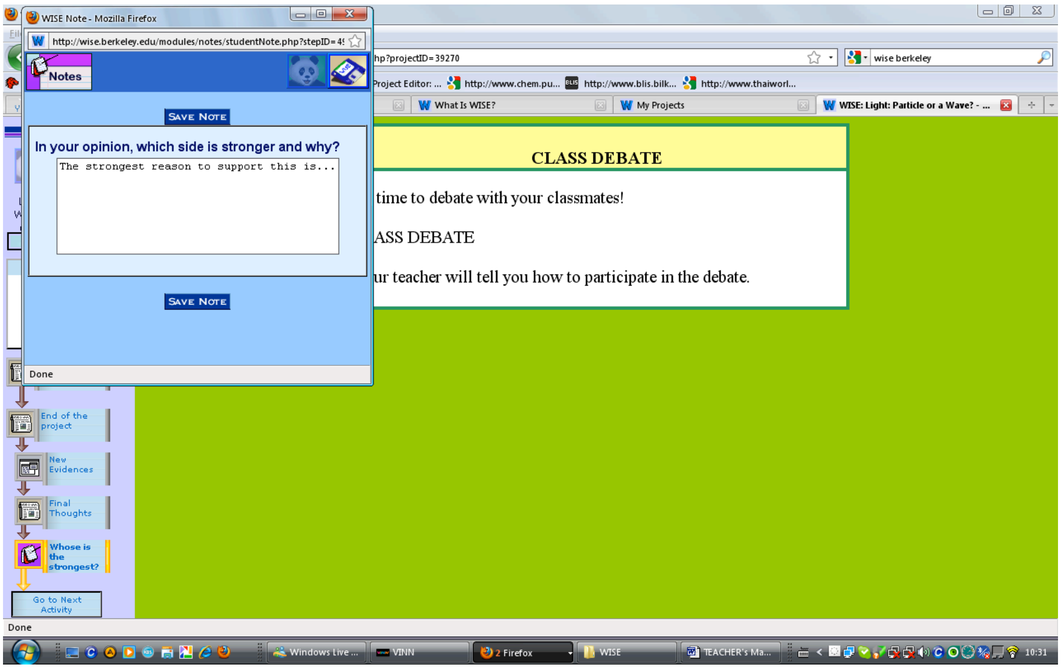


Display page shows a simple page of text especially to present curricular content – a page of information or a link to another site.

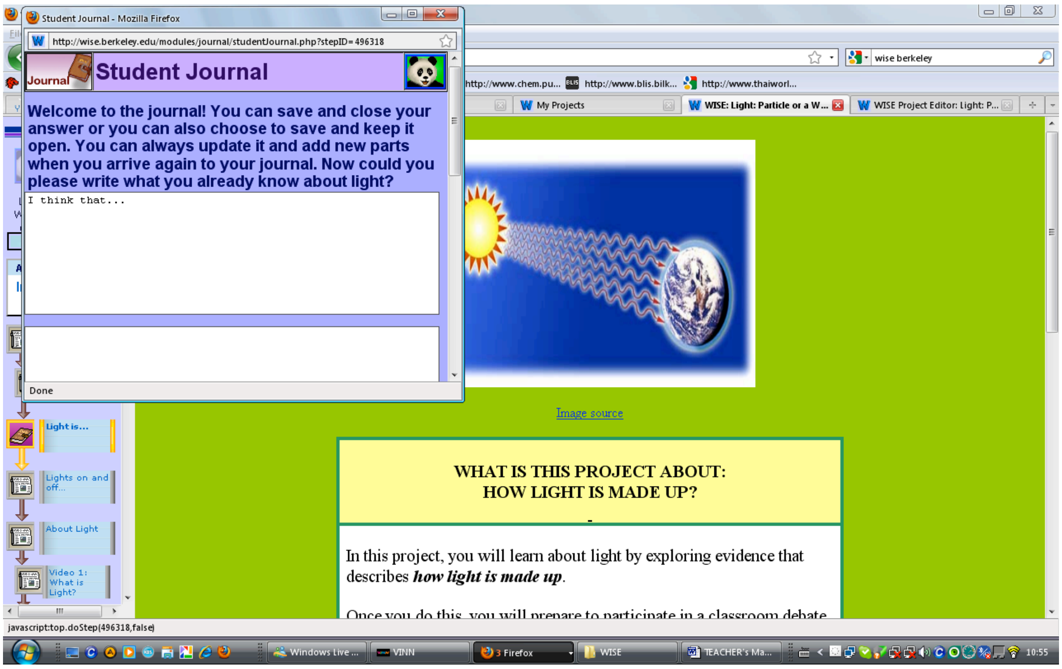
In a *brainstorm step*, students submit their answers to a question, and then rate each other's answers.



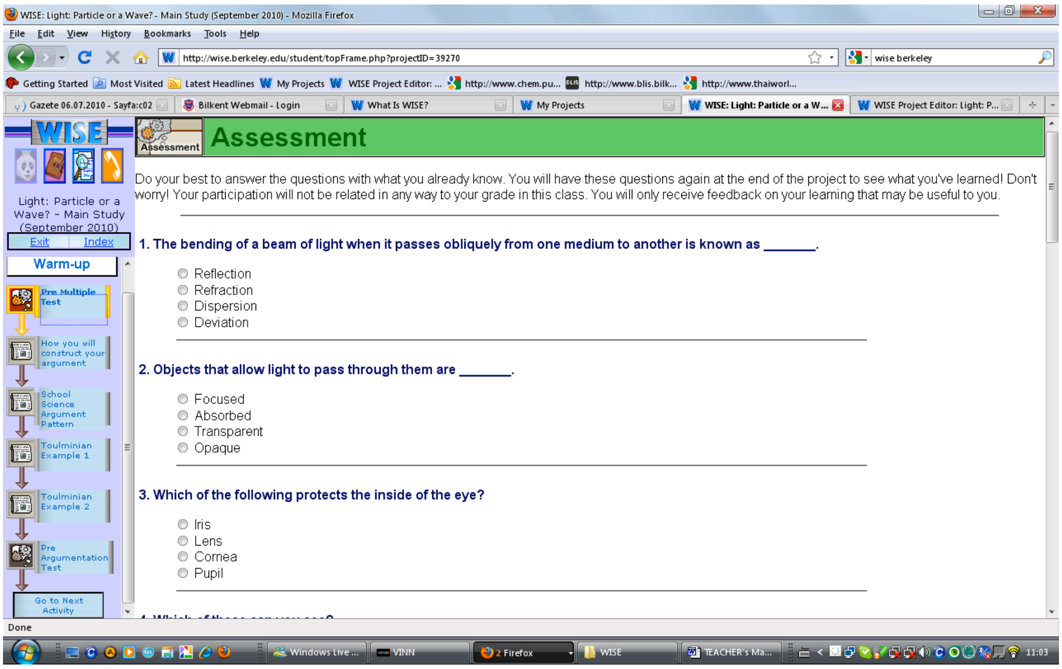
Notes allow students to reflect on what they have learned, integrate their ideas, and form predictions based on this integration.



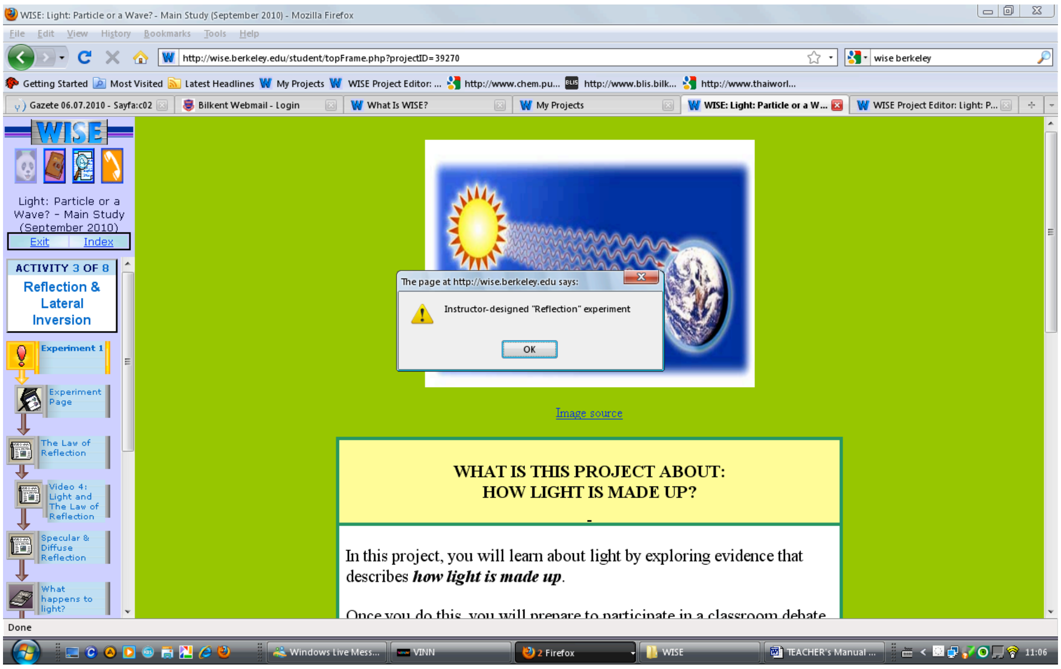
Student Journal is a persistent journal in which students revisit the same text and edit it on over time in response to evidence and new ideas. Can save stage-by-stage to show how the ideas over time.



In *Student Assessment,* students visit a short test of multiple choice and essay questions. Students cannot change their answers after they submit them.

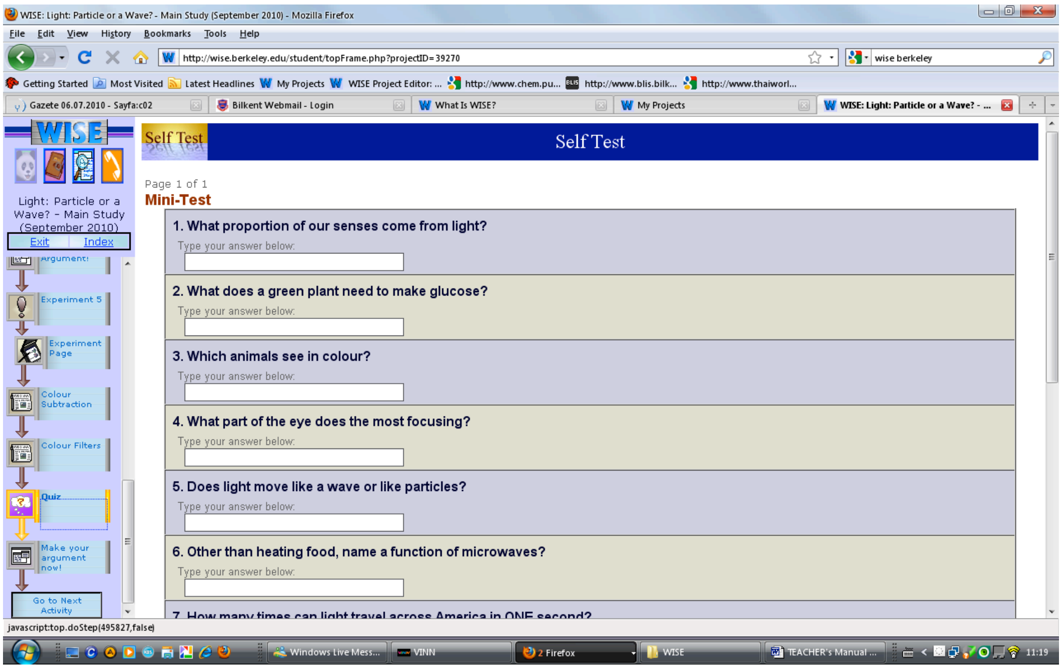


Show Alert is an alert box with a short message.

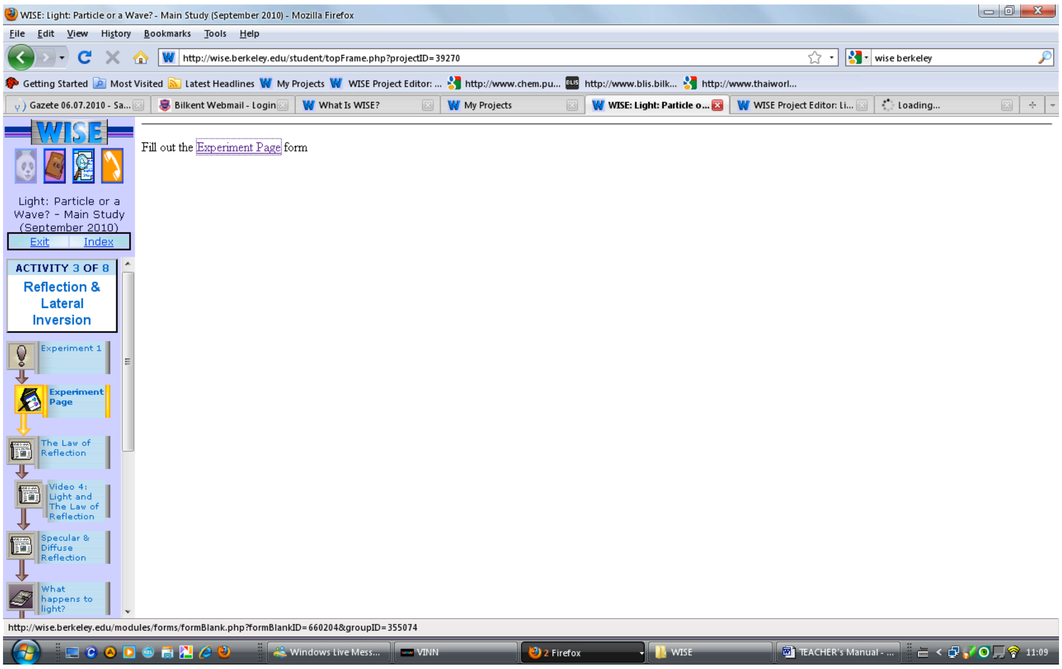


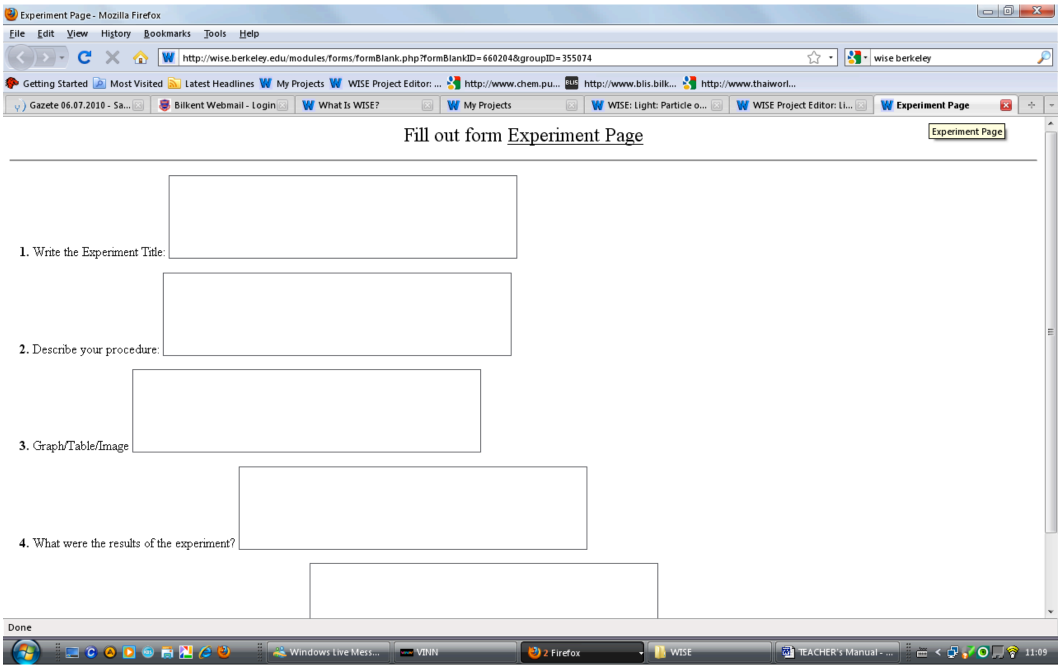
Challenge Question checks students' understanding a previous evidence item.

In *Self Test,* students take a short test and get immediate feedback about whether their answers were correct, plus additional explanation of the correct answer. Student work is not saved.

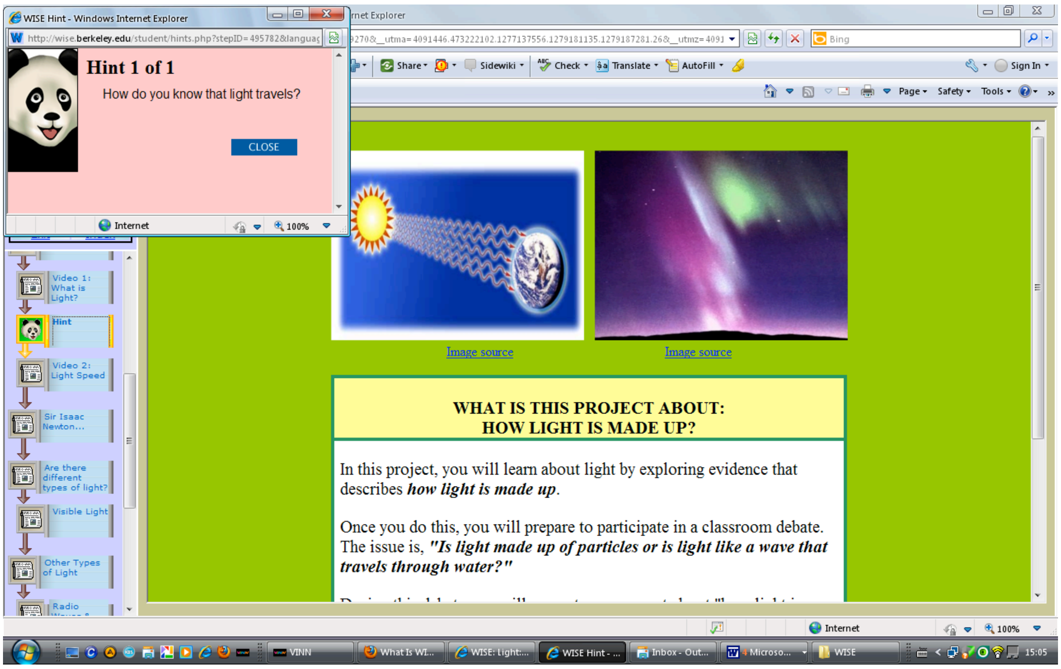


Form Blank is author's blank form to create a page for students to submit their answers.





Hints help to focus students' inquiry and probe for connections.



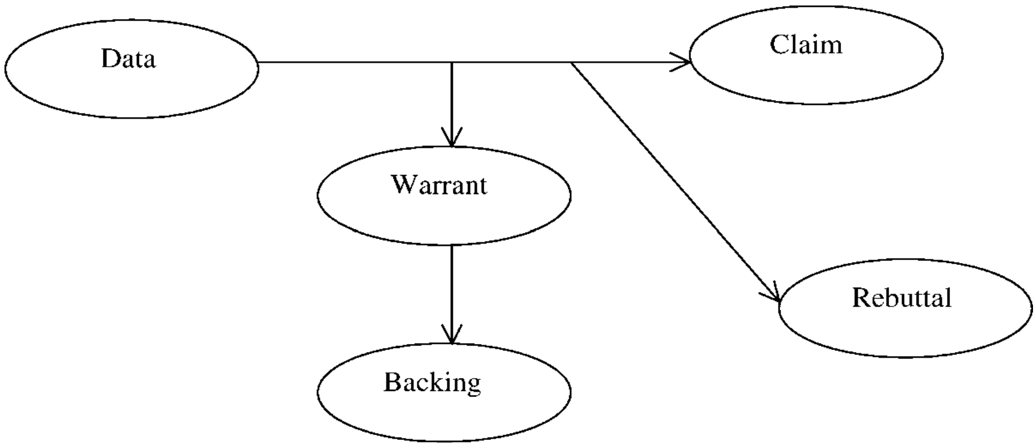
Research title

"Supporting Students' Learning and Scientific Argumentation in Technology-Enhanced Learning Environments: Distribution of Scaffolds"

Literature showed that students face a number of difficulties in constructing cogent and high-level arguments in schools (Cerbin, 1988). Students tend to use a single evidence rather than a set, provide claims instead evidence-based explanations or they ignore or distort evidence to support their claim (Choe & Jonassen, 2002). Scaffolding with computer-based tools is a way to support students to construct higher level arguments (Choe & Jonassen, 2002).

Student discourse in science have relied either on the application of analytical forms of arguments (Kuhn, 1993) or Toulmin's model for practical arguments (cited in Duschl, 2008)

Toulmin's argument pattern (Toulmin, 1958)



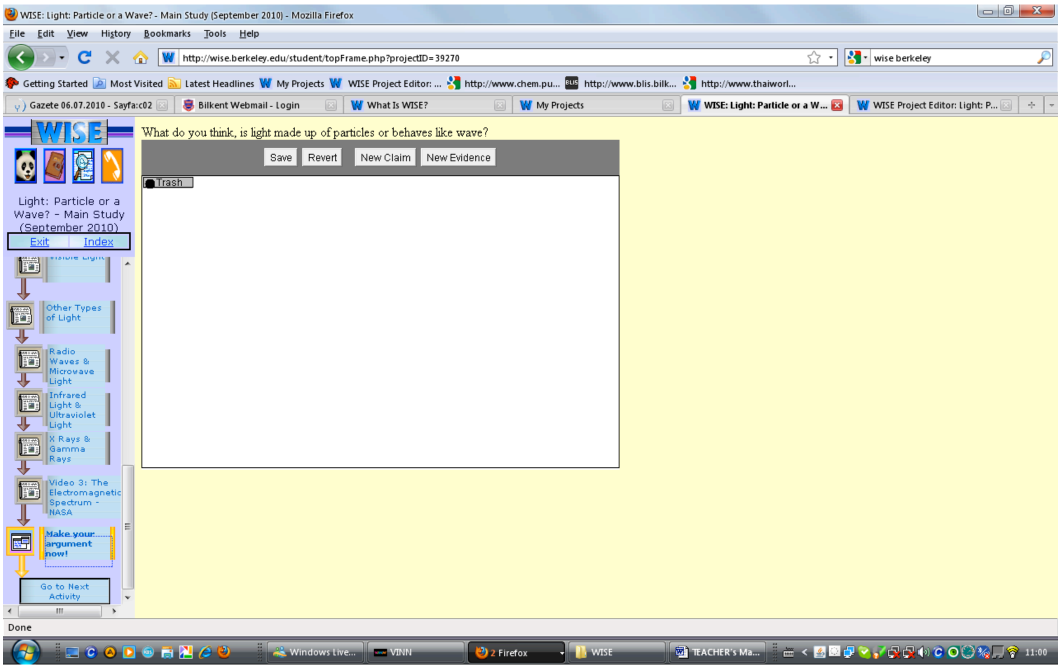
Significance of the study

To demonstrate that the scaffolds embedded in a technology-enhanced learning environment will elicit student argument construction, which offers evidence for knowledge integration. So Students using WISE learning environment will construct arguments that will include evidence and conceptual ideas.

To demonstrate how software scaffolds and teacher scaffolds interact and contribute to learning and argumentation of students.

The role of teacher is important in helping students developing an understanding of scientific argumentation. Some recommendations for encouraging students' use of evidence to support their claims can be "How do you know?" "What is your evidence for..?" and "What reasons do you have..?"

In *SenseMaker,* students organize sets of evidence by dragging elements into frames thus showing which arguments the evidence supports or refutes.


WISE: Light: Particle or a Wave? - Main Study (September 2010) - Mozilla Firefox
http://wise.berkeley.edu/student/topFrame.php?projectID=39270
Light: Particle or a Wave? - Main Study (September 2010)
Exit
Index
Other Types of Light
Radio Waves & Microwave Light
Infrared Light & Ultraviolet Light
X Rays & Gamma Rays
Video 3: The Electromagnetic Spectrum - NASA
Make your argument now!
Go to Next Activity
What do you think, is light made up of particles or behaves like wave?
Save
Revert
New Claim
New Evidence
Trash

THANK YOU

APPENDIX I. CONSENT FORMS

PARENT CONSENT LETTER

Dear Parent,

As a PhD student in Middle East Technical University – The Computer Education and Instructional Technology Department I am conducting a study titled "Supporting Students' Scientific Argumentation In Technology-Enhanced Learning Environments: Distribution Of Scaffolds". The aim of my study is to analyze the effect of technology-based scaffolds in the Web-based Inquiry Science Education (WISE) on Grade 6 students' scientific argumentation. In order to fulfill this purpose, I invite your children to participate in the study and fill in some questionnaires.

With your permission, your child will fill in the questionnaire during class hours at school. Please be ensured that the questions answered by your child are not going to negatively affect your child's psychological state/development. Your child's responses will be kept completely confidential and they will be used for only scientific purposes. After you have signed this form, your child has the right to discontinue participation at any time. The summary of research results will be made available through your school.

The information that your child will provide through his/her responses will be expected to make significant contributions to the determination of the effect of technology-based scaffolds in the Web-based Inquiry Science Education (WISE) on students' scientific argumentation. You may ask questions about the study via the following e-mail and address.

Best regards,

Hale Havva Üstünel
Tel: (0532) 445 0557
e-mail: e050310@metu.edu.tr

Please indicate your choice concerning participation in this study by responding to one of the following two options.

A) I permit my child__________________to be a participant. I am aware that my child can quit participation at any time, and I give my consent for the use of the information for scientific purposes.
Name-Surname of Father:................ Name-Surname of Mother:.....................
Signature:.. Signature:...

B) I don't want my child____________________to be a participant.

Name-Surname of Father:................ Name-Surname of
Mother:.....................
Signature:... Signature:...

INFORMED CONSENT FORM

This study will be conducted by Hale Havva Üstünel, PhD student in METU. The aim of the study is to collect data about the effect of technology-based scaffolds in the Web-based Inquiry Science Education (WISE) on 41 Grade 6 students' learning and scientific argumentation from Bilkent International & Laboratory School (BLIS), Ankara. Participation in the study must be on a voluntary basis and participants are free to withdraw at any time. No personal identification information is required in tests. Your answers will be kept strictly confidential and evaluated only by the researcher; the obtained data will be used for scientific purposes.

The study does not contain questions that may cause discomfort in the participants. However, during participation, for any reason, if you feel uncomfortable, you are free to quit at any time. In such a case, it will be sufficient to tell the person conducting the study that you have not completed the study.

After all the answers are collected back by the data collector, your questions related to the study will be answered. We would like to thank you in advance for your participation in this study. For further information about the study, you can contact Hale Havva Üstünel GSM: 0532 445 0557; E-mail: e050310@metu.edu.tr.

I am participating in this study totally on my own will and am aware that I can quit participating at any time I want/ I give my consent for the use of the information I provide for scientific purposes. (Please return this form to the data collector after you have filled it in and signed it).

Name Surname	Date	Signature	Course Taken
	----/----/-----		

DEBRIEFING FORM

This study will be conducted by Hale Havva Üstünel, PhD student in METU. The aim of the study is to collect data about the effect of technology-based scaffolds in the Web-based Inquiry Science Education (WISE) on 41 Grade 6 students' scientific argumentation from Bilkent International & Laboratory School (BLIS), Ankara.

Argumentation is an important skill in everyday life since people are usually faced with situations in which they have to decide on which action to take based on evidence after evaluating several scenarios (Evagorou & Avraamidou, 2008; Kuhn, 1991). However literature showed that students face a number of difficulties in constructing cogent arguments in school (Cerbin, 1988). Technology-based argumentation constructing tools have the potential to help students move towards more coherent and cohesive explanations (Linn, 2003). This study is designed to analyze the effect of technology-based scaffolds in the Web-based Inquiry Science Education (WISE) on 41 middle school students' scientific argumentation. Moreover the distribution of scaffolds between the teacher and the technology will be analyzed to understand how they complement each other in technology-enhanced environment and the design framework for argumentation-driven technology-enhanced learning environments will be developed.

It is aimed that the data from this study will be obtained during spring semester of 2011 and will be used only for research purposes. For further information, about the study and its results, you can refer to the following name. I would like to thank you for participating in this study.

Hale Havva Üstünel
GSM: 0 532 445 0557
E-mail: e050310@metu.edu.tr.

APPENDIX J. PERMISSION OF ETHICAL COMMITTEE

1956

Orta Doğu Teknik Üniversitesi
Middle East Technical University

Fen Bilimleri Enstitüsü
Graduate School of
Natural and Applied Sciences

[illegible] Ankara, Türkiye
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Fax: +90 (312) 2107656
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Sayı: B.30.2.ODT.0.AH.00.00/126/ 69 - 665

28 Ocak 2011

Gönderilen: Yrd. Doç. Dr. Saniye Tuğba Bulu
Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü

Gönderen : Prof. Dr. Canan Özgen
IAK Başkan Yardımcısı

İlgi : Etik Onayı

" Supporting Students Learning and Scientific Argumentation in Technology Enhanced Learning Environments: Distribution of Scaffolds " isimli araştırmanız "İnsan Araştırmaları Komitesi" tarafından uygun görülerek gerekli onay verilmiştir.

Bilgilerinize saygılarımla sunarım.

Etik Komite Onayı

Uygundur

28/01/2011

Prof.Dr. Canan ÖZGEN
Uygulamalı Etik Araştırma Merkezi
(UEAM) Başkanı
ODTÜ 06531 ANKARA

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Üstünel, Hale Havva
Nationality: Turkish (TC)
Date and Place of Birth: 6 July 1968, Manisa
Marital Status: Married
Phone: +90 532 445 05 57
Email: ustunel@bilkent.edu.tr

EDUCATION

Degree	Institution	Year of Graduation
MBA	The University of Leeds / UK	1995
BS	METU Statistics	1992
High School	Tevfik Fikret High School	1986

FOREIGN LANGUAGES

Good Level of English, French and Italian

WORK EXPERIENCE

Year	Place	Enrollment
2000-Present	Bilkent University	Instructor
1997-1999	Mednet	Finance Officer
1997-1998	Marmara University	Lecturer
1993-1994	Ministry of Health	Assistant

HOBBIES

Tennis, Cooking, Movies, Books