COMPARING THE EFFECT OF DYNAMIC AND STATIC VISUALIZATIONS ON EIGHTH GRADE STUDENTS' UNDERSTANDING OF PLATE TECTONICS AND EARTHQUAKE CONCEPTS

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Thesis Abstract

Ali Söken, "Comparing the Effect of Dynamic and Static Visualizations on Eighth Grade Students' Understanding of Plate Tectonics and Earthquake Concepts"

The purpose of this study is to investigate whether static or dynamic visualizations are more effective on students' understanding. It compares instruction with static visualizations and instruction with dynamic visualizations which is designed to help teach plate tectonics and earthquake concepts to 8^{th} grade students. A quasi-experimental design is implemented to 42 eighth grade students (control n=22, experimental n=20) in a public primary school in İstanbul. The experimental group received instruction with dynamic animations (animations) while the control group studied the same material with static pictures of the same animations. Student learning was investigated by the quantitative analysis of test measuring conceptual understanding and qualitative analysis of the classroom discourse. Wilcoxon Signed Ranks Test analysis shows that there is a statistical significance between pretest and posttest scores of the students in control and the experimental group. However, Mann-Whitney U Test result shows that there is no difference between the different types of visualizations with respect to students learning. Although there is no significant difference between two groups, qualitative analysis reveals that students in experimental group are more participant and ask more and complex questions during the classroom conversations.

Tez Özeti

Ali Söken, “8. Sınıf Öğrencilerinin Plaka Tektoniği Ve Deprem Kavramlarının Anlamalarında Kullanılan Sabit Görsellerin Ve Animasyonların Karşılaştırılması”

Bu çalışmanın amacı sabit ya da dinamik görsellerden hangisinin öğrencilerin anlamalarında daha etkili olduğunu araştırmaktır. Bu nedenle sekizinci sınıf öğrencilerinin plaka tektoniği ve deprem kavramlarını öğrenmelerine yardımcı olacak tasarıma sahip statik görseller içeren öğretim ile dinamik görseller içeren öğretim karşılaştırılmıştır. Bu yarı deneysel çalışma İstanbul’daki bir devlet okulunda 42 8. Sınıf öğrencisi (22 kişi kontrol, 20 kişi deney grubunda olmak üzere) ile gerçekleştirilmiştir. Deney grubundaki öğrenciler dinamik görseller(animasyonlar) içeren öğretimle görürken, kontrol grubunda öğrenciler konuyu bu animasyonların ekran görüntülerinden çalışmıştır. Bu çalışmada öğrenme kavramsal anlama testinin nicel analizinin ve öğrencilerin söylemlerinin nitel analizi ölçülmesiyle araştırılmıştır. Wilcoxon Signed Ranks test analizi kontrol ve deney grubundaki çocukların ön test ve son testleri arasında istatistiksel olarak anlamlı bir farklılık olduğunu göstermiştir. Ancak Mann-Whitney U test sonucu öğrencilerin konuyu kavraması bakımından farklı türdeki görseller arasında herhangi bir farklılık olmadığını göstermiştir. İki grupta yer alan öğrencilerin test sonuçlarında anlamlı bir farklılık olmamasına rağmen, analizler deney grubundaki çocukların derse daha fazla katıldığını ve sınıf içi tartışmalarsa daha kompleks ve daha çok soru sorduğunu göstermiştir.

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CONTENT

TABLES

FIGURES

CHAPTER 1

INTRODUCTION

Background of the Study

Current reform movements in some countries set scientific literacy as the main aim of the science education (Jenkins, 1997; Roberts, 2007). Scientific literacy defined:

> The knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity.” (NRC, 1996, p. 22).

Standards for Science Teacher Preparation (NSTA, 2003) a national document of USA stated that inquiry-based science teaching is the best method to create scientifically literate students. In an inquiry-based learning environment, learners can conduct scientific investigations, pose questions, collect and analyze data, evaluate evidence and come up with scientific explanations to ill-defined problems (NRC, 1996). According to the underlying rationale, the main target of inquiry-based science education is to provide an opportunity for learners to act as a scientist who has an integrated understanding of scientific concepts and process (Edelson, Gordin, & Pea, 1999). When students participated in a scientific inquiry, they can learn scientific concepts in a relevant problem context. Meaningful learning theory claims that prior knowledge is a key factor for learning because learners integrate new information into their existing schema intentionally (Novak, 2002). Numerous studies point out students has many alternative conceptions and they are incompatible with scientific facts and principles (Driver, 1989; Gilbert, Osborne, & Fensham, 1982; Vosniadou, 1991). Thus, students' ideas need to be taken into account in the learning process and those alternative conceptions should have been changed. In this perspective, Conceptual Change Model [CCM] (Posner, Strike, Hewson, & Gertzog, 1982) proposes a framework to deal with students existing misconceptions. CCM creates dissatisfaction with the existing conceptions first, then it becomes an opportunity for learners and finally it gives an idea to embrace a new and fruitful explanation. In that respect, it is possible to argue that learners are able to realize limitations of their existing ideas and alter those with scientific conceptions in an inquiry-based learning environment. 5E learning cycle model which supports conceptual change (Bybee, Taylor, Gardner, Van Scotter, Carlson,Westbrook, & Landes, 2006) provides a framework for learners to experience a scientific inquiry process (Wilson, Taylor, Kowalski, & Carlson, 2010).

Inquiry-based education is completely different from traditional science education because students search for evidence to find an answer to real life problems (Crawford, 1999). Mainly, students and teachers have new roles in this teaching paradigm. While students are active participants to conduct a scientific inquiry, teachers play a facilitator role to support learning process. However, inquiry-based learning is not magical and brings several challenges for both teachers and students into classroom setting such as teachers' new demanding role (Harris, & Rooks, 2010) and cognitive endeavor for students (Blumenfeld, Kempler, & Krajcik, 2006).

Technology can be used as a scaffold to address those challenges because it has three basic benefits to promote implementation of inquiry-based science into classroom (Edelson, 2001). Technology can enable collecting and retrieving data, presenting them in different formats to support inquiry process. Science education literature has some promising technological software tools to promote inquiry-based instruction as well. For example, Global Learning Observations to Benefit the Environment (GLOBE) supports students' understanding of environmental issues (Finarelli, 1998) and Geology Explorer provides an authentic learning environment for learners (McClean, Saini-Eidukat, Schwert, Slator, & White, 2001). Such research based technology environments create a plausible platform for learners to engage in scientific investigation by allowing learners to pose questions, collect data, analyze them and draw conclusions through embedded scaffolding features.

In this study, investigating effectiveness of technology support for learning plate tectonics and earthquakes have been chosen because learning of these topics relies heavily on visual representations. As a unique discipline (King, 2008a) geology is different from other scientific fields such as physics and chemistry. It is mainly defined as a visual and geometric science (Dott, 1998; Piburn et al., 2002; Reynolds et al., 2005). Because of these unique attributes, geology education requires utilization of visual diagrams and multimedia representations. In addition, since geological structures are not immediately visible and processes take place in large timeframes and spaces (formation of a volcanoe etc.), such disciplinary nature increase the necessity of visual representations (Reynolds, et al., 2005). Consequently, well-designed visual materials can help learners to understand complex concepts and processes (Cook, 2006; Roschelle, Pea, Hoadley, Gordin, & Means, 2000). Although visual materials have a great potential they deserve to be designed in accordance with some basic theoretical framework for being effective.

Purpose of the Study

Visualizations can be categorized under three groups: static, dynamic and interactive visualizations (Libarkin & Brick, 2002). Science literature has many studies to investigate which types of visualizations are better to promote learning (Höffler & Leutner, 2007). While many studies indicate that animations are superior to static pictures (Ryoo & Linn, 2012; Yarden & Yarden, 2010) other studies claim the contrary (Mayer, Hegarty, Mayer, & Campbell, 2005; Pane, Corbett, & John, 1996; Schnotz & Grzondziel, 1999; Tversky et al., 2002).

Ryoo and Linn (2012) state that we need new experimental studies to investigate which type of visualizations is better to promote learning. That is why; a mixed-method study is proposed to compare the effect of static (pictures) and dynamic visualizations (animations) in learning geological concepts and processes. In order to achieve this aim, 8^{th} class Science and Technology unit which is named “Natural Processes” will be taught through inquiry oriented instruction by involving static visuals and dynamic visuals. The aim of this study is to compare the effectiveness of dynamic and static representations in learning concepts of plate tectonics and earthquakes.

Research Questions

In order to examine the role of dynamic and static visualizations in science learning, following research question will be addressed:

- Is there a statistically significant difference between the conceptual understanding level of the 8th grade students who received instruction with dynamic visualizations and who received instruction with static animations?
- Are there any differences between the cognitive and discursive engagement level of the 8th grade students who receive instruction with dynamic visualizations compared to receiving instruction with static animations?

Significance of the Study

Due to the aim of comparing the noted two groups, dynamic and static visualizations have implemented in this study. It is important because instead of choosing only dynamic visualization, other important concerns must be taken into account (Hegarty, 2004). First, Tversky et al. (2002) argue that dynamic visualizations may involve additional information compared to static ones and if they have equal amount of information static pictures would be more powerful. Therefore, one important concern is that to while investigating the role of dynamic visualizations, static visualizations should involve the same amount of information as dynamic visualizations. Second, dynamic visualizations might be deceptively clear (Ryoo & Linn, 2012; Zhang & Linn, 2011). The term "deceptive clarity" implies that when the learner views an animation, she/he may just focus on surface details without understanding core concepts and underlying rationale. In this study, both of these problems are addressed through teacher explanations of visualizations. The study aims to imply that students are exposed to equal amount of information and core concepts through dynamic and static media. Third, cognitive load is the latest concern in learning from visualizations. By interacting with dynamic visualizations, students may cognitively overload (Zhang & Linn, 2011) because those may create extra load for learners (Ayres & Paas, 2007; van Gog, Paas, Marcus, Ayres & Sweller, 2009). The students' mental resources need to be considered in designing dynamic visualizations and specific strategies ought to be used during the instruction. Equal cognitive load concern has also been considered through focused, simple design of dynamic visuals. They require similar cognitive demands from the students as static visuals would.

Considering all these issues discussed above, it is still not clear what type of visualizations are more beneficial in learning scientific phenomena (Tversky et al. 2002; Schnotz & Rasch, 2005). In order to investigate the effectiveness of dynamic visualizations under specific circumstances, new experimental studies have been suggesting in the literature (Ryoo & Linn, 2012). This study aims to shed light on this disputable issue in the literature.

CHAPTER 2

LITERATURE REVIEW

Theoretical Framework

Current reform movements in education set scientific literacy as the main target of the science education (Jenkins, 1997; DeBoer, 2000; Roberts, 2007). For example, USA, Canada, England and Turkey described scientific literacy as a goal by sustaining reform movements (CMEC, 1997; MEB, 2005; Millar & Osborne, 1998; NRC, 1996). Although reform documents attempted to define scientific literacy, many researchers argue that it is a wide-ranging goal for public understanding of science (DeBoer, 2000; Norris & Phillips, 2003).

Science for All Americans (American Association for the Advancement of Science [AAAS], 1989) is a critical reform document providing guidelines to reach the aim of scientific literacy for every student (DeBoer, 2000). Another reform document in the Canadian context; The Common Framework of Science Learning Outcomes (CMEC, 1997) define the vision of the science education as "*the framework is guided by the vision that all Canadian students, regardless of gender or cultural background, will have an opportunity to develop scientific literacy."* (p. 4). Similar to the science for all Americans slogan, "all Canadian" sample indicates that there is no priority to anyone in the society to learn science. "Beyond 2000: Science Education for the Future" in the British context was another leading report that has been describing the aim of the science education as improving scientific literacy for all students from different backgrounds (Millar & Osborne, 1998). Similar to definitions of scientific literacy in the US and Canadian contexts, British report has an emphasis on creating population that appreciate science and use scientific knowledge on decision-making processes about daily life.

In reference to the global science education reform movements, Turkey also reviewed its science education policy in many perspectives. The main goals of the curriculum reform are defined by Board of Education and Discipline (2005) as following:

- Reducing the amount of content and number of concepts
- Arranging the units thematically
- Developing nine core competencies across the curriculum
- Moving from a teacher-centered didactic model to a student-centered constructivist model
- Incorporating ICT into instruction
- Monitoring student progress through formative assessment
- Moving away from traditional assessment of recall, and introduce authentic assessment
- Enhancing citizenship education
- Introducing second language courses from primary school
- Widening the scope of religious education and
- Establishing a system of student representation, and engaging students with the concept of the community work

New Turkish science curriculum, which has altered the role of teachers and students, curriculum design and teaching strategies, has been defining its goal as "*creating scientifically literate people no matter what their individual or cultural differences are*" (MEB, 2005).

It can be argued that reform movements have an impact on teaching strategies in the science learning. In this new paradigm, teachers are advised to use inquiry in the classroom setting (NRC, 1996; NSTA, 2000). For example, the *Standards for Science Teacher Preparation* (NSTA 2003) propose that inquiry-based science teaching is a plausible way to reaching the goal of the scientific literacy.

In an inquiry-based science classroom, students are active participants of a scientific work and acting as a scientist. In other words, students not only learn scientific concepts but also to manage their scientific investigations, and develop an understanding of the professional science (NRC, 2000). Thus, effective implementation of this strategy in classroom setting may have some guidelines and assumptions. Therefore, there should be premises and theoretical arguments for proper instructional approach. Meaningful learning, cognitive apprenticeship approach, and 5E instructional model are important cornerstones in teaching and learning science through the inquiry in the classroom.

In reference to the meaningful learning theory, Ausubel (1963) classifies two types of learning: rote learning based on memorization and meaningful learning where learner adds new knowledge in his or her existing schema consciously (Novak, 2002). According to the meaningful learning theory, prior knowledge of the learners has to be considered carefully in designing instruction because they play a major role in learning. The conceptual sequence of the presented material is another important aspect because it supports learner to construct knowledge piece by piece in an integrated manner. Using of advance organizers (concept maps, Venn diagrams etc) is noteworthy in assisting this process because it represents the disciplinary knowledge structure for the learners (Ausubel, 1960; Novak & Cañas, 2006,). As a conclusion, it can be claimed that meaningful learning is at the core of learning science through the inquiry, meaningful learning theory provides opportunity for learners to actively construct new information into his or her current knowledge.

Scaffolding has been defined firstly as the assistance provided by an adult or a knowledgeable peer for the success of the learner in a task which is not reachable without support (Wood, Bruner, & Ross, 1976). Scaffolding metaphor closely related with Vygotsky's term "zone of proximal development" (ZPD). The zone is an area between learner's capability and target place which could not be reached without any assistance (Vygotsky, 1978). Scaffolding is an interaction between the knowledgeable person and the learner to facilitate learning process. Scaffolding is closely related with cognitive apprenticeship which signifies the learners' process of participation in the practices of a discipline. Through process of cognitive apprenticeship, learners gradually become successful problem-solvers with the considerable support (Quintana, Reiser, Davis, Krajcik, Fretz, & Duncan, 2004).

Situated learning is a theory puts an emphasis on the context, authenticity and culture in learning processes (Brown, Collins, & Duguid, 1989). This theoretical perspective argues that novice learners observe members of the community in real environment and tries to internalize the new role for him or herself. Accordingly, situated learning requires active participation in an authentic activity and distinguishes from learning by doing because the tasks are embedded in the context (Dennen, 2002).

When considering meaningful learning theory and situated cognition together those overlapping premises can support scientific inquiry for learners. Scientific inquiry is a process that fosters meaningful learning by using students' existing ideas. However, learners need assistance not only for students' alternative conceptions but also the complexity of managing inquiry processes. Therefore, the instructional methods should take into account these premises to support scientific inquiry in learning setting.

Instructional Design

Instructional design in this study based on 5E cycle learning model and ARSC motivational design model. There are several learning models to implement inquiry-based teaching approach in the classroom setting. One of the most common models is BSCS (Biological Sciences Curriculum Study) 5E instructional model designed to enhance conceptual change (Bybee et al., 2006). BSCS entails five phases: engagement, exploration, explanation, elaboration and evaluation. The model creates a plausible opportunity for learners to participate in scientific inquiry process and provides guidance as well as enhances students' understanding (Wilson, Taylor, Kowalski, & Carlson, 2010). Bybee et al. (2006) argues that if curriculum materials aligned with 5E model students learn better.

Engagement, first phase of 5E model, aims to gain students' attention by activating prior knowledge about an object or a situation (Bybee et al., 2006). In this phase, teacher poses question to create conflicts and this makes the students engaged (see Table 1). When the students are cognitively engaged in learning tasks their motivation and interest would increase. After they mentally and physically involved in the process, the second step begins. In the exploration phase, second phase of the model, students can link the presented concepts, realize patterns in the data as well as describe parameters (Bybee et al., 2006). The role of teacher in this model is monitoring students and exploring the process. The most important thing is that teacher triggers the process and students have a chance to explore materials with their own ideas (Bybee et al., 2006).

Third E stands for explanation in the learning cycle. After exploring the concepts with their existing knowledge, students can create common explanations. Teacher directs students with the aim of creating more plausible and clear explanations (Bybee et al., 2006). The third step helps to find common terms with the guidance of teacher and students by using those explanations for new problems. Creating explanations are not the final step. Students should elaborate their explanations and be able to apply their findings to new cases. Group discussions are used generally to scaffold students' elaboration process. These discussions are designed to create interaction between students because of the complexity of the process students may need help (Bybee et al., 2006). Successful elaboration period enhances opportunities the way in which students can generalize concepts and processes with their explanations.

Table 1. 5E Cycle Learning Model (Bybee, 2006)

5E Phases	Teacher	Student
Engagement	Assess students' prior knowledge Poses questions Shows discrepancies in data Creates motivation and increases curiosity Classifies students' thinking	Raises a question Shows an interest Identifies problem and aims to solve it Makes connections with the existing knowledge
Exploration	Provides resources for the learners Models when it needs Gives feedback Asks questions and monitors the process Assesses students' understanding	Collects data Makes predictions based on the evidence Forms hypothesis Conducts investigations
Explanation	Evaluates students explanations Gives feedback Make generalizations Provides alternative explanations Evaluates explanations	Clarifies students' understanding Formulates explanations Seeks new explanations Reflects his or her own understanding
Elaboration	Asks questions Poses new problems Gives feedback Evaluates the students' understanding	Applies understanding to a new problem Makes decisions and solves problems Seeks further clarification
Evaluation	Assesses the students' understanding	Reflects his/her own understanding Evaluates his/her progress

The last step of the 5E model is evaluation. Similar to other learning strategies, evaluation is noteworthy to assess students' understanding. This process not only pushes students to assess their own understanding but also enables teachers to evaluate the progress of the students (Bybee et al., 2006).

Second underlying rationale in the instructional design of this study is ARCS motivational model whose steps are attention (A), relevance (R), confidence (C), and satisfaction (S) (Keller, 1999a; Keller, 1999b). According to this model, the first step aims to increase effectiveness of a lesson plan is gaining the attention of learners (Keller, 1999a; Keller, 1999b). In order to increase curiosity of learners, a story or a driving question can be utilized. In our design, we used driving question at the beginning of each lesson. Arousing curiosity is crucial but when the relevance is missed, content might be worthless to learn (Keller, 1999a; Keller, 1999b). Content and questions in a lesson should be meaningful for learner not only for meaning-making process but also creating the ownership of the scientific inquiry. Confidence is another important concern according to the ARCS model. In order to increase students' confidence objectives should be clear and achievements should be depicted (Keller, 1999a; Keller, 1999b). In this design, objectives are clear for the learner. In addition, hands-on activities can increase students' self-confidence. Even though all three steps are successfully implemented, the lesson may not motivate learner unless satisfaction is created. Keller (1999a, 1999b) describes satisfaction as the positive ideas of learners at the end of the learning unit. The lesson plans in this study contains learning activities that students can understand the complex concepts with interesting activities and well-designed visualizations.

Inquiry-Based Learning

The main goal of the inquiry-based learning is to aid students to develop an integrated understanding about scientific concepts and process as a scientist (Edelson et al., 1999). By participating in an inquiry-based activity which is open-ended and question-driven facilitates addressing three basic objectives: 1) developing general inquiry abilities, 2) acquiring context-specific investigation skills, and 3) comprehending scientific concepts in a meaningful context (Edelson et. al, 1999). For the sake of effectively representing the inquiry in science classes, NRC (2000) proposes five essential features in an inquiry-based science classroom as following:

- Learners are engaged by scientifically oriented **questions**
- Learners give priority to **evidence,** which allows them to develop and evaluate explanations that address scientifically oriented questions
- Learners formulate **explanations** from evidence to address scientifically oriented questions
- Learners **evaluate** their explanations in light of alternative explanations, particularly those reflecting scientific understanding
- Learners communicate and **justify** their proposed explanations

Asking questions is an initial point to conduct a scientific investigation because scientific processes start with questions. Next step is searching for the answer. Due to the fact that science is empirical-based (Abd-El-Khalick & Lederman, 2000); learners must collect evidence to find the solution. Thus, giving priority to the evidence is the second feature of the inquiry-based science instruction. The formulation of collected evidence is necessary to create coherent argument in an effort to find an answer for scientific questions which is being raised. The conclusion proposed by students should be checked through the scientific knowledge. Learners must revise the gained justification in accordance with common explanations in science. Scientists discuss their results, justify their findings, and come up with shared explanations. For this reason, as a part of scientific community, learners compare and contrast their conclusions to address scientific questions.

Inquiry can be examined as a continuum from structured to open in terms of provided guidance by the teacher for the process (Bell, Smetana, & Binns, 2005; Schwab, 1962). Inquiry creates a continuum from teacher-directed to student-oriented. For example, guided inquiry can be named under the condition that teacher defines the problem and students are responsible for the rest of the process. They develop strategies to find answers in a given problem. In this study, the guided inquiry perspective is utilized in design and implementation of instructional activities.

Challenges of Inquiry-Based Learning

The reform movement has changed the direction of science education from cookbook style verification activities to finding answers to ill-defined questions which ought to be explained with empirical evidence (Crawford, 1999). This new approach demands that teachers must have some certain skills to orchestrate the inquiry-based instruction. However, implementing inquiry-based instruction is not easy (Crawford, 1999) because it is challenging for students and teachers (Clark et al., 2003). It can be claimed that even if experienced teachers may have difficulty to implement the inquiry-based instruction in classroom setting (Krajcik et al., 1994). These challenges can be listed under two categories: challenges for teachers and students.

Harris and Rooks (2010) argue that inquiry-based learning changed the role of teacher and it might be challenging for teachers. These challenges can be listed as balancing guidance and independence, problems about technological tools, being unfamiliar with inquiry practices, scaffolding students’ engagement with tasks, sequencing learning unit as well as, assessment of students’ performance (Harris & Rooks, 2010). In addition, new role creates other obstacles where teachers have lack of action plan and inadequate curriculum materials (Breslyn & McGinnis, 2011). Another study also describes challenges for teachers while preparing a learning unit that entails the relationships between concepts with the help of driving ill-defined questions, supporting investigation processes of students is another challenge for teachers, creating a scientific community in classroom that students exchange their explanations and usage of technological tools to support inquiry process (Clark et al., 2003).

Similar to the teachers’ case, students also come face to face with new obstacles in this new paradigm. Inquiry is demanding for participation, ownership of the learning process, and cognitive endeavor (Blumenfeld et al., 2006). Edelson et al. (1999) list five challenges on implementing inquiry-based learning: (a) motivation, (b) accessibility of investigation techniques, (c) background knowledge, (d) management of extended activities, and (e) constraints of the learning context.

Motivation is pointed out as the first challenge that students may encounter. It is an outcome of the inquiry process promotes learning process (Edelson et al., 1999) and there is a positive correlation between the interest of students and their performance in science (Lee, 1989). In other words, when they have an interest on the subject, they can conduct their own scientific inquiry.

Students largely are not familiar with the investigation techniques in science. This unfamiliarity was determined as the second challenge of successful implementation of the scientific inquiry. They cannot handle investigations without necessary inquiry skills to come up with a conclusion (Edelson et al., 1999). Thus, conducting investigations is complicated for learners because it requires specific investigation strategies (Reiser et al., 2001).

Due to the fact that students are responsible for their own learning process which contains creating a plan, determining, and achieve the management of the tasks, inquiry process is generally difficult for learners (Kyza, Golan, Reiser, & Edelson, 2002). The development of students' current skills is a premise because they have difficulties to manage their own scientific investigations (Krajcik, Blumenfeld, Marx, Bass, Fredericks & Soloway, 1998) such as creating, critiquing and evaluating hypothesis (Clark et al., 2003), data collection, and drawing conclusion in the light of those data (Edelson et al., 1999).

Another difficulty is the lack of students' scientific knowledge. Similar to teachers who do not have background knowledge students are not be able to complete a successful inquiry process (Edelson et al., 1999). They can have problems to conduct an inquiry process such as posing questions, conducting investigations, designing experiments, and understanding results

(Sandoval & Reiser, 2004). Because of its characteristics, open-ended inquiry process requires the management of complex activities (Edelson et al., 1999). In the search for a unique answer of real world problems, students should coordinate scientific inquiry, even if students have some problems to find a starting point to pose questions for investigations (Royce & Holzer, 2003). When students do not have enough prior knowledge and personal experience about the concept this process would become more complicated and difficult (Cuevas, Lee, Hart, & Deaktor, 2005).

Last challenge is determined as the constraints in the learning setting. As a result of its demanding nature in terms of time and resource, learning environment should be appropriate for inquiry-based science learning approach (Edelson et al., 1999). Without taking into account the limitation in the learning context the reform may not be successful.

Students have some obstacles in science classes. Similar to teachers, their new role is demanding. They should have background knowledge, interest to conduct a scientific endeavor, as well as skills to manage inquiry process. Considering all those challenges, it can be argued that scaffolding inquiry process is necessary. Next section presents the technological tools as a scaffolding mechanism to address both teacher and student challenges.

Technology Design as a Scaffold

Owens, Hester and Teale (2002) describe some important factors which have an impact on effective implementation of inquiry-based learning into classroom. They emphasize the role of technology and claimed that it can motivate learners, increases their curiosity, provides multiple sources, and create opportunities for learners in this process. Nonetheless, Edelson

(2001) lists three important benefits of technology supported inquiry learning environments. Firstly, the advancement in technology facilitates scientific processes such as collecting and analyzing data. Secondly, storing and retrieving information and presenting them in dynamic interactive formats are possible with new computer tools. Thirdly, existence of computers in schools will be a great chance for the reform movements.

By supporting inquiry process, researchers may design software tools and literature may provide some implications for new technological designs. Thus, next part involves analysis of several software examples (GLOBE, WISE, GeologyExplorer, IQWST, and WorldWatcher) and their characteristics about technology-integrated inquiry-based learning environment.

Analysis of Previous Examples

Global Learning Observations to Benefit the Environment (GLOBE) is an educational program allows students to solve real life problems (Roschelle et al., 2000). The program aims to inform people about environmental issues, to enhance conceptual understanding of the Earth and to increase students' achievement in science and math (Finarelli, 1998). Finarelli (1998) proposes that GLOBE students become able to make scientific measurements related fields of the Earth; they may record their observations; use visual images that GLOBE provides and share their ideas with others students and scientists. GLOBE does not only focus on students but also teachers' development. The benefits of GLOBE[1] for teachers are a) professional development; b) teacher guides, videos and materials; c) online support for the next phases and d) contact with other members of the environment (scientists, students and teachers). The most crucial part of GLOBE is allowing students to play real scientific data.

[1] http://classic.globe.gov/fsl/pdf/GLOBE_ProgSummary.pdf

Roschelle et al., (2000) claim that 62% of teachers is admitting that student can investigate, argue and interpret scientific data by using GLOBE.

Web-based Inquiry Science Environment (WISE) is also an online science learning community that students have chance to work collaboratively on socio-scientific issues such as global warming, genetics etc. (Slotta, 2004). They can easily access information on the Internet by using their web browser. There is no need to install any software and students access the WISE platform everywhere. According to Slotta (2004), WISE a) provides inquiry-based activities; b) uses technology to support teachers and students; c) offers a library for the activities and d) supports teacher development to inquiry-based science teaching. Similar to the GLOBE, it also aims to develop teacher skills to increase the quality of science education. In this manner, teacher development is noteworthy because research shows that effective design of WISE has also a positive impact on teachers (Linn & Hsi, 2000).

Geology Explorer is a dynamic, multi-user and role-based science learning environment where users can explore geological structures (Saini-Eidukat, Schwert, & Slator, 2002). Its web-based means is accessible for the students from everywhere. Most importantly, learner is supposed to be a geologist in the environment and the program enables the user to think and acts like a scientist. To scaffold the learning process, intelligent tutoring helps learner by monitoring his or her actions. It can be argued that placing an authenticity in a learning environment makes sense because students' learning increases when virtual worlds are designed as the real world (McClean et al., 2001). Besides, Saini-Eidukat et al. (2002) claim that the Geology Explorer may propose an opportunity for learners like a geologist with built-in virtual equipment. In this way, managing the scientific inquiry becomes feasible for the learner.

Investigating and Questioning our World through Science and Technology (IQWST) is another project targeted to develop, design, and test middle school science materials (Krajcik

& Sutherland, 2009). Similar to the above-mentioned projects, IQWST is aligned with the national science education standards (Krajcik, McNeill, & Reiser, 2006). The program aims to promote students' science understanding and scientific literacy. Krajcik et al. (2006) state that IQWST is based on learning goals driven design model and it has three stages: a) specifying learning goals, b) materials development, and c) feedback. At the first stage, national standards and their correspondent learning performances are identified for describing learning goals of the unit. Then, driving questions, learning tasks, instructional sequence and rubrics for the assessment are prepared to develop material. After the development of the material, a pilot study is conducted and feedback is collected from external agents.

WorldWatcher, a scientific visualization environment, creates a valuable context for the learners to discover, generate and analyze scientific data (Edelson et al., 1999). By using WorldWatcher students may develop following abilities: 1) learning scientific concepts related with global warming and carbon cycle, 2) comprehending the political and economic issues about global warming, 3) exploring the reasons of global warming and 4) reflecting their understanding on the subject[2]. Similar to the Geology Explorer, authentic environment creates a framework that students can act as a scientist because they have tools required in scientific investigation processes. Edelson et al. (1999) stated that WorldWatcher also allows the users to visualize their data and create schemas and diagrams by using the given data.

There are implications for an effective technology-supported and inquiry-based science learning environment. Firstly, visualization can make sense for the learners and facilitate the science learning. Secondly, authentic learning may motivate students the way in which they can participate and experience the scientific investigation process. In reference to the noted learning environment, skills and knowledge are context-dependent so authenticity is noteworthy in learning (Edelson, 1998). Thirdly, all programs aimed to let students participate

[2] http://serc.carleton.edu/introgeo/roleplaying/examples/globwarm.html

in scientific inquiry process. The technology is deserved to be used purposefully and support the inquiry process.

Difficulties Experienced of Previous Examples

Using of technological tools in classroom is a multilayered issue in the science education literature. Although previous examples aim to show promising results and argue some implications, those programs do not commonly use in the science classroom setting. This issue can be explained by four basic reasons: a) classroom ecology, b) complexity, c) technology dependency, and d) technical limitations.

Classroom ecology: Waight and Abd-El-Khalick (2007) argue that there are a lot of experimental studies show the functionality of software tools as a part of the classroom ecology. According to this idea, a new tool must be integrated in a classroom setting and should be compatible with existing classroom dynamics. Beliefs, aims and new roles of students as well as teachers are the important factors that have an impact on effectiveness of technology in classroom (Waight & Abd-El-Khalick, 2007). It is apparent from this argument that a new technological tool is deserved to be taken those concerns into account.

Complexity: Kim, Hannafin and Bryan (2007) advocate that although technological tools are beneficial for science learning, they may complicate the situation. The noted authors explain it by several parameters such as lack of teacher guidance, contextual factors, and discrepancy between theoretical approaches with reality. For this reason, using technology should make the role teachers as simple as possible and not increase perplexity.

Technology dependency: Although those software tools are based on many studies and well-defined theoretical framework they are not commonly used in the classroom setting because they are heavily relied on technology. This issue can be a result of technical problems such as internet connection and computer configurations. Consequently, more research is needed to determine what the basic conditions are to create a framework which new tool can support teacher, classroom ecology and students' understanding. Specifically, more studies are needed to assess technology in natural setting and more holistic approach in classroom dynamics (Waight & Abd-El-Khalick, 2007). Therefore, it is arguable to claim that a software tool should work with the limited technological device.

Technical limitations: Researches point out that technology use in science classes is not common in Turkish context. For instance, a study is conducted with the participation of 129 teachers and the efficacy of the participant teachers in computer technology is evaluated (Karakoç, 2003). According to the results, they assessed their knowledge as "sufficient" about computer literacy and the use of computer software. However, they evaluate their technology use in education is "insufficient" (Karakoç, 2003). Similarly, Karamustafaoğlu (2006) analyzes 32 science and technology teachers and their use of classroom materials. 28 of them do not use presentations and 13 did not use DVDs and CDs. This indicates that teachers do not use technology in classes because they do not have enough knowledge about technology integration.

In order to examine the effectiveness of technology use in classroom setting we designed "Natural Processes" unit for the 8th grade students in reference to the above-mentioned instructional design methods. Because of the fact that geological understanding closely related with the unique features of the discipline next section will depict the geology discipline.

Geology as a Scientific Discipline

Geoscience is a branch of science that investigates the Earth, its history, structure, processes and dynamics that shaped it. It is an umbrella term that contains sub-disciplines such as geology, geophysics, and geochemistry. As a member of geoscience family, geology explores origin, structure, and history of the Earth as well as physical and chemical processes about its components such as soils, rocks etc. Geology is defined as visual (Piburn et al., 2002; Reynolds, Johnson, et al., 2005) and geometric science (Dott, 1998). The unique characteristics of the discipline are noteworthy in teaching and learning geology (Abell & Lederman, 2007). King (2008a) lists five unique attributes of geoscience as follows:

- Geoscience is interpretive and historical science
- Geoscience contributes to the development of holistic system approach
- Spatial thinking ability is necessary in geoscience
- Geoscience has its own time scale called deep time
- Specific methodologies and strategies of geoscientific fieldwork

Geology is also described as a historical and interpretive science (Dodick & Orion, 2003; Frodeman, 1995; King, 2008a; Raab & Frodeman, 2002). As a historical science, geology contains theories that assume past causes had an impact on observable phenomena (Cleland, 2001). This nature of scientific discipline leads geologists to observe present conditions for explain past events (Orion & Dodick, 2003).

Because of its unique characteristics, geology has its own theories and methods for inquiry but its five essential characteristics in inquiry-based learning will be mentioned here (Apedoe, 2008). Geological knowledge mainly relies on technology and technological tools. This feature may provide an opportunity for learners to observe past events because computers can store huge amount of data and represent it in a consistent and meaningful way.

For example, a collection of real earthquake data can be presented as a material by using technology.

Geology has its unique time scale that events can be evaluated and explained through this context-dependent phenomenon. The age of the Earth is an example of deep time. It is almost 4.6 billion years which is difficult to experience in daily terms such as minutes, hours and weeks. It is crucial because this time scale creates a framework to make clear the process such as extinction, evolution, and continental drift (Orion & Dodick, 2007). Visual materials encourage learners to observe this geological time span.

Geology is a geometric science (Dott, 1998) so visualization of data is noteworthy to interpret geologic data. Understanding geological structures requires the concept of distribution (Piburn et al., 2002). Accordingly, Rudwick (1978) states that geologists use multiple representations to facilitate understanding process of geological units. Technology has a great potential because geological data can be analyzed, be interpreted, and be modeled via computers. This helps educators to promote students' geological understanding (Libarkin & Brick, 2002).

In a broad framework, these unique attributes of geoscience has an impact on the way of teaching and learning geology. For the sake of supporting learning geology, instruction needs to contain visualizations as any other scientific disciplines.

Visualization in Science Education

Science includes complex concepts, explanations about nature and their dynamic relationships between each other. Although scientific phenomena are directly related with daily life, some of them are not observable. Visualization can make the abstract concepts more concrete for the learners (Buckley, 2000; Cook, 2006) such as Newton's laws, computer algorithms and mathematical rules (Scheiter, Gerjets, & Catrambone, 2006). Visualizations may also be beneficial to show and organize data, and enhance understanding of scientific concepts (Kozma, 2003). In this manner, learning can be problematic without visual representations (Carter & Wiebe, 2005). This potential can foster conceptual learning if it is carefully designed.

Several studies pointed out that visualization should create a framework that make science accessible, provide a valuable context for inquiry, enhance development of certain skills and knowledge, and understand scientific concepts and critique them (Gordin & Pea, 1995); give a chance to learners for experiencing them (Buckley, 2000; Rapp & Gilbert, 2005). They also can create an opportunity for learners to realize multiple relationships and processes about complex phenomena (Cook, 2006); dealing with large data sets (Libarkin and Brick 2002), and support process of teaching scientific concepts (Roschelle et al., 2000). For instance, dynamic visualizations may enhance chemistry learning (Zhang, & Linn, 2011) and support process of developing integrated understanding (Ainsworth, 1999).

However, learners need some certain requirements when they deal with animations. This complicates learning process (Scheiter et al., 2006). Lowe (1999) claims that if there are more irrelevant details learners would not focus on important concepts and this limits learners' effective knowledge construction. However, when visual representations are created considering cognitive load, they can remove the potential barriers and become beneficial for the learners because it does not exceed their mental resources (Patrick, Carter, & Wiebe, 2005).

Dynamic Visualization in Science Learning

Visualization can be defined as a visual form of data (Rapp & Gilbert, 2005); it also comprises diagrams, graphs, two or three dimensional objects. There are three types of visualization: static, dynamic and dynamic interactive (Libarkin & Brick, 2002). Static visualizations can be depicted as "pictures", dynamic visualizations refer to "animations" and dynamic interactive visualizations are relevant with "simulations". In other words, learners can observe a snapshot from a process via pictures, realize the process from an animation as well as manipulate the process and dynamic relationships through a simulation.

Science education literature has been paid special attention to students' understanding of scientific concepts via different types of visualizations (Höffler & Leutner, 2007; Ryoo & Linn, 2012; Yarden & Yarden, 2010; Zhang & Linn, 2011). There is an ongoing debate on the type of visualizations which is more effective in supporting learning. Although several studies show that dynamic representations are more effective for learners (Ardac & Akaygun, 2005; Yarden & Yarden, 2010); others advocate that static pictures are equally effective or superior to dynamic visualizations (Mayer et al., 2005; Tversky et al., 2002).

Dynamic visualizations provide significant advantage for learners in many phenomena from different disciplines such as DNA polymers (Yarden & Yarden, 2010), photosynthesis (Ryoo & Linn, 2012), molecular genetics (Marbach-ad, Rotbain, & Stavy, 2008), chemical reactions (Zhang & Linn, 2011), solubility (Kelly & Jones, 2007), phases of matter and transition between them (Trindade, Fiolhais, & Almeida, 2002), particular nature of matter (Williamson & Abraham, 1995), population analysis (Ainsworth & VanLabeke, 2004), anatomy (Khalil, Lamar, & Johnson, 2005b) and statistical concepts (Bodemer, Ploetzner, Feuerlein, & Spada, 2004). These studies point out those visualizing concepts in a more concrete way may increase understanding.

The research conducted by Ardac and Akaygun (2005), states that 52 eighth grade students are formed in three groups to determine the effectiveness of dynamic visualizations in learning chemical change at molecular level. Group 1 (n=17) interacted with computers, group 2 (n=17) had an instructor and used to software tool as a classroom material for whole class and group 3 (n=18) learned the concepts via static pictures with whole class. Ardac and Akaygun (2005) argue that when students are interacted with dynamic representations, they have been showing more accurate understanding in chemistry concepts at molecular level. Students in multi-media group do not only show more accurate understanding about particular nature of matter at molecular level but they also show high motivation and enthusiasm (Ardac & Akaygun, 2005).

Ryoo and Linn (2012) evaluate the role of dynamic representations in learning photosynthesis. In their design, the students are divided into two groups. While experimental group is interacted with dynamic representations, control group is viewed the same material with static pictures. At the end of the study, researchers found that compared to control group, students in dynamic group have significantly higher level of understanding on the subject. Researchers also realize that dynamic group students understood invisible processes more accurately. Nonetheless, one interesting finding in this study is that 10% of students in control group developed a new naïve conception about the photosynthesis (Ryoo & Linn, 2012). Thus, presenting a process with static pictures may oversimplify the process and leads some alternative explanations.

Although several studies claim that dynamic visuals are advantageous in learning, many studies imply the reverse. For example, Tversky et al. (2002) analyze various studies and conclude that dynamic visualizations do not have any advantage over static pictures even if static pictures are more effective. They claim that there are several studies showed the effectiveness of dynamic visualizations just because they have more information or contain interactivity (Tversky et al., 2002). In addition, some complex animations can impede learning instead of supporting it because learners may not able to perceive them (Tversky et. al, 2002).

Similarly, Mayer et al. (2005) find that compared to animations, static media is equal or more successful in learning and retention. Moreover, Klein and Koroghlanian (2004) state that not only students learn less in animation group but also they spent more time. Morrison, Tversky and Betrancourt (2000) also argue that finding any positive effect of animations is not surprising because animated graphics are not equal to static pictures. That's why; people cannot easily perceive animations in many cases (Morrison et al., 2000).

Another study conducted by Hegarty, Kriz and Cate (2003) have two basic implications about static visualizations. Firstly, students have been learning the work of a mechanical system with diagram and related verbal description. Secondly, static group students also develop an understanding to predict how the device works which is important for understanding the system. Finally, students in both groups (static and dynamic) develop an integrated understanding about the mechanical systems which means dynamic visualizations are not superior to static ones (Hegarty et al., 2003).

Höffler and Leutner (2007) conducted a meta-analysis of 26 studies comparing dynamic and static visualizations by implying significant results. They conducted 76 pair-wise comparisons and 21 of them showed animations are statistically significant, two of them are the reverse and 53 comparisons showed that there is no significant difference between static and dynamic visualizations. Höffler and Leutner (2007) conclude that instructional animations compared to static pictures has a benefit in general. However; there are important variables that have an effect on their support in learning process. Authors also argue that animations are more effective when they are representational not only decorative (Höffler & Leutner , 2007; Plass, Homer, & Hayward, 2009).

Zhu and Grabowski (2006) conducted a research with three treatment group (static, animation as attention-gaining, and animation as attention-gaining and elaboration) with 111 college students. The results of their studies pointed out those students in static group have similar gaining compared to other two animation groups (Zhu & Grabowski, 2006). There was not a statistical significance in favor of the animations so they concluded that static visualizations are more effective and efficient in terms of cost (Zhu & Grabowski, 2006).

On the other hand, Kühl (2011) analyzes the studies published after the date of 2004 and lists the results of 34 studies with 42 experiments in terms of effectiveness of dynamic visualization (see Table 2). According to this meta-analysis, 28 experiments (67%) point out superiority of dynamic visualizations, 8 experiments (19%) are neutral, and 6 experiments (14%) prove that static visualizations are better.

Table 2. Meta-analysis of Different Types of Visualizations (Kühl, 2011)

Effects in Favor of Dynamic Visualizations from Studies Comparing Learning with Dynamic and Static Visualizations Published Since 2004		
	Authors	**Effect of Dynamic**
1	Ardac & Akaygun, 2005a	Positive
2	Arguel & Jamet, 2009	Positive
3	Ayres, Marcus, Chan, & Qian, 2009 (Exp. 1)	Positive
4	Ayres, Marcus, Chan, & Qian, 2009 (Exp. 2)	Positive
5	Boucheix & Guignard, 2005	Positive
6	Boucheix & Schneider, 2009 b	Positive
7	Fischer, 2008 (Exp. 2) b	Positive
8	Höffler, 2007 (Exp. 1)	Positive
9	Höffler, 2007 (Exp. 2)	Positive
10	Imhof et al., 2009 b	Positive
11	Imhof, Scheiter, Gerjets, & Edelmann, 2010	Positive
12	Iskander & Curtis, 2005 a	Positive
13	Kim, Yoon, Whang, Tversky, & Morrison, 2007 b	Positive
14	Kriz & Hegarty, 2007 a	Positive
15	Lin, Chen, & Dwyer, 2006	Positive
16	Lin & Dwyer, 2010	Positive
17	Marbach-Ad, Rotbain, & Stavy, 2008 a	Positive
18	Münzer, Seufert, & Brünken, 2009 b	Positive
19	Pfeiffer, Gemballa, Jarodzka, Scheiter, & Gerjets, 2009	Positive
20	Rebetez et al., 2010	Positive
21	Schnotz & Rasch, 2005 a	Positive
22	Stebner, 2009	Positive
23	Wang, Vaughn, & Liu, 2011 a	Positive
24	Watson, Butterfield, Curran, & Craig, 2010	Positive
25	Wong et al., 2009 (Exp. 1)	Positive
26	Wong et al., 2009 (Exp. 2)	Positive
27	Wong et al., 2009 (Exp. 3)	Positive
28	Yarden & Yarden, 2010 a	Positive
29	Höffler, 2007 (Exp. 3)	Neutral
30	Höffler, Prechtl, & Nerdel, 2010	Neutral
31	Kalyuga, 2008	Neutral
32	Koroghlanian & Klein, 2004	Neutral
33	Tunuguntla et al., 2008 a	Neutral
34	van Oostendorp & Beijersbergen, 2007	Neutral
35	van Oostendorp, Beijersbergen, & Solimani, 2008 a	Neutral
36	Zhu & Grabowski, 2006 a	Neutral
37	Lowe, Schnotz, & Rasch, 2011	Negative
38	Mayer et al., 2005 (Exp. 1) a	Negative
39	Mayer et al., 2005 (Exp. 2) a	Negative
40	Mayer et al., 2005 (Exp. 3) a	Negative
41	Mayer et al., 2005 (Exp. 4) a	Negative
42	Scheiter, Gerjets, & Catrambone, 2006	Negative

a. Studies that are not methodological sound, for instance, in terms of a “fair” comparison of dynamic and static visualizations, as recommended by Tversky et al. (2002).

b. These studies included either different types of dynamic visualizations or different types of static visualizations, where not every comparison was in favor of dynamic visualizations.

The indicator “a” shows the information equivalence between static and dynamic visualizations. (Tversky et al, 2002). 14 experiments do not provide this issue, so 28 experiments are proper for a “fair” comparison among them. When static and dynamic visualizations have equal amount of information, 21 of 28 experiments (75%) indicate that dynamic visualizations are better than static visualizations.

The details of the experiments in those studies were examined. The researcher could not access several of them and listed the available one in terms of their subject and sample (see Table 5). Studies are mostly related with physics (7) and chemistry (6). There are other subjects such as medicine and astronomy but any the field of geology. In those studies, mostly undergrad students were participated in. While 17 studies have university level, other studies conducted with students from college, primary and secondary grade level. It is arguable to claim that conducting a research with 8th grade level in the field of geology makes a point.

Table 3. The Context and Participants in the Studies Compared Different Type of Visualizations

	Authors	Subject	Participants
1	Ardac & Akaygun, 2005a	Chemistry - Molecular representation	n=52 (8th grade)
2	Arguel & Jamet, 2009	Medicine - First aid	n=123 (undergrad)
3	Ayres, Marcus, Chan, & Qian, 200)	3 knots (Scoubidou knots)	n=72 (high school - undergrad)
5	Boucheix & Guignard, 2005	Physics - Gear functioning	n=123 (7th-8th grade)
6	Boucheix & Schneider, 2009 b	Physics - Mechanical systems	n=107 (undergrad)
7	Imhof et al., 2009 b	Biology - Biodiversity	n=120 (undergrad)
8	Imhof, Scheiter, Gerjets, & Edelmann, 2010	Biology - Classification	n=75 (undergrad)
9	Iskander & Curtis, 2005 a	Physics - 3D vectors	n=43 (high school)
10	Kim, Yoon, Whang, Tversky, & Morrison, 2007 b	Physics - mechanism of bicycle pump	n=208 (4th-6th grade)
11	Kriz & Hegarty, 2007 a	Physics - Siphon mechanism	n=60 (undergrad)
12	Lin, Chen, & Dwyer, 2006	Literature - English learning	n=58 (undergrad)
13	Lin & Dwyer, 2010	Physiology	n=582 (undergrad)
14	Marbach-Ad, Rotbain, & Stavy, 2008 a	Biology - Molecular genetic	n=248 (11th-12th grade)
15	Münzer, Seufert, & Brünken, 2009 b	Biology - Synthesis of ATP	n=94 (undergrad)
16	Pfeiffer, Gemballa, Jarodzka, Scheiter, & Gerjets, 2009	Marine Biology - fish species	n=35 (undergrad)
17	Rebetez et al., 2010	Astronomy - Planets	n=160 (undergrad)
18	Schnotz & Rasch, 2005 a	Geography - time and date differences	n=40 (undergrad)
19	Stebner, 2009	Chemical processes during washing laundry	n=102 (undergrad)
20	Wang, Vaughn, & Liu, 2011 a	Statistic	n=123 (university)
21	Watson, Butterfield, Curran, & Craig, 2010	Engineering - AUTOMAT Engineering Kit	n=30 (university)
22	Wong et al., 2009 (Exp. 1)	Origami - folding	n=32 (6th grade
23	Wong et al., 2009 (Exp. 2)	Origami - folding	n=26 (3th-4th grade)
24	Wong et al., 2009 (Exp. 3)	Origami - folding	n=24 (3th-4th grade)
25	Yarden & Yarden, 2010 a	Biotechnology - Polymerase chain reaction	n=173 (12th grade)
26	Höffler, Prechtl, & Nerdel, 2010	Biology - Photosynthesis	n=60 (11th grade)
27	Kalyuga, 2008	Mathematics - Graph Transformation	n=33 (university)
28	Lowe, Schnotz, & Rasch, 2011	Cognitive psychology - kangaroo hop	n=98 (university)
29	Mayer et al., 2005 (Exp. 1) a	Geography - Lightning	n=95 (college)
30	Mayer et al., 2005 (Exp. 2) a	Physics - How a toilet tank works	n=31 (college)
31	Mayer et al., 2005 (Exp. 3) a	Geography - Ocean waves	n=40 (college)
32	Mayer et al., 2005 (Exp. 4) a	Physics - Car breaking system	n=31 (college)
33	Scheiter, Gerjets, & Catrambone, 2006	Mathematics - Probability	n=124 (university)

In a broader context, it can be arguable that this meta-analysis (Kühl, 2011) is in consensus with previous study conducted by Höffler and Leutner (2007). It is reasonable to claim that several studies showed controversial findings about learning outcomes of students via different types of visualizations. Dynamic visualizations are not a panacea and not effective in isolation as any other instructional strategies. For this reason, potential barriers should be eliminated and supportive strategies need to be developed. Hegarty et al. (2003) list four basic elements that decrease the effectiveness of dynamic visualizations. Firstly, the term *resemblance fallacy* underlines the inconsistency between internal and external representations. People tend to learn a system by understanding its component independently in a chain of causes, but animations contain several synchronized motions which are difficult to comprehend. Secondly, showing an animation about a specific concept to the learners does not guarantee understanding of it. In other words, animations do not have any positive effect on learning when they are used alone. Thirdly, visualizations can overload the people's visual attention limits and this may hinder the understanding of the concepts. Lastly, learners are passive when they see an animation. Taken together, dynamic visualizations can foster students understanding more when possible obstacles are addressed in a coherent instructional design and implementation.

In summary, the ongoing discussion point out that there is a need for more experimental studies to analyze the effectiveness of dynamic visualizations with the consideration of potential problems. Next section will elaborate the design of the study and describe how to implement dynamic visualization in a science classroom.

CHAPTER 3

METHODOLOGY

The purpose of this study is to investigate which type of visualization is more effective on students' understanding. It aims to study on the question of whether instruction with dynamic visualizations promotes 8^{th} grade students' understanding on plate tectonics and earthquake concepts. This part presents the study's research questions, research design, and technology tool, data collection as well as data analysis.

Research Questions

In order to examine the role of dynamic visualizations in science learning, following research questions are asked:

- Is there a statistically significant difference between the conceptual understanding level of the 8th grade students who received instruction with dynamic visualizations and students who received instruction with static animations?
- Are there any differences in the cognitive and discursive engagement level of the 8th grade students receiving instruction with dynamic visualizations compared to receiving instruction with static animations?

Research Design

This research utilized a mixed method approach aiming to collect data both qualitatively and quantitatively (Creswell, 2003). While quantitative data is largely in numerical form, qualitative data is basically descriptive. Creswell (2003) describes mixed method as a process which combines collecting, analyzing, and putting both qualitative and quantitative data to understand research problem in depth. Using these two types of methods together creates a valuable framework to comprehend the issues better and support an integrated analysis (Greene & Caracelli 1997; Tashakkori & Teddlie 1998).

In social science, some settings do not allow the researcher to have control over data collection procedures and an experimental stimulus - which means true experimentation is not possible - quasi-experimental design can be used (Campbell & Stanley, 1966). There are different types of quasi-experimental design and *pretest-posttest non-equivalent group* type is used in this study. This type of design implies that both groups are conveniently assigned rather than randomly chosen, however, control and experimental group will be compared (Campbell & Stanley, 1966). Owing to random selection is not feasible in our study, one group of students is in the control group whereas other classroom becomes experimental.

Similar to the design of the study conducted by Ryoo and Linn (2012), whereas experimental group learns the subject with dynamic visualizations, control group studies the same material and unit with static pictures of the same animations. The control group will be exposed the same amount of information about plate tectonics, and earthquakes. All research questions will be answered with the data gathered through pre and posttest, students' worksheets, and classroom observations.

Technology Tool

The learning materials (animations, lesson plans, activity worksheets, concept maps) used in the study was developed by Güven (2012). In order to conduct the research, an inquiry-based and technology enhanced science learning environment is developed (www.fentek.boun.edu.tr). The content, lesson plans, conceptual sequence are developed by a group of people (one science educator, one educational technologist and one subject matter expert, and three teachers) throughout 1 year. After this period of time a professional software developer worked to create the web site and animations for three months with ongoing feedback process. The web site was designed as a classroom material. The web can only be available for registered users.

Figure 1: Homepage of the web site

After creating an account on the system, teachers can log in. Teacher has two options: preview and classroom activities. While teachers can see instructional strategies, misconceptions, and lesson plans (see Figure 2), s/he can also open up classroom materials for the lessons.

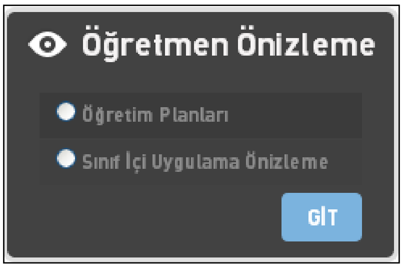


Figure 2: Teacher preview

The web site is useful for teachers and they can easily access the conceptual sequence, lesson plans, and concept maps (see Figure 3).

Figure 3: User interface

The conceptual sequence was developed compatible with the “Science and Technology” curriculum (MEB, 2005). Before developing lesson plans, common misconceptions of the students related with subjects were determined. Literature provided several alternative conceptions of students about the world, earthquake, plate tectonics etc. For example, Dove (1998) points out that students think “Earthquakes occur in hot countries” and “Magma flows from the centre of the Earth”. Therefore, objectives were identified and sample activities were developed to address students’ alternative conceptions. CCM implies that in order to change the alternative conceptions instructors should create dissatisfaction. For this reason, the activities contain several critical questions to show the limitations of their existing knowledge. For example, “how can we know that the Earth has a core inside?” can aid to reveal current ideas of students about the structure of the Earth.

Objectives are aligned with the 8th grade Science and Technology curriculum. The interface gives teacher a chance to use objectives, misconceptions, and activities in an integrated way. When the teacher chooses the objective, s/he would see possible misconceptions and activities to foster students' understanding. This holistic approach is an opportunity for the teacher because we expected to design the platform as a classroom material to be compatible with classroom ecology.

The unit contains rich visualization to enhance the realization of complex geological process because they are not visible due to time and space limitations. This means that intrinsic load of the content is high. In order to reduce complexity, conceptual sequence was structured. Following completing previous topic, learners can study next topic. This step-by-step approach is designed to reduce cognitive load.

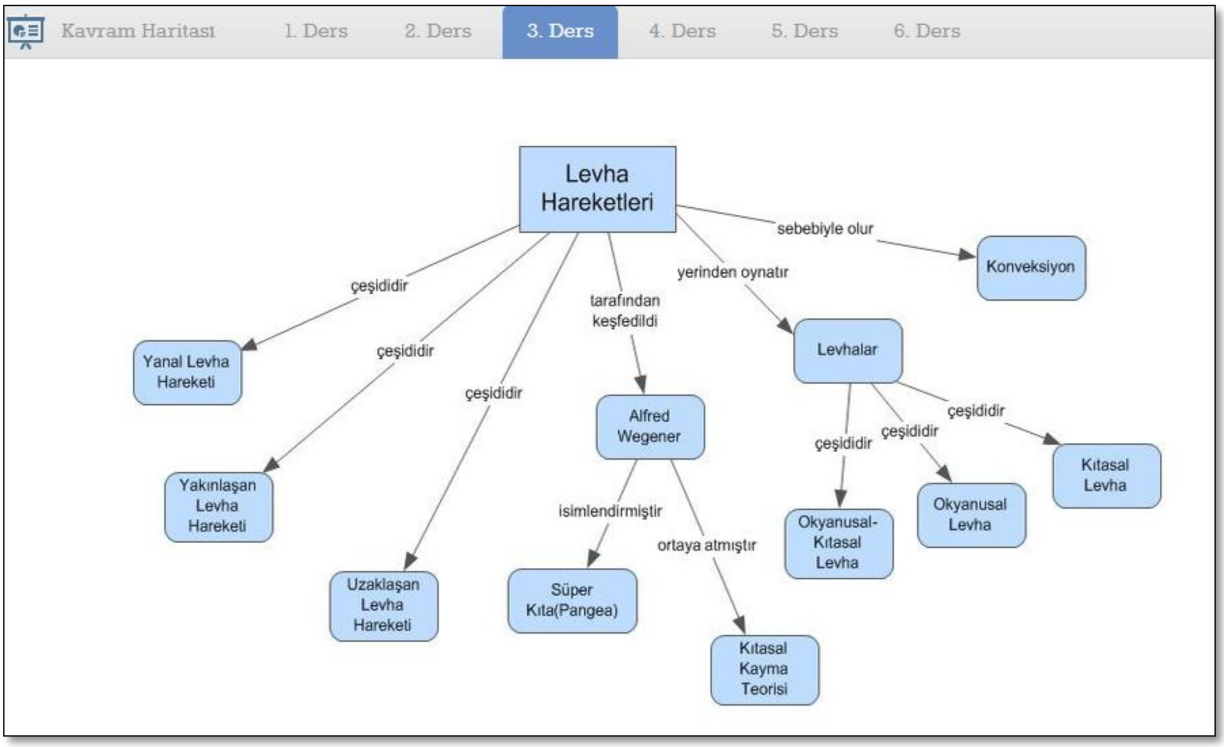


Figure 4: Lesson3 - Concept Map

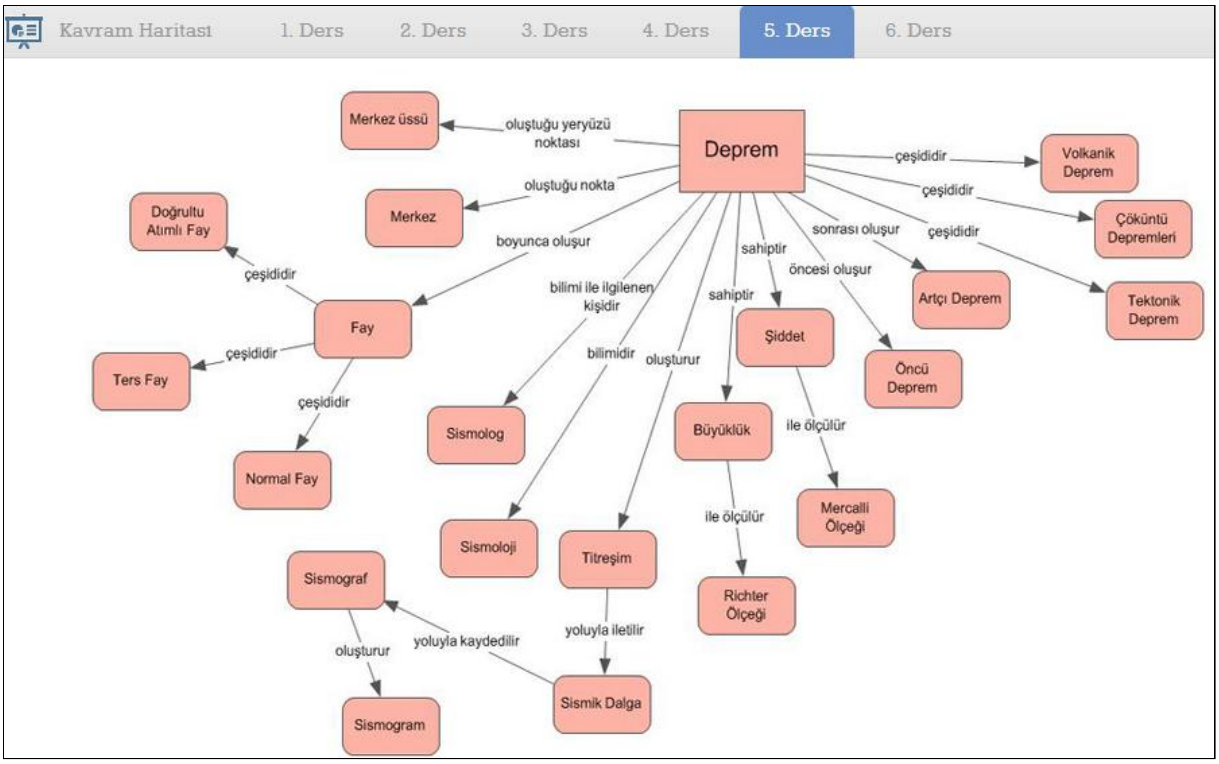


Figure 5: Lesson 5 - Concept Map

To promote conceptual learning, concept maps (see Figure 4 and Figure 5) were developed. Teachers and students can investigate concepts in the unit and detect relationship between them. Design contains a) subject; b) the objectives compatible with curriculum (MEB, 2005); c) activities to address objectives and d) concepts will be covered in that activity. After developing enough materials, lesson plans were prepared according to 5E learning cycle model (Bybee et al., 2006) and ARCS motivational model (Keller, 1999a; Keller, 1999b).

Each lesson plan and worksheet was prepared according to the theoretical framework and instructional design principles designed by Güven (2012) stated in Chapter 2. First of all, the driving questions at the beginning of each lesson help to attract students' attention. This will help student for meaning-making process. Parallel to the meaningful learning theory, this method creates curiosity and driving questions can play the role of advance organizer in the theory. Secondly, CCM approach is embedded in the lesson plans. The worksheet has "what I know" and "what I have learned" part which aids researcher to investigate the students' prior knowledge about the topic and new concept covered in the lesson such as fault types or convection. At the same time, those question also an indicator of scaffolding strategies. With the guidance of those questions the instructor can help students to learn new and complex geological concepts and structures. Lastly, animations were designed in accordance with the multimedia design principles. Next section will describe the underlying principles (multimedia learning theory and cognitive load theory) under our design.

Learning Materials

Multimedia learning has a promise to foster students' understanding in reference to two specific reasons: a) multimedia learning is compatible with the way in which people learn so it supports cognitive processes and b) studies showed that students have high scores when they interacted with multimedia representations (Mayer, 2003). Hence, it can be said that effective use of multimedia representations can enhance science learning.

Mayer (1997) proposes the most common model of multimedia learning and Moreno and Mayer (2000) argue that it has three basic assumptions: a) human have visual and auditory channels to process information, b) the capacity of these channels are limited and c) transferring organized material from working memory to long-term memory, audio and visual channels contain several cognitive processes such as choosing related material, organize them into coherent representations and incorporate related verbal and visual representations. Although it has a great potential, multimedia representations are not always beneficial for learners. Thus, an effective multimedia design needs to meet basic multimedia design principles as following features.

Split attention principle refers to the idea that when essential part of the materials is separated, learners need to split their attention between those components and this hampers the comprehension of materials (Moreno & Mayer, 2000, Clarke, Ayres, & Sweller, 2005). For example, if an animation and its explanation are physically separated and complex, learners experience a split-attention effect (Plass et al., 2009) which can decrease their understanding.

Modality principle refers that when narration used in visual materials the learning of students increase compared to animation with on-screen text (Mayer & Moreno, 1998; Moreno & Mayer, 2000). Redundancy principle implies that when animation has a narration the text is redundant in visual materials (Moreno & Mayer, 2000). In other words, an effective animation contains narration but not the exact information via on-screen text.

Contiguity principle asserts that learning can be fostered with the way of presenting related sources of information (Mayer, 2005). This principle has two sub-principles: spatial contiguity principle is related with arrangement of different sources and temporal contiguity principle affects synchronicity of the materials (Plass et al., 2009). Spatial contiguity principle states that related visual and verbal information should be represented by integrating with an animation due to the aim of increasing students' understanding (Moreno and Mayer, 2000; Mayer, 2003). Temporal contiguity principle emphasizes that students learn more when related pictures and texts are represented simultaneously (Moreno and Mayer, 2000). Not only verbal and pictorial information should be represented near to each other but also they should be represented at the same time. Coherence principle is related with the extraneous material and it declares that understanding of students' increases when irrelevant material is excluded (Moreno & Mayer, 2000; Mayer, 2003).

These principles should be taken into account when designing animations for the sake of supporting learning. The dynamic visualizations used in this study are designed in accordance with the multimedia learning principles. Split attention, modality and contiguity principles are addressed through only explanatory text and teacher explanation about animations.

Cognitive load theory has also an impact on the design of the animations. Cognitive load theory aims to explain how people learn and how their cognitive processes work. It depicts cognitive architecture of people as a framework that entails long term memory, working memory and their interaction with each other (Chandler & Sweller, 1992). The basic premise of cognitive load theory is that when learners' working memory resources are exceeded learning will be delayed (Cook, 2006; de Jong, 2010; Khalil, Paas, et al. 2005). Cognitive load theory identifies three types of load: intrinsic, extrinsic and germane (Pass et. al, 2003b). Intrinsic load refers to the complexity of subject matter and generally emerges when people learn new materials (Clark, Nguyen & Sweller, 2006). Extraneous cognitive load is independent from the subject and it is visible when learners introduce irrelevant activities to learn new tasks. In contrast to intrinsic and extraneous load, germane load facilitates learning process (Sweller, van Merriënboer & Paas, 1998). Total cognitive load incorporates sum of these three types of load. Effective learning strategy needs to consider the fact that total load should not exceed the limit of cognitive resources of a human (Pass et. al, 2003b). The animations used in this study are designed to reduce extraneous cognitive load by focusing on student attention about relevant concepts and it aims to increase germane load by carefully structuring and sequencing concepts.

The learning materials encompass videos, animations and screenshots. The static visualizations are the screenshots of the animations to create equal information for two groups of students.

The following table contains the learning materials on the dynamic visualization group. The videos are how the universe existed, how the Earth is formed and the convection movement.

Table 4. Number of Dynamic Visualizations

Lesson	Experimental Group Learning Materials
1	2 videos
2	5 animations
3	4 animations, 1 video
4	6 animations
5	5 animations
6	3 animations

The animations are developed in compatible with the existing multimedia learning principles and by using existing resources such as USGS (United State Geological Survey). The animations have a consistency in terms of colors and sense of reality. For example, while an animation shows the shadow zones and the interior structure of the Earth (see Figure 7); other demonstrates the focus and epicenter with consistent design (see Figure 8).

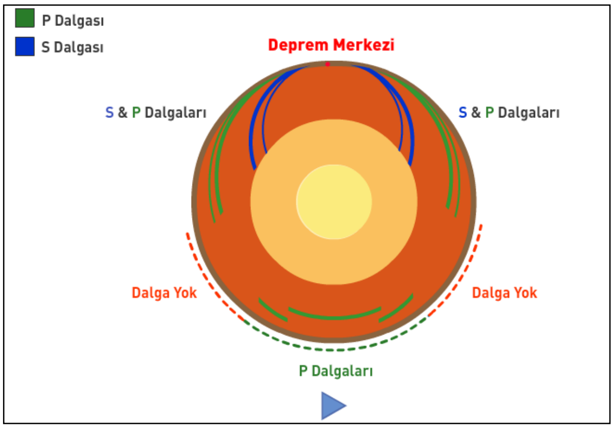


Figure 6: Animations for seismic waves

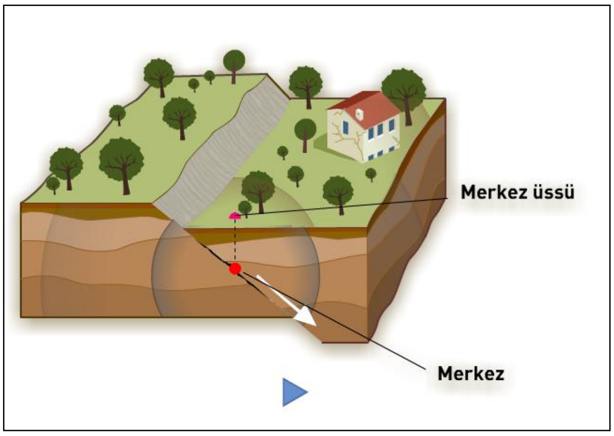


Figure 7: Animation of focus and epicenter

Static visualizations were prepared in compatible with animations. The researcher took screenshots from the animations and created PowerPoint presentations for each lesson. In order to create a fair comparison between two groups the amount of information was concerned as recommended by Tversky et al. (2002). Thus, two frames were captured (the beginning and the end of an animation). As shown in the Figure 9, students in static groups experienced the oldest and the newest phases of Pangea.

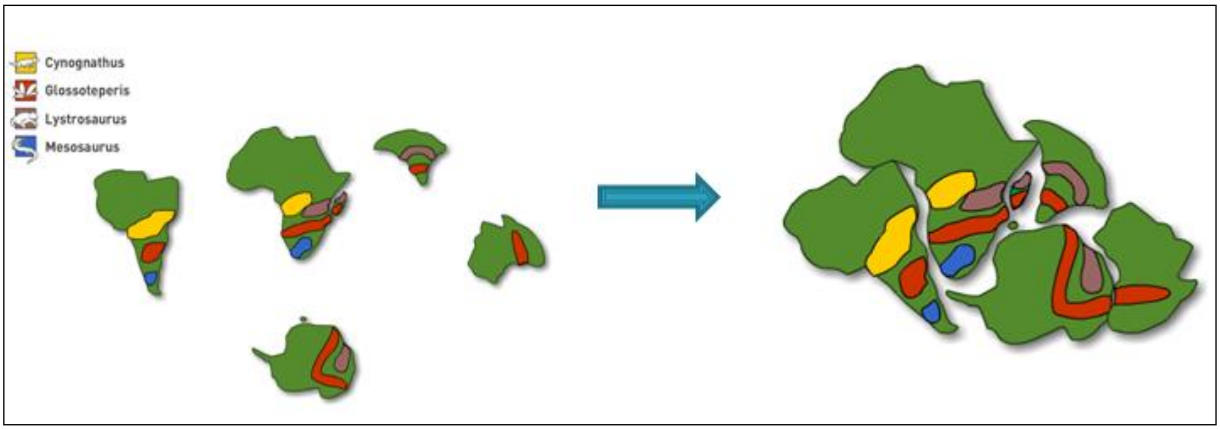


Figure 8: Screenshots of Pangea animation

Similarly, normal faults animations were used with before and after the earthquake as shown in the figure below (see Figure 10).

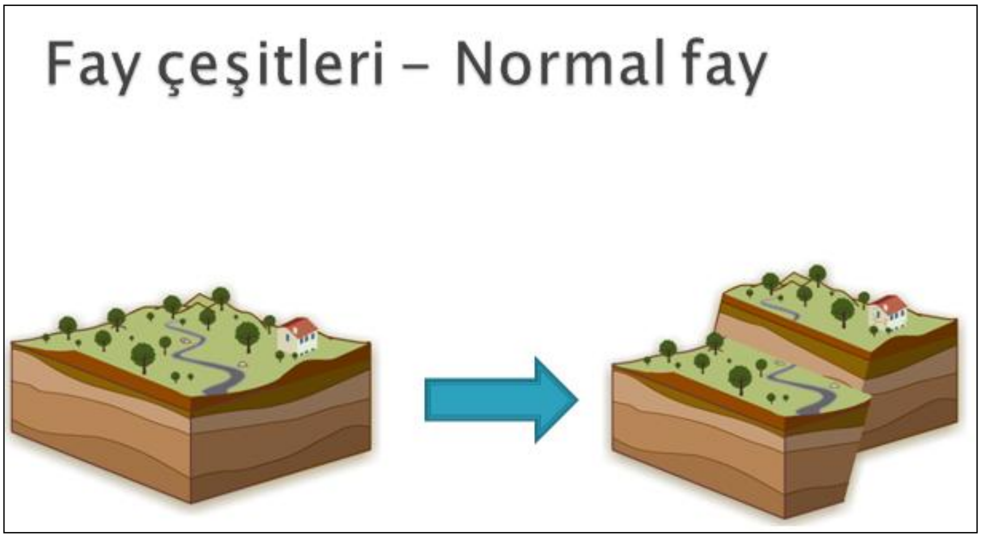


Figure 9: Screenshots of normal fault animation

Participants

This study sheds light on technology-enhanced and inquiry-based learning approach among 8th grade students. The treatment is conducted with the attendance of 42 students at 8th grade from a public primary school in Istanbul.

Table 5. Distribution of Participants

	Male	Female
Experimental Group	13	7
Control Group	9	13
Total	22	20

During the treatment, school had limited technological infrastructure such as no computer lab and no projection on the classroom.

Procedure

The attendant students were divided into two classes. A class was determined as control group (n=34) and the other (n=30) was chosen as experimental group randomly. At the beginning, 64 students took a pre-test which contains 25 multiple choice questions about plate tectonics and earthquakes with the aim of recording their prior knowledge.

The instruction was based on inquiry-based learning in both classes. Students in control group acquired geological concepts with static images while experimental group interacted with dynamic visualizations through a web site. At the beginning, the learning unit was planned for 6 class hour but in the treatment process whole lessons were covered for 8 class hours in both groups.

Both control and experimental group received instruction in classroom setting. Students in experimental group examine animations through a web site; however, students in control group viewed static screenshots of the same animations via PowerPoint presentations. This helped the researcher to test which representation (dynamic or static) is better in learning noted geological concepts. In both groups, students were invited to share their ideas and pose questions about concepts and processes during instruction through specifically designed guiding questions and the worksheets.

At the end of the treatment, 56 students took the posttests. There are some students who did not attend 2 or more classes and took the posttest. The average attendance of students in each group was listed in Table 5. The researcher used data gathered from the students who attended at least 5 lessons. Thus, even if more students attended pre or posttest the number of participants was 42 in this study.

Both experimental and control group lessons were recorded by a camera and audio recorder. The record was transcribed (where student questions and comments are present) by the researcher to codes and analyze student engagement in terms of cognitive level and discourse patterns.

The study aims to explore the relationship between students' engagement and type of visualizations. Student engagement, a broad term, has some dimensions and they are students conceptual test scores, types of their questions, their comment and explanations. As an explanatory mixed-method design (Creswell, 2003) quantitative data collected and analyzed first than qualitative data gathered and analyzed.

The first instrument in this study is The Achievement Test (See Appendix A). The aim of pre-test is to assess student knowledge level and to explore whether students' scores of control and experimental groups are similar. The test was developed with contribution of three science educators and a subject-matter expert. Face and content validity of the instrument was established by the experts carefully matching the concepts measured to the concepts covered in the instruction. Due to this content area being quite new to the learners pretest reliability of the test in a study was determined to be below acceptable level (Cronbach's alpha value is .432). However post-test reliability analysis of the instrument was found to be at acceptable level (Cronbach's alpha value is .635). At the end of the treatment the same test was used to examine students' post instruction understanding of the topic.

The qualitative data was gathered through the student worksheets. In addition, researcher took field notes to describe the context in which lesson is taking place. Moreover, he also recorded video of the lessons during the treatment.

Data Analysis

The data gathered by several instruments (achievement test, video records etc.) were analyzed into two parts: quantitative and qualitative. While quantitative analysis contains statistical analysis, there is transcription of the worksheet and classroom interaction in qualitative analysis of the process.

Quantitative analysis was aimed to examine the previous level of students' knowledge about the plate tectonics and earthquake concepts. The pretest and posttest scores of two groups were testified to control whether the data was normally distributed or not by Kolmogorov-Smirnov Test. As the result stated, non-parametric tests were chosen. For the sake of a fair comparison, similarity of two groups was analyzed by Mann-Whitney U Test. Then Wilcoxon Signed Ranks Tests were performed the pretest and posttest scores for control and experimental group. The aim of this analysis was check whether learning outcome is statistically significant or by chance. After analyzing each group dependently, a potential advantage of dynamic visual treatment was investigated by another Mann-Whitney U test.

The second part contains qualitative data analysis to assess the students' learning during the treatment. Qualitative analysis was performed in two parts: analysis of students' worksheet and interaction in the classroom. Names of the students were encoded with letters with number 1 for control and 2 for experimental group.

Student worksheets were prepared to play a crucial role in this research in terms of facilitating student learning and obtaining qualitative data. Every lesson plan, control and experimental groups had one worksheet contains guiding questions, the "what I know" and "what I have learnt" parts. The researcher aimed to obtain information about prior knowledge of students and newly learned in each class.

The students' ideas on the worksheet were transcribed. The researcher was categorized them into four groups: 0: nothing, 1: misconception, 2: partially true, 3: scientifically correct and 4: irrelevant. Nothing means not answered, misconception depicts a scientifically falsified theory or an alternative conception, partially true entails there is a scientific term or phrase but incomplete, scientifically correct encapsulates a complete idea or an explanation, irrelevant points out a sentence, statement or word not related with the context.

After analyzing students' worksheets the researcher also investigated the classroom interactions by using video-records. Conversations in the classroom and questions of the students were examined to draw a conclusion about students' current understanding and engagement level about the subject. Each lesson was analyzed, control and experimental groups' analysis was presented respectively. The aim was to compare the understanding level of the students during the instruction.

CHAPTER 4

FINDINGS & DISCUSSIONS

The findings are organized within two groups: quantitative and qualitative analysis. While quantitative analysis contains statistical test result, qualitative analysis entails analysis of worksheet and student interaction.

Quantitative Analysis

Findings in the first part are based on quantitative analysis of test scores. Quantitative analysis investigates the similarity of control and experimental group before treatment. Then another statistical analysis was applied to check whether the treatment is plausible or not in each group of students. At the end of the quantitative analysis, two different teaching strategies (instruction with static visualization and dynamic visualization) were compared to each other to examine which is better to support the learning of students.

First of all, the descriptive statistics of pretest and posttest scores for both groups was identified (see Table 6).

Table 6. Descriptive Statistics

	Control Group				Experimental Group			
	n	mean	sd	variance	n	mean	sd	variance
Pretest	22	8,59	2,68	7,20	20	8,55	3,26	10,68
Posttest	22	11,72	3,11	9,73	20	11,55	3,21	10,36

After entering all the dataset in SPSS 21, test of normality was applied for both pretest and posttest scores. The test results for each variable in both groups computed as following:

Table 7. Test of Normality - Control Group Pretest

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	,178	22	,068	,916	22	,061

a. Lilliefors Significance Correction

Table 8. Test of Normality - Experimental Group Pretest

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	,229	20	,007	,888	20	,025

a. Lilliefors Significance Correction

Table 9. Test of Normality - Control Group Posttest

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Posttest	,135	22	,200*	,972	22	,757

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Table 10. Test of Normality - Experimental Group Posttest

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Posttest	,174	20	,115	,957	20	,484

a. Lilliefors Significance Correction

The sigma value of three variables are higher than 0.05 and only experimental group pretest result is significant. The Kolmogorov-Smirnov test results showed that posttest values and control group pretest scores are not normally distributed. Thus, non-parametric tests were utilized in the data analysis. Nonparametric tests are sometimes called distribution-free tests because they are based on fewer assumptions (e.g., they do not assume that the outcome is approximately normally distributed).

In this research it was aimed to see the prior knowledge of the students in both groups. This quasi-experimental study compares the treatment in two groups. For the sake of a fair comparison, groups must be similar before treatment.

The Mann-Whitney U test is the non-parametric equivalent of the independent samples t-test. It should be used when the data are not normally distributed, and they cannot be transformed to a normal distribution by means of a logarithmic transformation. In order to check whether the groups are similar or not a Mann-Whitney U Test should be used.

Table 11. Pretest Comparison of Control and Experimental Group Students

Mann-Whitney U Test

Ranks

	Class	N	Mean Rank	Sum of Ranks
Pretest	1	22	21,66	476,50
	2	20	21,33	426,50
	Total	42		

Test Statistics[a]

	Pretest
Mann-Whitney U	216,500
Wilcoxon W	426,500
Z	-,090
Asymp. Sig. (2-tailed)	,929

a. Grouping Variable: Class

The result showed that sigma value (0.92) is greater than 0.05 which means these groups are not significantly different from each other. Thus, it can be stated that the prior knowledge of students in both groups are similar and an experimental study is proper.

After pre and post-test design it was aimed to investigate the potential benefit of static visualization in learning. The Wilcoxon Signed-Ranks Test is a non-parametric statistical hypothesis test used when comparing two related samples, matched samples, or repeated measurements on a single sample to assess whether their population mean ranks differ (i.e. it is a paired difference test).

Table 12. Pretest Posttest Comparison of Control Group Students

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
Posttest - Pretest	Negative Ranks	4[a]	3,13	12,50
	Positive Ranks	16[b]	12,34	197,50
	Ties	2[c]		
	Total	22		

a. Posttest < Pretest

b. Posttest > Pretest

c. Posttest = Pretest

Test Statistics[a]

	Posttest - Pretest
Z	-3,463[b]
Asymp. Sig. (2-tailed)	,001

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Sigma value is equal to 0.001 (smaller than 0.05) means that there is a significantly difference between pre and posttest scores of the students because of the instruction (static visualizations).

Another Wilcoxon Signed Ranks Test will be used to evaluate the possible effect of dynamic visualization on students understanding of plate tectonics and earthquakes.

Table 13. Pretest Posttest Comparison of Control Group Students

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
Posttest - Pretest	Negative Ranks	2[a]	7,25	14,50
	Positive Ranks	17[b]	10,32	175,50
	Ties	1[c]		
	Total	20		

a. Posttest < Pretest

b. Posttest > Pretest

c. Posttest = Pretest

Test Statistics[a]

	Posttest - Pretest
Z	-3,253[b]
Asymp. Sig. (2-tailed)	,001

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Sigma value is 0.001<0.05 mean that the difference is statistically significant. In other words, students learn earthquake concepts and plate tectonics effectively with this instructional method (dynamic visualizations).

Another important concern for the research is the comparison of two groups' gained knowledge after treatment. This is important because the study try to examine which method is better to promote learning of plate tectonics and earthquake concepts and processes.

Pretest comparison shows that there is not a statistically significant difference between control and experimental group students' prior knowledge. For this reason, we can use another Mann-Whitney U test to check the possible difference between two treatments.

Table 14. Comparison of Instruction with Static and Dynamic Visualization

Mann-Whitney U Test

Ranks

	Class	N	Mean Rank	Sum of Ranks
Posttest	1	22	21,43	471,50
	2	20	21,58	431,50
	Total	42		

Test Statistics[a]

	Posttest
Mann-Whitney U	218,500
Wilcoxon W	471,500
Z	-,038
Asymp. Sig. (2-tailed)	,970

a. Grouping Variable: Class

The results pointed out that sigma=0.97>0.05 so the difference between two groups are not statistically significant.

The sigma value is 0.59 showed that there is not statistical significance between post test scores of two groups. The researcher also tried to investigate the practical significance and apply an effect size. Effect size after a Mann Whitney U test analysis can be evaluated by a formula (Rosenthal, 1991). The formula is:

$r=\frac{Z}{\sqrt{N}}$ where Z: sigma value, N: number of participant r: effect size

r= - 0.526 / √47 = 0.076 which is so close to 0 which means there is not a practical significance.

Qualitative Analysis

Second research question of the study was “Are there any differences between the cognitive and discursive engagement level of the 8th grade students who receive instruction with dynamic visualizations compared to receiving instruction with static animations?” In order to obtain more knowledge about the process qualitative analysis was conducted. Qualitative analysis has two important instruments: worksheet and classroom interactions.

Student Worksheets

The general overview of the worksheets showed that students do not have scientific ideas about geological concepts before the treatment. Especially, students in control group generally had misconceptions and they did not reflect their ideas on worksheets (see Table 15). The numbers represents students’ answer and categories were 0: nothing, 1: misconception, 2: partially true, 3: scientifically correct and 4: irrelevant. The given number of the students in control group is generally 0 because they did not give any answer to what I know part. For example, while there are only 2 students have an answer in lesson 1, 4, and 5; there is no answer in lesson 2, 3, and 6. Because of the finding epicenter activity in lesson 6 took long time they did not completely filled out that worksheet. However, dataset pointed out that students do not want to share their current knowledge about the concepts covered in each lessons.

Nevertheless, students were generally filled out the “what I learned” part and the answer were mostly “partially true” or “scientifically correct”. Generally the data pointed out that students learn some scientific terms or explanation in the treatment.

Table 15. Summary of Students' Worksheet in Control Group

Control Group - Summary of Worksheets												
	Lesson 1		Lesson 2		Lesson 3		Lesson 4		Lesson 5		Lesson 6	
Students	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
A1	1	0	0	0	0	1	0	3	0	3	0	0
B1	0	3	0	2	0	3	0	3	0	0	0	0
C1	1	0	0	3	0	3	0	2	0	0	0	0
D1	0	3	0	3	0	0	0	3	0	2	0	0
E1	0	4	0	1	0	2	0	2	2	2	0	3
F1	0	2	0	2	0	2	0	2	0	3	0	3
G1	0	2	0	3	0	3	0	2	0	3	0	0
H1	0	3	0	3	0	3	2	3	0	2	0	0
I1	0	3	0	2	0	3	3	3	0	2	0	0
J1	0	2	0	3	0	3	0	2	0	2	0	0
K1	0	2	0	2	0	3	0	1	0	0	0	0
N1	0	2	0	2	0	3	0	0	2	0	0	3
O1	0	3	0	2	0	3	0	3	0	0	0	0
P1	0	3	0	3	0	2	0	3	0	3	0	0
R1	0	3	0	2	0	2	0	2	0	2	0	0
S1	0	3	0	0	0	2	0	0	0	3	0	0
T1	0	1	0	1	0	2	0	1	0	2	0	0
U1	0	1	0	2	0	0	0	3	0	2	0	0
V1	0	1	0	1	0	0	0	3	0	0	0	0
Z1	0	1	0	1	0	1	0	2	0	2	0	0
X1	0	2	0	1	0	0	0	0	0	0	0	0
W1	0	3	0	2	0	3	0	0	0	0	0	0

0: Nothing, 1: Misconception, 2: Partially true, 3: Scientifically Correct, 4: Irrelevant

When examined the worksheets in experimental group students also had some misconceptions. In contrast to control group, students in experimental group were willing to fill out the student worksheets. For example, there are only 8 students who had no answer in lesson 1. Similar to the static group, worksheets of lesson 6 were not filled by the students.

Students generally had scientific ideas compared to their knowledge before the treatment (See table 16). This means the treatment had a positive impact on their understanding of plate tectonics and earthquake concepts.

Table 16. Summary of Students' Worksheet in Experimental Group

Experimental Group - Summary of Worksheets												
	Lesson 1		Lesson 2		Lesson 3		Lesson 4		Lesson 5		Lesson 6	
Students	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
A2	1	3	0	0	0	0	2	2	0	3	0	0
B2	4	3	0	4	0	0	2	3	1	2	0	0
C2	1	2	2	0	0	0	3	3	0	2	0	0
D2	0	2	0	3	2	3	0	2	2	3	0	0
E2	3	3	2	3	0	3	3	3	3	3	0	0
F2	3	3	2	3	0	0	2	3	2	3	0	0
G2	0	3	0	0	3	2	3	3	0	0	0	0
H2	2	2	3	3	2	0	3	3	3	3	0	0
I2	2	2	0	0	0	2	3	3	3	3	0	0
J2	1	2	3	0	0	2	2	2	2	0	0	0
K2	0	3	0	0	0	2	3	3	2	3	0	0
L2	0	2	2	0	0	2	2	3	0	0	0	0
M2	0	2	0	3	0	3	2	3	0	3	0	0
N2	2	2	3	0	3	3	2	3	0	0	0	0
O2	0	2	3	0	0	3	2	3	0	0	0	0
P2	0	2	0	0	0	0	0	2	0	0	0	0
R2	0	3	3	0	4	0	3	2	0	0	0	0
S2	1	0	0	0	0	2	2	2	0	0	0	0
T2	1	3	0	0	0	2	0	2	0	0	0	0
Y2	1	3	0	3	0	3	2	2	0	3	0	0

0: Nothing, 1: Misconception, 2: Partially true, 3: Scientifically Correct, 4: Irrelevant

The worksheet analysis demonstrated that students were generally not comfortable with or were used to give an answer to a worksheet question. This was the common concern in two groups. This issue was compatible with the field notes of the researcher before the treatment. In control group, positive change in students' understanding for every lesson was quantified. The summary of the students' worksheet assists to evaluate data in a holistic way (see Table 17). While before and after row shows the category of the students' answer, the lessons rows contain the number of students who write down answers in this category. For example, there were 10 students who have no answer before and a scientific explanation after the lesson 3.

Table 17. Gained Difference in Worksheets – Control Group

Control Group							
Gained Difference		Lessons					
Before	After	1	2	3	4	5	6
0	0		2	4	4	7	19
0	1	4	5	2	2		
0	2	6	9	6	7	8	
0	3	9	6	10	7	5	3
0	4	1					
1	0	2					
2	0					1	
2	2					1	
2	3				1		
3	3				1		
# of participants		22	22	22	22	22	22

0: Nothing, 1: Misconception, 2: Partially true, 3: Scientifically Correct, 4: Irrelevant

The direction of the change in the students' worksheets was labeled as positive or not. The positive changes were defined as the change from nothing to partial (0→2), nothing to scientifically correct (0 → 3) and partial to scientifically correct (2 → 3). The highest positive change (72.73) was in the lesson 3 (see Table 18).

Table 18. Summary of the Gained Difference in Worksheets – Control Group

Control Group								
Gained Difference			Lessons					
Before	After	Change	1	2	3	4	5	6
0	0			2	4	4	7	19
0	1		4	5	2	2		
0	2	+	6	9	6	7	8	
0	3	+	9	6	10	7	5	3
0	4		1					
1	0		2					
2	0						1	
2	2						1	
2	3	+				1		
3	3					1		
Positive Change		%	68.18	68.18	72.73	68.18	59.09	13.64

0: Nothing, 1: Misconception, 2: Partially true, 3: Scientifically Correct, 4: Irrelevant

After analysis of the control group, same operations were done for experimental group students' worksheets (see table 19). Because of the fact that students in control group generally gave an answer to the "what I know part" there are more variance in change compared the control group.

Table 19. Gained Difference in Worksheets – Experimental Group

Experimental Group							
Gained Difference		Lessons					
Before	After	1	2	3	4	5	6
0	0		7	5		8	20
0	2	5		6	3	1	
0	3	3	3	4		3	
0	4		1				
1	0	1					
1	2	2				1	
1	3	3					
2	0		2	1		1	
2	2	3			4		
2	3		2	1	6	3	
3	0		4				
3	2			1	1		
3	3	2	1	1	6	3	
4	0			1			
4	3	1					
# of participants		20	20	20	20	20	20

0: Nothing, 1: Misconception, 2: Partially true, 3: Scientifically Correct, 4: Irrelevant

Similar to the control group analysis the direction of the change was examined. The positive changes were defined as the change from nothing to partial (0→2), nothing to scientifically correct (0 → 3), misconception to partial (1 → 2), misconception to scientifically correct (1 → 3), partial to scientifically correct (2 → 3), and irrelevant to scientifically correct (4 → 3). The highest positive change (70) was in the lesson 1 (see Table 16). Compared to control group the percentage was low, however, it stems from the variance in the before column.

Table 20. Summary of the Gained Difference in Worksheets – Experimental Group

Experimental Group								
Gained Difference			Lessons					
Before	After	Change	1	2	3	4	5	6
0	0			7	5		8	20
0	2	+	5		6	3	1	
0	3	+	3	3	4		3	
0	4			1				
1	0		1					
1	2	+	2				1	
1	3	+	3					
2	0			2	1		1	
2	2		3			4		
2	3	+		2	1	6	3	
3	0			4				
3	2				1	1		
3	3		2	1	1	6	3	
4	0				1			
4	3	+	1					
Positive Change		%	70	25	55	45	40	0

0: Nothing, 1: Misconception, 2: Partially true, 3: Scientifically Correct, 4: Irrelevant

Analysis of the worksheet showed students learned the basic terms and concepts related with plate tectonics and the earthquake. Obtaining information from different sources, data triangulation, may increase the validity of a qualitative study (Guion, 2002). Hence, after analyzing the worksheet, researcher were transcribed the students comments and questions.

<u>Lessons</u>

Lesson 1: The Formation of the universe and the earth

The target of first lesson was to introduce the students with the theories about the formation of the universe and the earth. In order to assist this process researcher set up some important terms science and scientific theory then the several important explanations about these geological events. The researcher conducted the lesson and listed several important concerns here.

The students' prior knowledge was interesting in terms of their ideas about geological concepts before the treatment. They have non-scientific explanations about the formation of the universe and the earth.

A2: "God created the universe and the earth"
C2: "God created and configured…"
J2: "It is the will of the God"
Y2: "God created the universe"
S2: "God created universe and the world"

The researcher used videos and materials to explain two theories for each phenomenon. At the end of first lesson, students' ideas were changed in accordance with scientific theories covered in the classroom. For example, participant A2 stated that "The earth formed after the Big Bang". At that point, it is reasonable to claim that students had a perspective about the formation of the earth and Big Bang theory. After the lesson, students in control group did not relate the formation of the Earth with God.

Although many scientific explanations existed in the class, several students had still the same misconception about the formation processes. For example, A1 argued that "The Earth that was a detached part of the Sun cooled. It is formed at the end of the noted process." In addition, there were other students in the control group have the same ideas about the existence of the Earth:

C1: "The Earth that was a detached part of the Sun is formed by cooling."
I1: "The universe is constant and does not have a starting point."
T1: "Earth was formed by a detached body from the Sun."
U1: "The Earth is a detached part of the Sun. Universe is constant…"

In the experimental group, students did not have this type of explanations. These difference between students' comment about the formation of the universe and the earth can be an important point to underline by the researcher. The only difference between each group is the existence of a video about how we find these scientific theories. Students in experimental group study the terms with a video. However, the researcher provided information verbally and with the help of static images on the presentation for students in control group. The aim was investigating the effectiveness of the video which shows how scientists explain the expanding universe and Big bang theory.

Lesson 2: Structure of the Earth

Lesson 2 encapsulates the knowledge about the inner structure of the Earth. After giving the scientific explanations about the universe and the earth, the researcher aimed to help students to understand how science explains the Earth's inner structure. Worksheets examination showed that there is not any misconception about the structure of the Earth at the beginning of the lesson. At the end of the class, students have a general idea about layers and seismic waves. For example, participant G1 stated that "There is a core at the center and we realize structure of the earth with the help of those waves." Also, H1 told that "I learnt structure of the earth, P and S waves, and their directions."

It is notable to state that the mechanism inside the Earth model was a new idea for students in both groups. While the researcher talked about the seismic waves and their function to understand inner structure of the Earth was significant for the students. Their feedback was surprising because seismic waves' critical role assisted them to understand how we know about the inner structure of the earth. For instance, J1 stated that "I comprehended that P and S waves help to understand the inside of the world and its layers". Moreover, Y2 commented that "We know the layers inside the earth by using seismic waves". Thus, learning materials were effective to assist students understanding of seismic waves and how they shows there is a core and a liquid state inside the earth.

Lesson 3: Plate Tectonics I

Plate tectonics, the main concept in the treatment, was given in the lesson three. The lesson contains seismic waves and continental drift theory of Albert Wegener. Students were also given the convection video in both control and experimental groups. The existence of the convection video is notable here. Because of the important role in understanding the motion of the plates, researcher used the video in control group too.

The basic problem for the students during the lesson was the unawareness of the difference between plate and continents. They used the term continents instead of plate. For example, U2 said that "As a consequence of convection at the center of the Earth, continents are constantly moving and new places would be formed". In addition, N1 argued that "Structure of the earth bring about the movement of the continents". Similarly, G2 told that "Several continents go away, many continents coming close to each other". It is reasonable to claim that some students in each group do not have a clear understanding about the term plate.

However, many of them were aware of the plate concepts for instance, I1 pointed out that: "I learn that plates are in motion and continents move away from each other". Furthermore, J1 stated that "Plates are moving and continents are diverging". And, G1 stated that "The movement of the continents stem from the earth's structure". The similar understanding is visible in experimental group. For instance, E2 claimed "Because of the convection, while several plates are diverging some of them converging". This was a significant parameter for the researcher because plate is a new concept and although it is not clear for some students, many students have learned it.

Interestingly, some students used a more general term "surface" to explain the effect of convection to the Earth. They used it to explain several geological processes such as volcanoes and earthquakes. For instance, H1 said that "In the lesson we discussed the convection. Convection is a result of the heat inside of the earth and creates a movement on the surface". In addition, S1 stated that "Hot liquid material inside the earth results in divergence or convergence on the surface". Furthermore, C1 stated that "Because of the inner structure of the Earth volcanoes and earthquakes happen". O2: "We learned the mechanism how the volcanoes, mountains and ocean floor by observing them one by one."

In addition, many students have focused on the Pangea and the potential position of the continents in the future. For instance, V2 stated that "We learned continents were a single body and we know that billions years later they will become closer again". More interestingly, Albert Wegener's story was so exciting for the students and they were participated the discussion. His story was crucial for the students to comprehend the emergence of continental drift theory. In addition, there are several key concepts such as nature of science and knowledge building process in a scientific domain. Researcher asked several questions such as what is the problem of Wegener's theory, "Can we label his observations about the continents as an experiment?" and "Can scientists have different explanations with the same dataset?"

Students were able to comprehend important ideas about the nature of science. For example, N1 stated that "Yes. While a scientist draws a conclusion another one can come up with different consequence in scientific context. The discussion about the Wegener's story was important to assist students' understanding of the emergence of a scientific theory, the rationale under the acceptance or resistance of the theory, the importance of experiment in building a theory, drawing different conclusions with the same dataset.

Lesson 4: Plate tectonics II

Lesson 4 is the complementary of lesson 3 and tried to assist students to understand movements of plates and the geological structure in the consequence of it. Because of the fact that plate tectonics is a complex concept lesson 4 also contains the movements of the plates and changes on the Earth with specific examples. For example, each group had a chance to learn how Andes Mountains in Chile and Hawai islands were formed through the plate movements. Below are some of the student responses to what I have learnt question after the lesson.

A1: “Plates can be a cause of natural disasters when they collided”
B1: All plates’ movements result in earthquakes. When two continental plates are collided mountains exist.
D1: When two continental plates come close mountains, when they move away a new place emerges. If oceanic plates converges trench, they diverges ocean floor formed.
P1: “All plate movements stem from earthquakes. “
V1: “Plate movements give rise to earthquakes. When two continental plate come closer mountains formed”
C2: “Movements of plates can create natural disasters like volcanic eruption.”
D2: “Formation of mountains ocean floor and trenches.”

After the lesson, students have a general idea about plate movements compared to previous lesson. They could understand why we have such volcanoes, mountains, and several other places. The terms convection, plates’ movements and earthquake helped students to develop a holistic and integrated understanding.

Lesson 5: Earthquake

Lesson 5 was designed to teach students the earthquake and related concepts. For example, A1 stated that “Earthquakes happens with the fall of faults with different size inside the surface”. Seismic waves were evaluated the basic reason of the earthquakes. For instance, H2 stated that “The reason of the earthquake is the seismic waves”. And, K2 argued that “P waves comes first then S waves and lastly the surface waves generate high destruction during an earthquake”. Moreover, M2 claimed that “I understand that how an earthquake happens and the seismic waves travel. Also I realized the disasters after an earthquake.”

Students had also a general comprehension about the earthquake concept. For instance, F1 stated that “I learned that seismology is the science dealing with earthquakes. Also, epicenter is the place that earthquakes are felt”. Moreover, A2 talked that “I learn that the scientist study earthquakes called seismologist”. We can see that students in each group have a general idea about what is an earthquake and how it happens.

Lesson 6 Seismogram Analysis

The final activity of the unit plan is finding the epicenter of an earthquake by using real seismogram from 3 different locations. Students worked in groups and mostly they were successful to realize S and P waves, calculating the time difference, converting it into the actual difference, finding its equal data in the small extend, then drawing a circle. Both experimental and control groups did not completed the task.

Summary of worksheets

The analysis of worksheets has several important conclusions. Students learned many concepts during learning unit. Students in experimental group had no scientific explanations about the formation of universe and the earth before the treatment. They reflected scientific expressions at the end of the lesson. This change in the students' sentences could be interpreted as video was effective for understanding the formation of earth and universe.

Moreover, no one had a misconception about structure of the Earth. The seismic waves and their function were a new concept for them. Qualitative data showed that students have a clear understanding about the seismic waves and their role. Nevertheless, student in both groups had a conflict between plate and continents. They use them interchangeably to express the consequences of the waves.

Although several students had a conflict about plate tectonics, many students comprehended the term plate and use it effectively in each group. Several students used the term surface and talked about other geological events like volcanoes. They present an interest in Pangea and Wegener's story. Nonetheless, all the students had the same chance to observe different geological places because of the plate movements. Also, students presented a general idea about an earthquake with its terms.

The students were reluctant to use worksheet and researcher could not be able to collect rich data about their existing knowledge. In addition, sixth questions was has the lowest percentage among both groups because of the time that the finding epicenter activity took.

Students have a general problem in the plates. Although they showed a general understanding about the seismic waves, they had problem with the 11th question that asks what happens when two continental plates would collided. Only 4 students in control and 6 students in experimental group answered the question correctly. 13 and 15th questions were also related with movements of plates but totally 12 and 14 students answered the questions respectively. Lastly, the students also have a problem about 20th questions which as the type of fault. They showed high performance on understanding the concepts related with earthquakes, however, they were not sure about the types of faults.

Classroom Interaction

Second part of qualitative analysis investigates the interaction during the lessons in both groups. As a researcher, I have observed two classes of control and experimental groups. One of them was science class for both, other one was Math class in control and English class in experimental group to understand participation and interaction patterns.

Observations suggest that the students in both groups were similar in terms of participation in classroom activities. The nature of class atmosphere in both of these lessons can be described as noisy; teachers were generally trying to take attention of the students by increasing the volume of their voice. The participation of the students was limited and they just asked very few questions. However, compared to what was observed in these lessons, students showed much more attention participated to the lesson more by asking questions during the implementation of treatment.

To understand if there is any difference between the control and treatment group with respect to the cognitive and discursive engagement level of the 8th grade students. The videos were transcribed selectively (where student questions and comments are taking place) by the researcher to analyze the students' questions and comments. Students' phrases and sentences were translated into English.

There is a general analysis about the students' questions and conversations so the codes are not the same as the numbers in the worksheet analysis. Control group and experimental group interactions during the treatment were analyzed based on the transcribed records and they were listed here respectively. In addition, the number of conversation and questions, and the types of the questions compared at the end of the analysis.

Control Group

According to the data analysis, first lesson entailed 2 questions and 2 conversations. The lesson had a discussion part at the beginning related with science and scientific theory. First conversation showed that students could give examples about science.

Researcher (R): What is science?
Ç1: Ability to learn
R: Tell me a scientific discipline
Ç1: Chemistry
R: What do you know about chemistry?
Ç1: Atom, substance
Ç2: Archeology. It analyzes historical masterpieces.
R: How science can do this? What is the process to find something in any field of study?
Ç3: It is exploring. It tries to find certain things to proceed.
Ç4: It tries to reveal the unknown things. For example, the spherical shape of the Earth.
R: Do you know how the scientists explain the shape of the Earth?
Ç4: It was a part of the Sun which was getting colder…
R explained that it is a theory and falsified. Then he gave the definition of science

While the researcher explain the terms one of the students were asked the meaning of a word: “What do you mean by systematic?” The researcher explained the term with several examples. Another conversation between a student and the researcher was related with the definition of a scientific theory:

R: What is scientific theory?
Ç1: The sentences about the science?
R: Can you give me an example?
Ç2: Making an assumption
R explained it by the law of gravity then gave the definition of scientific theory.

Another question was directed to researcher “Is it a formula?” and the researcher answered that scientific theory is complex explanation about daily life.

Second class also involved 2 questions and 2 conversations. After the balloon activity the researcher aimed to talk about the observation:

R: What do you do during the activity? How was it?
Ç1: The distance between them increased when we blow up the balloon.
R: Is there any other kind of observation during the activity?
The answer is “we have the similar observation”

The researcher showed the screenshot about the layers of the Earth and two questions came: Where is hydrosphere? And where is magma? The researcher started another conversation about the structure of the center of the Earth.

R: How do we know there is a core at the center?
Some students insisted on we can travel and observe directly
Ç1: Scientists tell us
Ç2: I have heard on the news scientists digging to reach there.
Ç3: The volcanoes indicate that there is how substance inside the Earth and scientist analyze them.

There were not any questions in third lesson. However, 3 conversations were emerged during the lesson. First conversation started with the guiding question of the researcher and students realized the similarity of the continents. Nevertheless, they could not explain the reason why they are similar.

R: Do you see any similarity between the boundaries of the continents?
Ç1: No I can not
R: I think the Asia and Europe has a similarity…
Ç2: Teacher, I realize a resemblance in the South and North America
R: What could be the reason of this overlapping? What do you think?
Ç3: I guess it may be a consequence of the plates.
R: How?
Ç3: I do not know. Maybe

After the puzzle activity researched asked what they did during the activity and what made them to complete the puzzle. The activity helped them to recognize the continents were a part of a single body.

R: How did you conduct the activity?
Ç1: We used the boundaries and the figures
R: What is the meaning of the figures on each part?
Ç1: Animals. We make use of them to find the interrelated parts.
R: You created one single body by using the pieces. What can we infer from this?
Ç2: They were together in the past

The researcher gave the story of Wegener which contained his effort to find and prove continental drift theory. There were several questions about the story and they were used as a guide to start discussion.

R: What is the importance of attending this type of meetings?
Ç1: He wanted to share.
R: Why did he go there?
Ç1: In order to tell the people
R: Ok. Did the scientists believe in the Wegener's argument easily?
Ç2: They did not believe
Ç3: Wegener explained the movements of the plates but he did not give the reason.

Students were aware the importance of the scientific conferences and other scientist' refusal against Wegener's explanation of the movement of plates. One of the students were replied the deficiency of the theory of Wegener.

Another question was related with the Wegener's story asked the role of experiment in science. Students labeled observations of the Wegener as an experiment because he provided evidence for his theory.

R: Do you think finding fossils as an example of the experimental study?
Ç1: Yes
R: Why?
Ç1: He proved it, he observed.
R: Do two scientist can come up with different explanation by using the same dataset?
Ç2: Yes they can because they have different perspectives

Lesson 4 only involved one conversation about movement of plates. Moreover, Lesson 5 contained one conversation and one question about the earthquakes. The conversation was about the key terms related with the earthquake.

R: What is an observatory?
Ç2: The place where the earthquakes are measured.
R: What is the difference between center and epicenter?
Ç3: Center is at the bottom, inside of the surface.
R: What kind of waves we have learned so far?
Ç4: P and S
Ç5: Surface waves as well as.
R: What is the difference between magnitude and intensity?
Ç6: Magnitude shows what the damage of the earthquake. Intensity tells what the number is. It is measured by Richter.
R: Intensity
Ç7: Mercalli.
R: What could be the consequences of an earthquake?
Ç8: Flood
Ç7: Tsunami

One of the students was hesitated about the consequences of an earthquake and asked "Teacher, how the fire could be as a result of the earthquake?"

In summary, students were actively participated in the classes. Although they were active in the lessons, their questions was limited and low level. They focused on the words and meanings in generally. Moreover, they were able to give examples about science but not successful about scientific theory. In addition, they realized the importance of participating in scientific conferences and the deficiency of Wegner's theory. They showed a general understanding about the key terms and concepts.

Experimental Group

Compared to control group, lessons of experimental group were more interactive and students asked more questions and participant in the discussions.

Lesson 1 contained three short conversations about science, scientific theory and the formation of the Earth.

R: What do you think about the term “science”?
Ç1: Knowing the truth
R: What is science?
Ç1: Learning
Ç2: Explore. Revealing any new ideas… Learning more than we know…
Ç3: To explain

Students were expressed the science as knowing the truth and learning. They thought that it is a kind of means to get certain information by learning new things. While they had a perspective on science they did not tell much about the scientific theory.

R: What is a scientific theory?
Ç1: Formulas. We used them in math to calculate.
R: Can you give me an example of a scientific theory?
Ç2: Rotation of the Earth
R: Can it be a theory?
Others: Yes it can
R: Does rotation of the Earth or explaining why/how it rotates an example?
Others: explaining.

Another conversation, the researcher initiated was searching for the formation of the Earth. One student proposed a non-scientific explanation about the formation of the earth; however, other students answered the question correctly.

R: What do you about the formation of the Earth?
Ç1: It was in a gaseous state. It became denser and getting bigger
R: Does it getting bigger or changing the form?
Ç1: I think it became bigger.
Ç2: Its form is changing.
Ç3: it was a part of the Sun in the past

Lesson 2 covered the inner structure of the Earth. There were two short interactions happened in the classroom. Students were able to answer there is a core at the center.

R: What do you know about the inner structure of the Earth?
Ç1: There is a core and layers.

Ç2: Mantle and crust

In this conversation, one of the students were answered the mechanism to inspect the existence of the core at the center. He proposed that it can be inferred from the calculation of the heat produced by the Earth. However, his ideas were changed after studying the animation.

R: It is impossible to reach the core of the Earth. How can we know there is a core at the center?
Ç1: Measuring the heat it produced.
Ç2: With the help of seismic waves.
After the animations Ç1: P waves in both S waves travel only in liquid state

Lesson 3 and 4 were the mostly interacted lessons and 6 questions and 5 conversations were emerged during the lessons.

Similar to the control group, several students were able to see the similarity of the boundaries of the continents. However, there was an explanation which was not completely true but partially correct about overlapping of the continents. They were also conscious about the role of fossils and animals to find the relationship between continents.

R: We will focus on the inside of the Earth. Do you see any similarity between the boundaries of the continents?
Ç1: No
Ç2: Yes
R: Where do you see?
Ç3: In Europe
R: What is the reason of this overlapping?
Ç4: The continents are in motion.
Ç5: I agree with him

R: How did you put the pieces together?
Ç1: By using the figures and boundaries of the continents.

One answer of the students to the research's question about the aim of the puzzle activity was important because he perceived the activity as finding an explanation about the continent overlapping.

R: Why did we do this activity? What was our aim?

Ç2: In order to create our scientific explanation about this subject

After puzzle activity story of Albert Wegener were studied. Students tried to answer about the importance of the scientific conferences. One of the students proposed that while there are many information people do not believe in one scientist normally.

R: What was the importance of attending this kind of meetings?
Ç3: He founded that they were union in the past
R: Why does he explain in such platforms?
Ç4: He tried to explain his findings.
R: Who is the audience?
Ç4: Scientists.
R: Is it important? Why the scientists do not agree with the idea of Wegener?
Ç1: They think that we need to study
Ç2: While there is a lot of information not believing one scientist is normal.

Similarly, students in experimental group were also evaluated the comparing fossils and stones as experiment however they used more specific verbs like compare, investigate and explore.

R: He compared the fossils and stones. Do you evaluate this as an experiment?
Ç3: Yes because he compared and investigated.
R: Why we do experiments?
Ç3: To explore
R: Ok. Do two scientists can come up with different results by using the same data?
Ç4: Yes

After convection video students have a better understanding about the layers of the Earth.

R: What is the structure of mantle?
Ç1: Liquid
R: What kind of motion you observed?
Ç2: Upward

They showed a clear understanding about the heat at the center and its potential consequences on the surface. They also concluded that the continents will become a single body again in the future.

R: What can be the potential consequences of this convection movement?
Ç1: earthquakes
Ç2: Volcanoes
R: What will be in the future?
Ç3: They become one body again

The questions were mostly comprehension questions to make sure about some concepts like volcano and plates.

Q1 – Where is the place that the biggest explosion? Which volcano?
Q2 – What is the biggest volcano?
Q3 – What is happen the volcano? How it is formed?
Q4 – Converging and diverging of the plates creates volcanoes. This is the only way we have volcano? Can it be a volcano in constant motion?
Q5 – Is it true in the worksheet? Why is this one the oldest layer in Atlantic ridge?
Q6 – Can we reach the mantle when we follow the volcanic vent?

Lesson 5 had also a high interactivity and involved 3 conversations and 3 questions. First conversation was like summary of the first 4 lessons and students correctly expressed the key terms and issues in the unit.

R: What we have learned so far?
D1: Waves
D2: Inner structure of the Earth
D5: volcanoes, mountains, ocean floor
A2: Plate types
Ç1: We learned what science is
Ç6: We learned the formation of the Earth

The researcher asked another guiding question and expect student to answer why we have earthquakes places not located in the plate boundaries. One of the students used the term faults.

R: We learned that there are earthquakes on the boundaries of the plates. Is it the only place we have the earthquake?
E1: Yes
R: How can we explain the earthquakes happing in Turkey?
Ç1: Because of the seismic waves.
Ç3: There is a term faults

The researcher started another conversation about the reason of the tension stored in the faults. Students could able to answer the question correctly and proposed other details related with the subject.

R: There is a tension on the crust. Who can tell me what is the reason of this tension?
B2: It can be a cause of the faults
R: What is the reason of this tension?
A1: when the plates are converging the tension increases.
R: What is the source of the tension?
A1: Because of the waves.

Questions were more sophisticated compared to control group because students tried to learn the concept in a deeper way.

Q7 - A1: why one is normal and the other reverse. How?
Q8 – If the center of the earthquake is under 4-5 km lower the surface does it travel slowly? Some people argue that 1 week later we would have an earthquake. How is it?
Q9 – How can we differentiate the intensity and magnitude of an earthquake?

Sixth lesson of the unit, only 1 conversation and 2 questions were raised in the classroom. Students could not successfully answer how we can find the epicenter of an earthquake.

R: Does the seismic waves contain information about the center of an earthquake? How we measure the exact place of the earthquake?
Ç4: We can count the waves
Ç4: We can calculate the intensity
Ç5We can calculate by the time of it.

Q10 - When R shows the seismogram A1 asked where is surface waves?

The researcher explained that surface waves are not important to determine the earthquake's epicenter. Next question was so crucial because the student tried to apply his knowledge to another situation and asked what if we had another observatory. Researcher explained the situation by using another animation.

Q11 – Does the difference between P and S is higher in this observatory because of it is far away from the earthquake compared the other stations?

It is reasonable to come up with the conclusion that students were more participant in and active in experimental group. There were more conversations and questions compared to control group (see Table 21).

Table 21. Comparison of Conversations

CONTROL GROUP							
	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Total
# of questions	2	2	-	-	1	-	**5**
# of conversations	2	2	3	1	1	-	**9**
EXPERIMENTAL GROUP							
	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Total
# of questions	-	-	2	4	3	2	**11**
# of conversations	3	2	2	3	3	1	**14**

In addition to the number of the questions the cognitive level of them are also better in the experimental group. While there were one simple wording and 4 comprehension questions, experimental group had 9 comprehension and 2 analysis questions (see Table 22).

Table 22. Distribution of the Questions

Question types	Control	Experimental
Simple wording or phrase	1	
Comprehension	4	9
Analysis		2

As a conclusion of the qualitative analysis, experimental group students were more participated in the classroom discussion. Students in control group asked less number of questions which focused on terms, however, there were more complex questions of the students in experimental group.

Not only their understanding was increased in terms of test scores, but also they had a high participation and active engagement in the treatment compared to their classes before the treatment. Although there is not statistical significance on the test scores of the students,

students in the experimental group had a high interaction and participation compared to control group.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATION

With the advancement of multimedia learning in educational setting, science education research also paid much attention to use technological tools. For example, WISE aimed to create a possibility for learners to work collaboratively on global warming (Slotta, 2004). Scientific disciplines have many complex and abstract concepts, and process. Because of their context-dependent difficulties visualizations create a plausible context to support learning science trough inquiry. For this reason, researchers in science education have focused on students' understanding of scientific concepts via different types of visualizations (Höffler & Leutner, 2007; Ryoo & Linn, 2012; Yarden & Yarden, 2010; Zhang & Linn, 2011). There is an ongoing debate on the type of visualizations which is more effective to support learning. Although several studies showed that dynamic representations were more effective for learners (Ardac & Akaygun, 2005; Yarden & Yarden, 2010); others advocated that static pictures were equally effective or superior to dynamic visualizations (Mayer et al., 2005; Tversky et al., 2002).

The study aimed to examine the possible difference between static and dynamic visualizations to assist students for learning plate tectonics and earthquake concepts. The basic assumption here is that these two interventions is better than the methods without a technological tool. In order to test these hypotheses, a quasi-experimental study was conducted and data was analyzed quantitatively and qualitatively.

For both groups, tests results point out that there is a statistically significant difference between students' pretest and post test scores in favor of their posttest scores. The qualitative data collected by worksheets, video-records and field notes. Students showed an integrated understanding about the core concepts like seismic waves, earthquake, plate tectonics, convection etc. Based on these findings, we can conclude that the intervention had a statistically significant positive effect on students' understanding of targeted concepts. Thus, the results confirm the idea that instruction containing visualizations can assist students learning processes (Höffler & Leutner, 2007; Ryoo & Linn, 2012; Yarden & Yarden, 2010; Zhang & Linn, 2011). In other words, results in this study argue that proper use of technology can promote students' achievement in learning plate tectonics. Our findings specifically show that dynamic visualizations work, especially in teaching about dynamic processes because students post test scores were significantly higher than their pretest scores.

The findings of the study raise the questions about the deep difference between the instruction with static and dynamic visualizations. Qualitative and quantitative data analysis points out that, although dynamic visualizations can provide a valuable context for learning and have a great potential as a learning tool, static visualizations are not necessarily inferior to them. Both students in control and experimental group had better post test scores compared to their pretest scores, however, it was not statistically significant. Although the post test scores, number and quality of the questions and interactivity were better in experimental group students, the difference was not significant statistically.

The results also confirms the findings of previous studies that argue dynamic visualizations are not superior to static visualizations (Hegarty et al., 2003; Mayer et al., 2005; Klein and Koroghlanian, 2004; Morrison et al., 2000; Tversky, et al., 2002). However, it did not agree with the results of other studies that show a significant advantage of dynamic visualization over static ones (Ainsworth & VanLabeke, 2004; Bodemer, Ploetzner, Feuerlein, & Spada, 2004; Kelly & Jones, 2007; Khalil, Lamar, & Johnson, 2005b; Marbach-ad, Rotbain, & Stavy, 2008; Ryoo & Linn, 2012; Trindade, Fiolhais, & Almeida, 2002; Williamson & Abraham, 1995; Yarden & Yarden, 2010; Zhang & Linn, 2011). The results argue that dynamic visualizations are not superior to static ones in terms of supporting students' learning.

In their research, Tversky et. al (2002) argue that dynamic visualizations has no advantage over static visualization in terms of learning. They claim that if the students' scores on the dynamic visualizations are high it is just because of they have more information compared the static visualizations. However, this argument is not plausible in this setting because in this study all parameters except the type of the visualization embedded in the instruction were the same. The static visualizations were produced by taking screenshots from the animations. The instructor, instructional time, lesson plans, and materials were the same in control and experimental groups.

Another study conducted by Hegarty, Kriz and Cate (2003) concluded that students in static and dynamic groups can have an integrated understanding about the mechanism of a flushing cistern. Similarly, students in control and experimental groups have a general understanding about plate tectonics, layers of the earth, seismic waves and earthquake. It shows that students can come up with scientific explanations whether they study with static or dynamic visualizations. This can be explained by the plausibility and effectiveness of the lesson plans and learning sequence.

The meta-analysis of Höffler and Leutner (2007) point out there is not superiority of dynamic visualizations to static visualizations. 53 comparison out of 76 show there is not a statistical significant between those different types of materials. They also conclude that animations are not helpful if they are decorative and the only way to be effective is being representative (Höffler & Leutner, 2007). The argument is valid and do not have a conflict with the results of our study. Höffler and Leutner (2007) criticized the use of animations for attraction or fun; however, animations used in this study, which were prepared in accordance with the multimedia learning theory, were specifically created to promote student understanding.

Similarly, another study of Zhu and Grabowski (2006) used three treatment groups: static group, animation as taking attention, animation as taking attention and elaboration. They found that students in static groups are also knowledgeable about how human heart works. With that result they also imply that static visualizations are cost-effective and efficient (Zhu & Grabowski, 2006). However, dynamic visualizations can be effective under optimum circumstances. Indeed, they were helpful on the learning process and increasing students' curiosity and gaining their attention. Although there is not a statistical significance between groups, scores was higher and lessons were more interactive in experimental group than in control group. This results favors dynamic visualizations to some extent both product and processes of learning.

Limitations

Although the research has positive implication to facilitate students' understanding of plate tectonics and earthquake concepts, there are several issues need to be improved.

First of all, thanks to Provincial Directorate for National Education, Istanbul, the researcher was able to choose a public primary school. Also the teachers and school principal facilitated to implement the treatment in the school. However, new exam schedule made the process problematic. In addition, they placed the "Natural Process" at the end of the 8^{th} grade curriculum. The treatment process was difficult to conduct because of the upcoming TEOG (Entrance Exam for Secondary Education). For this reason, teachers and students were not motivated in the study at the beginning of the treatment.

Secondly, achievement test of this study was developed with the contribution of subject-matter expert by mapping the concepts in the learning unit. However, the Cronbach alpha values were low. While gathering qualitative data this achievement test was used and because of its validity different results can be measured.

Thirdly, the sample size was limited in the study. Because of the time limitations of the researcher only two classes used in the treatment. In addition, due to school dynamics students missed several classes or post-test so the number of participants decreased.

Suggestions

This study pointed out that instruction with visualizations was, to a certain extent, effective for students to comprehend geological structures (plate tectonics and earthquake). In addition, instruction was effective in each group; although there is not a statistical difference between two groups, students in experimental group were better in terms of participation and engagement (interaction and questions).

Findings of this research encourage further research. Another study with the same research design can be conducted with a larger sample. More participants can contribute the effectiveness of the study and help the researcher to draw more general conclusions about the effectiveness of the visualizations.

Secondly, the achievement test is needed to improve. A further study can focus on the improvement of the test and a more valid instrument can be developed by using high participants. With the help of another instrument intervention can be analyzed more effectively. In addition, it would be helpful for a more fair comparison between different types of visualizations.

Thirdly, Ryoo and Linn (2012) argued that we still need to have more experimental studies to evaluate which types of visualizations are better for the learners. This study showed that dynamic visualizations do not have an advantage over static visualization on students' achievement. However, there was no study in geology with this age group who compares different types of visualizations (Kühl, 2011). Thus, there should be other studies to examine under which circumstances they were worth to use animations especially in the field of geology.

APPENDICES

A: ACHIEVEMENT TEST

ADI SOYADI: SINIFI:

8. sınıf Doğal Süreçler ünitesinin levha hareketleri ve depremler konuları ile ilgili ön bilgilerinizi ölçmek amacıyla aşağıdaki bilgi testi hazırlanmıştır. Size verilen testteki soruları uygun seçeneği işaretleyerek cevaplayınız.

1. Aşağıdaki gözlemlerden hangisi genişleyen evren teorisini destekler?

   a) Evrenin çok büyük olması
   b) Gezegenlerin hareket etmesi
   c) Galaksilerin birbirinden uzaklaşması
   d) Evrenin başlangıcının olması

2. Güneş sistemi ve Dünya 'nın gaz ve toz bulutundan oluşumu sürecinde gaz bulutlarının yoğunlaşarak çökmesini sağlayan kuvvet aşağıdakilerden hangisidir?

   a) Sürtünme kuvveti
   b) Kütle çekim kuvveti
   c) Manyetik kuvvet
   d) Rüzgar kuvveti

3. Dünya'nın katmanlarıyla ilgili bilgiye hangi yöntemle ulaşıyoruz?

   a) Deprem dalgalarının (sismik dalgalar) iletimini ölçerek
   b) Yerküreyi delip, direk gözlem yaparak
   c) Manto katmanındaki sıcaklık farkını ölçerek
   d) Depremlerin büyüklüğünü ölçerek

4. Aşağıdaki ifadelerden hangisi veya hangileri doğrudur?

   I. Mantodaki bulunan akışkan ve ergimiş kayalara magma denir.
   II. Mantonun hemen üzerinde katılaşmış yerkabuğu levhaları vardır.
   III. Manto katmanı sürekli ve yavaş bir hareket halindedir.

   a) Yalnız I
   b) Yalnız II
   c) I ve III
   d) I, II ve III

5. Dünya'nın derinliklerine indikçe ortam yoğunluğu artıyorsa, derinlik arttıkça sismik (deprem) dalgaların hızı nasıl değişir?

   a) Değişmez

b) Artar
c) Azalır
d) Önce artar, sonra azalır

6. Sismik dalgalarla ilgili aşağıdaki ifadelerden hangisi veya hangileri doğrudur?

I. P ve S dalgaları manto boyunca ilerleyebilir.
II. P ve S dalgaları sıvı dış çekirdek boyunca ilerleyebilir.
III. P ve S dalgaları katı iç çekirdek boyunca ilerleyebilir.

a) Yalnız I
b) I ve II
c) I ve III
d) II ve III

7. Yeryüzünü oluşturan levhalar, aşağıda verilen katmanlardan hangisinin üzerinde hareket ederler?

a) Suküre
b) Magma
c) Dış çekirdek
d) Manto

8. Dünya'nın iç kısmından gelen ısı enerjisinin büyük bir kısmı aşağıda belirtilen hangi yayılma biçimi ile iletilir?

a) Işıma
b) Doğrusal İletim
c) Yansıma
d) Konveksiyon

9. Yer kabuğunu oluşturan levhalarla ilgili olarak; aşağıdaki yargılarından hangileri doğrudur?

I. Levhalar sürekli hareket halindedir.
II. Levha hareketliliğinin nedeni depremlerdir.
III. Levha hareketleri çok yavaş bir hızla gerçekleşir.

a) Yalnız I
b) I ve II
c) I ve III
d) I, II ve III

10. Yaklaşan levha hareketinde, levhalardan birinin diğerinin altına dalma hareketi gerçekleştirip gerçekleştirmeyeceği levhanın hangi özelliğine bağlıdır?

a) Levhanın sertliğine
b) Levhanın ağırlığına
c) Levhanın kalınlığına

d) Levhanın yoğunluğuna

11. İki kıtasal levha birbirine yaklaşma hareketi yapıyorsa, __________________.

a) İki levha birden dalma hareketi yapar.
b) Levhalardan sadece birisi dalma hareketi yapar.
c) Levhalar çarpışarak, levha sınırlarında bozulmalara yol açar.
d) Birbirini durdurur.

12. Bir okyanusal levha ile kıtasal levha birbirlerine yaklaşma hareketi yapıyorsa, ______________.

a) İki levha birden dalma hareketi gerçekleştirir.
b) Sadece kıtasal levha dalma hareketi gerçekleştirir.
c) Sadece okyanusal levha dalma hareketi gerçekleştirir.
d) Levhalardan hiçbiri dalma hareketi gerçekleştirmez.

13. Aşağıda, farklı levha çeşitlerinin yaptığı yaklaşma hareketi sonucunda oluşabilecek yeryüzü şekilleri listelenmiştir. Hangi şıkta verilen levhaların yaklaşması sonucu oluşan yeryüzü şekli doğrudur?

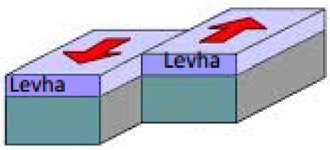
	Kıtasal- Kıtasal	Okyanusal- Kıtasal
a)	Sıradağ	Hendek
b)	Volkan	Sıradağ
c)	Sıradağ	Volkan
d)	Volkan	Sıcak nokta volkanı

14. Aşağıdaki seçeneklerden hangisinde İki okyanusal levhanın uzaklaşması sonucu oluşabilecek jeolojik yapı doğru olarak verilmiştir?

a) Hendek
b) Ada
c) Okyanus tabanı
d) Ova

15. İki levhanın yanal hareket yapması sonucunda aşağıda verilen olay yada jeolojik yapılardan hangisi oluşur?

a) Deprem ve sıradağ
b) Deprem ve hendek
c) Sadece sıradağ
d) Sadece deprem



16. Aşağıdakilerden hangisi depremi en iyi açıklar?

a) Bir deprem oluştuğu zaman yerin üzerinde yarıklar oluşur.
b) Bir deprem oluştuğu zaman insanlar yerin sallandığını hissederler.

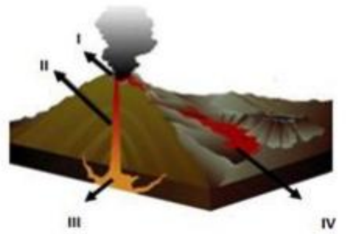
c) Bir deprem oluştuğu zaman yapılar zarar görür.
d) Bir deprem oluştuğu zaman yerin içinden enerji salınımı gerçekleşir.

17. Aşağıdakilerden hangisi sonucu depremler oluşabilir?

a) Dünya'nın alt yüzeyinde bulunan kayaların ani hareketleri sonucu
b) Volkanik gazların ve magmanın hareketi sonucu
c) Büyük ölçekli toprak kaymaları veya büyük bir mağaranın çökmesi sonucu
d) Yukarıdaki seçeneklerin hepsi sonucu deprem oluşabilir.

18. Aşağıdaki resimde numaralarla gösterilmiş yapıları tanımlayan kavramlar hangi seçenekte doğru olarak verilmiştir?

	I	II	III	IV
a)	Baca	Magma	Lav akıntısı	Krater
b)	Krater	Baca	Magma	Lav akıntısı
c)	Lav akıntısı	Krater	Baca	Magma
d)	Baca	Magma	Krater	Lav akıntısı



19. Şekilde, depremin oluştuğu an gösterilmektedir. Seçeneklerden hangisinde A ve B noktalarını açıklayan deprem ile ilgili kavramlar doğru verilmiştir?

	A	B
a)	Fay	Deprem Merkezi
b)	Deprem Merkezi	Deprem Merkez üssü
c)	Fay	Deprem Merkez üssü
d)	Deprem Merkez üssü	Deprem Merkezi

20. Yukarıdaki şekilde gösterilen, fay bloğu aşağıya doğru hareket etmiş faylara _____________denir.

a) Normal Fay
b) Anormal Fay
c) Doğrultu atımlı fay
d) Ters Fay

21. Richter ölçeği, depremlerin aşağıda verilen özelliklerinden hangisini belirlemek için kullanılır?
a) Şiddetini
b) Büyüklüğünü
c) Genliğini
d) Yerini

22. Aşağıdaki boşluklara uygun kavramları yerleştirin.

I. Deprem bilimiyle uğraşan bilim insanına ……………………… denir.

II. Yapay ve doğal yollarla oluşan sismik dalgalar ile dünyanın yapısını inceleyen bilim dalına ……………………… denir.

III. Deprem sırasında oluşan dalgaların yarattığı titreşimleri kaydeden aygıta ……………………… denir.

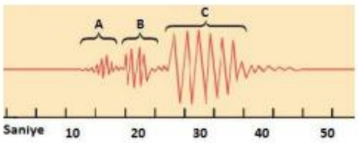
	I	II	III
a)	Sismolog	Sismoloji	Sismograf
b)	Sismograf	Sismoloji	Sismolog
c)	Sismolog	Sismograf	Sismoloji
d)	Sismograf	Sismolog	Sismoloji

23. Aşağıdakilerden hangisi artçı depremi en iyi şekilde tanımlar?
   a) Ana depremden sonra oluşan ufak sarsıntılar
   b) Şiddeti öncü depremden küçük olan sarsıntılar
   c) Fayın çevresinde oluşan kayma ve kırılmaların sebebiyle oluşan sarsıntılar
   d) Büyüklüğü 3 ve altında olan depremler

24. Aşağıdakilerden hangisi bir depremin yol açabileceği olaylardan biri değildir?
   a) Tsunami
   b) Yangın
   c) Toprak kayması
   d) Hava sıcaklığının artması

25. Aşağıdaki şekil bir depremin sismogramını göstermektedir. Seçeneklerden hangisinde A, B ve C dalgaları doğru olarak verilmiştir?

	A	B	C
a)	S dalgası	P dalgası	Yüzey dalgaları
b)	Yüzey dalgaları	P dalgası	S dalgası
c)	P dalgası	Yüzey dalgaları	S dalgası
d)	P dalgası	S dalgası	Yüzey dalgaları



B: SAMPLE LESSON PLAN

1.Ders: Evrenin ve Dünyanın Oluşumu

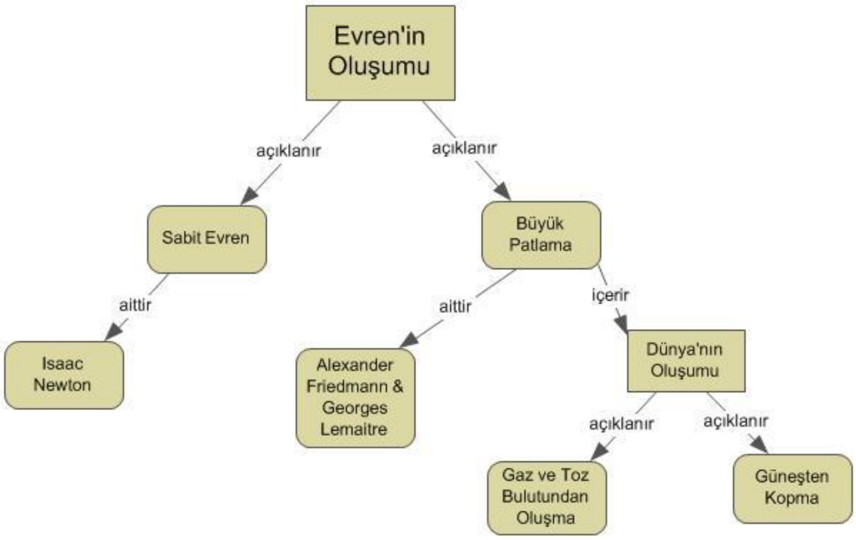
Kazanımlar:

- Öğrenciler izledikleri Evrenin Oluşumu videosu ve yaptıkları Büyük Patlama etkinliği sonucunda büyük patlama teorisini, teoriyi destekleyen delilleri kullanarak kısaca açıklar.
- İnceledikleri doğal olaylar hakkında geçmişte ve günümüzde ortaya atılmış ve kabul görmüş olan düşünceleri ve teorileri karşılaştırarak, bilimsel bilginin yeni kanıtlar çerçevesinde nasıl değişip geliştiğine örnekler verir.
- Öğrenciler izledikleri Dünyanın Oluşumu videosu ile Güneş Sistemi ve Dünya'nın oluşumunu ilgili bilimsel delilleri kullanarak açıklar.
- Bilimsel bilginin oluşturulmasında ve başkalarına açıklamak amacıyla sunumunda modellerden yararlanmanın yeri ve önemini Balon Etkinliğini göz önünde bulundurarak açıklar.

Öğrenilen / Kullanılan Bilimsel Süreç Becerileri

Ölçme, bilgi ve veri toplama, verileri kaydetme, veri işleme ve modelleme, yorumlama ve sonuç çıkarma, sunma.

Kavramlar:



Kavram Yanılgıları:

- Evrenin ve Dünya'nın bir başlangıcı yoktur.
- Evren ve Dünya şimdi nasılsa geçmişte de aynı şekildeydi.

Öğrencilerin Edindikleri Önbilgiler:

1. Öğrenciler, uzayda bulunan gök cisimlerini ve Güneş sistemini, uzay gözlemlerinin yapılmasına olanak sağlayan optik araçlarını 7. sınıfın 7. ünitesi olan Güneş sistemi ve ötesi: Uzay Bilmecesi ünitesinde öğrenmişlerdir.
2. Öğrenciler, cisimleri yeryüzünün merkezine doğru çeken bir kuvvetin var olduğunu, farklı gezegenlerdeki kütle çekim kuvvetinin büyüklüklerinin farklı olduğunu 6.sınıf 2.ünite: Kuvvet ve Hareket ünitesinde öğrenmişlerdir.

Dersin Akışı:

1. Öğrencilere **Bilim nedir?** sorusu sorulur. Öğrencilerden bilimin temel özelliklerinden bahsetmeleri beklenir. Öğrencilerden alınan cevaplardan sonra; sayfadaki sorunun üstüne tıklanarak tanım açılır ve öğrenci cevapları ile karşılaştırılarak değerlendirilmesi istenir.
2. Sizce bilimsel teori ne demektir? Öğrencilerden alınan cevaplardan sonra bilimsel teori ve günlük dilde kullandığımız teori kavramlarının açıklaması sayfadaki sorunun üstüne tıklanarak yapılır.
3. Öğrencilere **Evrenin oluşumu ile ilgili bilimsel açıklamalar** hakkında neler bildikleri sorulur ve çalışma kâğıtlarına not almaları istenir.
4. İlk olarak Newton'un 17. yy da ortaya attığı sabit ve başlangıcı olmayan evren teorisi ile ilgili bilgi verilir.
5. İkinci olarak genişleyen ve başlangıcı olan evren teorisi ile ilgili kısaca bilgi verilir. Detaya girilmeden etkinliğe geçilir. **Büyük Patlama etkinliği öğrencilere yaptırılır[a].** Etkinlik sonuçları öğrencilerle beraber tartışılır.
6. Bilimsel bilginin oluşturulmasında ve başkalarına açıklamak amacıyla sunumunda modellerden yararlanmanın önemi vurgulanır.
7. **Büyük patlama videosu[1]** öğrencilere gösterilir – öğrencilerden videoyu izlerken çalışma kâğıtlarına Büyük Patlama Teorisini destekleyen delilleri not alması istenir. Büyük Patlama Teorisinin evrenin oluşumu ile ilgili en güncel ve geçerli teori olduğu vurgulanır.
8. Öğrencilere **Dünya'nın oluşumu ile ilgili bilimsel açıklamalar** hakkında neler bildikleri sorulur.
9. Dünya'nın oluşumu ile ilgili Güneş'ten kopma ve gaz ve toz bulutundan oluşma ile ilgili açıklamalar öğrencilere sunulur. Gaz ve toz bulutundan oluşma teorisinin en güncel ve geçerli açıklama olduğu vurgulanır.
10. **Dünya'nın oluşumu videosu[2]** öğrencilere izletilir.
11. Öğrenciler dersin başında yanıtladıkları Ne Biliyoruz sorularına verdikleri yanıtları gözden geçirerek Neler Öğrendik sorularına cevap verirler.

C: SAMPLE ACTIVITY

Aktivite 3. Yap Boz Dünya Etkinliği

Etkinliğin amacı: Bu etkinliğin sonunda öğrencilerin Kıtaların Kayması Teorisini ve bilim insanlarının teori geliştirmek için farklı kanıtları nasıl kullandığını anlamaları amaçlanmıştır.

Süresi: 15dk

Malzemeler:

- Dünya haritası

Bir Set Etkinlik Malzemesi:

- Etkinlik puzzle parçaları
- Yapıştırıcı

Akış:

1. Öğrencilere bir dünya haritası gösterilir ve kıtalar arasında benzeşme olup olmadığı sorulur. Öğrencilerin cevaplarından sonra, bu benzeşmeye neyin sebep olmuş olabileceği tartışılır. "Bütün kıtalar milyonlarca yıl önce bir bütündü." Fikrine ulaşıldığında "bu fikri doğrulamak için hangi kanıtlar kullanılmış olabilir?" sorusu ile etkinliğe geçiş yapılır.
2. Öğrenciler 4'er kişilik gruplar oluşturur.
3. Her grup bir set etkinlik malzemesi alır. Malzemelerini alan öğrenciler puzzle parçalarını inceler ve yönlendirme sayfasını dikkatlice okur.
4. Puzzle parçalarının 220 milyon yıl önceki kıtaları ve bazı büyük adaları temsil ettiği öğrencilere belirtilir.
5. Çalışma kağıdındaki harita bilgilerinin, bilim insanlarının 220 milyon yıl önce var olduğuna inandıkları Pangea'ya ait kanıtlar olduğu söylenir. Bu kanıtların neler olduğu öğrencilerle konuşulur.
6. Çalışma kağıdında yer alan kanıtları inceleyerek hangi parçaların birbiriyle birleşmiş olması gerektiğine karar veren öğrenciler, kararlarına uygun halde birleştirdikleri puzzle parçalarının çember üzerine yapıştırırlar.
7. Öğrenciler etkinliği tamamladıktan sonra modellerini tahtada asarak sunarlar.
8. Öğrencilerin sunumları sırasında öğretmen," pangeanın dünya üzerindeki yerine nasıl karar verdiniz?, Parçaların birbirleriyle neye göre birleştirdiniz?" sorularını sorarak tartışmayı yönlendirir.

Öğretmen için notlar:

- Öğrencilerin puzzle parçalarının en uygun haline kesin karar vermeden etkilik kağıdına yapıştırma yapmamaları için öğretmen uyarıda bulunmalıdır.

D: SAMPLE WORKSHEET

3.Ders – Levha Hareketleri	**Ad- Soyad:**
Tarih:	**Sınıf:**

Neler biliyorum? - Sizce sıradağlar, volkanlar, okyanus tabanı gibi yeryüzü şekilleri nasıl oluşmuştur? Sizce depremler neden ve nasıl oluşmaktadır?

……

……

……

Yapboz Dünya Etkinliği:

Size verilen yapboz parçalarının üzerindeki özellikleri göz önünde bulundurarak parçaları birleştirip, aşağıdaki boşluğa yapıştırınız.

Levhalar:

Kıtasal levha:

Sadece .... yer kabuğundan oluşan levhalardır.

Okyanusal levha:

Sadece .... yer kabuğundan oluşan levhadır.

Kıtasal- okyanusal levha:

Hem .... hem de .... yer kabuğundan oluşan levhadır.

Alfred Wegener'in Hikayesi:

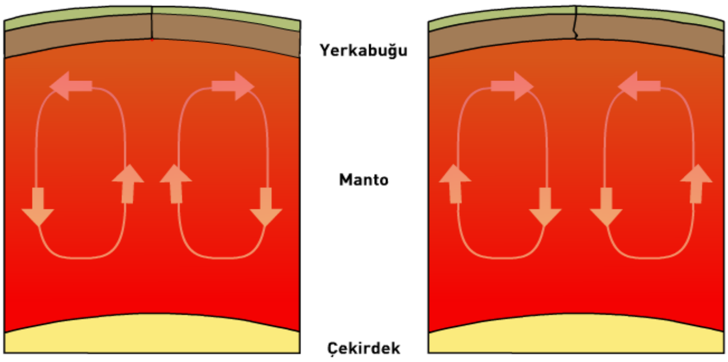
Wegener'in hikayesi ve ilgili tartışmadan bilimin özellikleri ile ilgili ne gibi çıkarımlarda bulundunuz?

....

....

....

Konveksiyon: Konveksiyon hücrelerindeki hareketlere bakarak levhaların hareket yönlerini tahmin edelim.



Neler öğrendim? - Dünya'nın içyapısının Dünya yüzeyini nasıl etkilediğine dair neler öğrendik?

....
....
....

E: GENERAL OVERVIEW OF THE LESSONS

Lesson 1

Experimental Dynamic	Control Static
Researcher gave worksheet to the students	Researcher gave worksheet to the students
Researcher asked what do you know about science? What is science for you?	Researcher asked what is science?
Students gave some responses such as: "math, chemistry, biology"	Students gave some responses such as: "astronomy, archeology"
One student said: "science is exploring" and added "learnnig new things to expand our knowledge" another one said: "Explaining the events"	One student said: "it tries to find unknown information"
After collecting several responses the researcher gave a general definition of the science	After collecting several responses researcher gave a general definition of the science
Then he asked another questions"What about scientific theory? Can you give me an example of a scientific theory?	Then he asked another questions"What about scientific theory?
One girl stated: "The explanation about Earth's movement"	One student said: "making an assumption"
The researcher pointed out two common explanations about the formation of the universe	Researcher provided gravity theory to explain falling object
Asked which one is more acceptable for you?	The researcher pointed out two common explanations about the formation of the universe
In order to make it concrete balloon activity was conducted	Asked which one is more acceptable for you?
This analogy was aimed to help the students to understand the idea of expanding universe.	In order to make it concrete balloon activity was conducted
After the collecting the data studens shared their ideas and results	After the collecting the data studens shared their ideas and results
Researcher indicated two theories about the existence of the earth	Researcher asked: "What do you know about the formation of the Earth"
Another **video** was shown in the classroom	Researcher indicated two theories about the existence of the earth
At the end of the lesson they articulate ideas by using worksheet	At the end of the lesson they articulate ideas by using worksheet

Lesson 2

Experimental Dynamic	Control Static
Researcher asked a guiding question: "What do you know about the inside of the Earth"	Researcher asked a guiding question: "What do you know about the inside of the Earth"
One of the students gave an answer: "There is a core at the center"	One of the students: "There is magma inside of the earth"
After getting several answers researcher gave information about the layers and the core by using the **animation.** After the animation he asked "How do we know the structure of the Earth?"	After getting several answers researcher gave information about the layers and the core by using the **presentation.** Then asked: "How do we know the structure of the Earth?"
The students tried to find express the situation	The students tried to find express the situation
Researcher talked about seismic waves: P, S and surface waves	Researcher talked about seismic waves: P, S and surface waves
Researcher showed the waves by using helezon spring	Researcher showed the waves by using helezon spring
Then he showed an **animations** about the waves and their movement in both liquid and solid state	Then he showed a **picture** about the waves and their movement in both liquid and solid state
He concluded that: "The behaviour of the seismic waves proved that there is a solid core and liquid layers inside the Earth"	He concluded that: "The behaviour of the seismic waves proved that there is a solid core and liquid layers inside the Earth"
Researcher also showed the waves' speed in low and high density via an **animation**	Students were given a **presentation** which contains several pictures about waves' speed in low and high density
Students filled out related fields in the worksheet	Students filled out related fields in the worksheet

Lesson 3

Experimental Dynamic	Control Static
Researcher asked several questions about the first 2 lessons and reviewed important points	Researcher gave a general framework of the lesson and use another guided questions: "Do you see any overlap between the boundaries of the continents."
He gave a general framework of the lesson and use another guided questions: "Do you see any overlap between the boundaries of the continents."	Puzzle activity was conducted to show the idea of overlapping continents and continental drift
Puzzle activity was conducted to show the idea of overlapping continents and continental drift	While students working in groups researcher monitor the students and help them
While students working in groups researcher monitor the students	After the completing each group, several groups shared their work with other groups and students asked questions
After the completing each group, several groups shared their work with other groups and students asked questions	Researcher showed two snapshot of Pangea and current state of the Earth
Researcher showed an **animation** about continental drift	Then he gave the worksheet about the life of Albert Wegener
Then he gave the worksheet about the life of Albert Wegener	A discussion was conducted and students try to give answers to the
A discussion was conducted and students try to give answers to the questions related with the reading passage	Researcher stated the deficiency of Wegener's theory and asked the mechanism of continental drift
Researcher stated the deficiency of Wegener's theory and asked the mechanism of continental drift	Then he showed students the convection video developed by the researcher
Then he showed students the convection video developed by the researche	Another quiding question: "How this movement inside the Earth can affect the Earth?"
Another quiding question: "How this movement inside the Earth can affect the Earth?"	Students were shown a **presentation** contains movements of plates
An **animation** of movements of the plates were shown	Researcher asked based on this movement at the begining of the Earth formation, what would you expect billions years later
Researcher asked based on this movement at the begining of the Earth formation, what would you expect billions years later	Students has some predictions and researcher stated that next lesson will help them to find an answer to this question
Students has some predictions and researcher stated that next lesson will help them to find an answer to this question	

Lesson 4

Experimental Dynamic	Control Static
The researcher made a summary of previous lessons	The researcher made a summary of previous lesson and asked students if they have any questions
Then, he introduced the types of plates	He introduced the types of plates
What do you expect the movements of plates?	What do you expect the movements of plates?
The resracher asked is there any relationship between volcanoes and boundaries of plates?	The resracher asked is there any relationship between volcanoes and boundaries of plates?
Researcher continue the movements of plate and gives sample **animations**	Researcher continue the movements of plate and used a presentations which contains snapshots from the basic geological structures
And Mountaion, Hawaii Island, The Red Sea are several examples to illustrate plate movements	And Mountaion, Hawaii Island, The Red Sea are several examples to illustrate plate movements
Then students were given a worksheet to fulfill the sample geographical structures and their names	Then students were given a worksheet to fulfill the sample geographical structures and their names

Lesson 5

Experimental Dynamic	Control Static
Researcher gave the worksheets to the students and asked what we have learned so far?	Researcher gave the worksheets to the students and asked what we have learned so far?
Students answered: waves, plates, movements of plates	Students answered: waves, plates, movements of plates
Researcher showed a map of Turkey shows earthquakes in 2012	Researcher showed a map of Turkey shows earthquakes in 2012
Another guiding question was asked: "How can we explain the earthquakes out of plate boundaries?"	Researcher asked "How can you explain the earthquakes out of plate boundaries?"
The students were given a news about Van earthquake and underline the terms related with earthquake	The students were given a news about Van earthquake and the task was underlining the terms related with earthquake
After everyone have read, several students read the sentences aloud and stated the term.	After everyone have read, several students read the sentences aloud and stated the term
Other students listened and added if they have a suggestion. All sentences were analyzed one by one	All sentences were analyzed one by one
Researcher showed the **animation** about types of faults	Researcher showed **several pictures** about types of faults
The focus and epicenter terms were shown on the **animation**	The focus and epicenter terms were shown on the **static visualizations**
The seismic waves and seismograph **animations** were shown	The seismic waves and seismograph **presentations** were shown
Another **animation** about magnitude of the earthquake was shown and impact of them were discussed in the classroom	Students used worksheets to reflect their ideas and researcher collected them at the end of the lesson
Students used worksheets to reflect their ideas and researcher collected them at the end of the lesson	

Lesson 6

Experimental Dynamic	Control Static
Researcher summarized the terms related with earthquake covered in previous lesson	Researcher summarized the terms related with earthquake covered in previous lesson
He asked: "Does seismograph data can be an indicator of epicenter of an earthquake?"	The guiding question of this lesson was asked: "Does seismograph data can be an indicator of epicenter of an earthquake?"
Students were shown a seismograph **animation** explains the time difference between p and s waves	Students were shown a seismograph **photos** and explanation about the time difference between p and s waves
They performed to understand the starting point of p and s waves to determine time difference between them	They performed to understand the starting point of p and s waves to determine time difference between them
Researcher showed an example of determination of an earthquake	Researcher showed an example of determination of an earthquake
Students are expected to realize while the station is far the time difference between p and s increases	Students are expected to realize while the station is far the time difference between p and s increases
Researcher told the procedure to use the time values two determine the epicenter of an earthquake	Researcher told the procedure to use the time values two determine the epicenter of an earthquake
They were given real data to determine the exact place of an earthquake	They were given real data to determine the exact place of an earthquake
They articulated their knowledge about the lesson by using worksheet	They articulated their knowledge about the lesson by using worksheet

REFERENCES

Abd-El-Khalick, F., & Lederman, N. G. (2000). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching, 37*(10), 1057-1095.

Abell, S. K., & Lederman, N. G. (2007). Handbook of research on science education. Mahwah, N.J.: Lawrence Erlbaum Associates.

Ainsworth, S. (1999). The functions of multiple representations. Computers and Education, 33, 131–152.

Ainsworth, S., & VanLabeke, N. (2004). Multiple forms of dynamic representation. *Learning and Instruction*, 14(3), 241-255.

American Association for the Advancement of Science (1989). *Project 2061: Science for all Americans*, Washington, D.C.

Apedoe, X. S. (2008). Engaging students in inquiry: Tales from an undergraduate geology laboratory-based course. *Science Education, 92*(4), 631-663.

Ardac, D., & Akaygun, S. (2005). Using Static and Dynamic Visuals to Represent Chemical Change at Molecular Level. *International Journal of Science Education, 27*(11), 1269-1298.

Ausubel, D. P. (1963). The Psychology of Meaningful Verbal Learning. New York: Grune and Stratton.

Ayres, P., & Paas, F. (2007). Making instructional animations more effective: a cognitive load approach. *Applied Cognitive Psychology*, 21(6), 695-700.

Bell, R.L., Smetana, L., & Binns, I. (2005). Simplifying inquiry instruction: Assessing the inquiry level of classroom activities. *The Science Teacher*, 72(7), 30-33.

Blumenfeld, P. C., Kempler, T. M., & Krajcik, J. S. (2006). Motivation and cognitive engagement in learning environments. In R. K. Sawyer (Ed.), Cambridge handbook of the learning sciences (pp. 475–488). New York: Cambridge University Press.

Bodemer, D., Ploetzner, R., Feuerlein, I., & Spada, H. (2004). The active integration of information during learning with dynamic and interactive visualizations. *Learning and Instruction*, 14(3), 325-341.

Breslyn, W., & McGinnis, J. R. (2011). A comparison of exemplary biology, chemistry, earth science, and physics teachers' conceptions and enactment of inquiry. *Science Education, 96*(1), 48-77.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.

Buckley, B. C. (2000). Interactive multimedia and model-based learning in biology. *International Journal of Science Education, 22*(9), 895-935.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins, effectiveness, and applications, Colorado Springs: BSCS.

Campbell, D. T. and J. C. Stanley (1966). Experimental and Quasi-Experimental Designs for Research. Houghton Mifflin, Boston, MA.

Clark, D., Weinberger A., Jucks, I., Spitulnik M. & Wallace, R. (2003). Designing effective science inquiry in text-based computer supported collaborative learning environments. *International Journal of Educational Policy, Research & Practice* 4(1): 55–82.

Clark, R., Nguyen, F. & Sweller, J. (2006). Efficiency in learning: Evidence-based guidelines to manage cognitive load. San Francisco, CA: Pfeiffer.

Clarke, T., Ayres, P., & Sweller, J. (2005). The impact of sequencing and prior knowledge on learning mathematics through spreadsheet applications. *Educational Technology Research and Development, 53*(3), 15-24.

Cleland, C.E. (2001) Historical science, experimental science, and the scientific method. *Geology*, 29, 987–990.

Cook, M. P. (2006). Visual representations in science education: The influence of prior knowledge and cognitive load theory on instructional design principles. *Science Education, 90*(6), 1073-1091.

Council of Ministers of Education, Canada (CMEC). (1997). Common framework of science learning outcomes K to 12. Toronto: Council of Ministers of Education, Canada.

Crawford, B. A. (1999). Is It Realistic to Expect a Pre-service Teacher to Create an Inquiry-based Classroom? *Journal of Science Teacher Education, 10*(3), 175-194.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches.* Thousand Oaks, CA: Sage.

Cuevas, P., Lee, O., Hart, J., & Deaktor, R. (2005). Improving science inquiry with elementary students of diverse backgrounds. Journal of Research in Science Teaching, 42(3), 337-357.

de Jong, T. (2010). Cognitive load theory, educational research, and instructional design: some food for thought. Instructional Science, 38(2), 105-134.

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching, 37*(6), 582-601.

Dennen, V. (2002). Cognitive apprenticeships in educational practice. In D. Jonassen (Ed.), *Handbook of Research for Educational Communications and Technology* (2nd ed.). Hillsdale, NJ: Erlbaum.

Dodick, J., & Orion, N. (2003). Geology as an Historical Science: Its Perception within Science and the Education System. *Science & Education, 12*(2), 197-211.

Dott, R. H. (1998). "What is unique about geological reasoning? *GSA Today* 10 15-18.

Dove, J. E. (1998). "Students' alternative conceptions in Earth science: a review of research and implications for teaching and learning." Research Papers in Education 13(2): 183-201.

Driver, R. (1989). Students' conceptions and the learning of science. *International Journal of Science Education, 11*, 481-490.

Duit, R., & Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education, 25*(6), 671-688.

Edelson, D. C. (1998). Realising authentic science learning through the adaptation of scientific practice. In B. Fraser (Ed.), *International handbook of science education* (pp. 317–331). Dordrecht, The Netherlands: Kluwer.

Edelson, D. C., Gordin, D. N., & Pea, R. D. (1999). Addressing the Challenges of Inquiry-Based Learning Through Technology and Curriculum Design. *Journal of the Learning Sciences*, *8*(3-4), 391-450.

Edelson, D. C. (2001). Learning-for-use: A framework for the design of technology-supported inquiry activities. *Journal of Research in Science Teaching, 38*(3), 355-385.

Finarelli, M. G. (1998). GLOBE: A Worldwide Environmental Science and Education Partnership. *Journal of Science Education and Technology, 7*(1), 77-84.

Frodeman, R. (1995). Geological reasoning: Geology as interpretive and historical science. *GSA Bulletin*. 107: 960-968.

Garnett, P. J., Garnett, P. J., & Hackling, M. W. (1995). Students' Alternative Conceptions in Chemistry: A Review of Research and Implications for Teaching and Learning. *Studies in Science Education, 25*(1), 69-96.

Gilbert. J. K., Osborne, R. J. & Fensham, p. J. (1982). Children's science and its consequences for teaching. *Science Education, 66,* 623-633.

Gordin, D. N., & Pea, R. D. (1995). Prospects for scientific visualization as an educational technology. *Journal of the Learning Sciences, 4*(3), 249-279.

Greene, J. C,. & Caracelli, W. J. (1997). Defining and describing the paradigm issue in mixed-method evaluation. *New Directions for Evaluation, 74,* 5-17.

Guion LA. Triangulation: Establishing the Validity of Qualitative Studies. *University of Florida Extension--Institute of Food and Agricultural Sciences.* 2002; (FCS6014).

Guven D. (2012). Bilimsel Sorgulamaya Dayalı Öğrenme Teknolojilerinin Öğretim Sürecine Entegrasyonu (41612D01R1). Scientific Research Projects Boğaziçi University

Harris, C., & Rooks, D. (2010). Managing inquiry-based science: Challenges in enacting complex science instruction in elementary and middle school classrooms. *Journal of Science Teacher Education, 21*(2), 227-240.

Hegarty, M., Kriz, S., & Cate, C. (2003). The Roles of Mental Animations and External Animations in Understanding Mechanical Systems. *Cognition and Instruction*, 21(4), 209-249.

Hegarty, M. (2004). Dynamic visualizations and learning: getting to the difficult questions. *Learning and Instruction*, 14, 343-351.

Höffler, T. N., & Leutner, D. (2007). Instructional animation versus static pictures: A meta-analysis. *Learning and Instruction, 17*(6), 722-738.

Karamustafaoğlu, O. (2006). Fen ve Teknoloji Öğretmenlerinin Öğretim Materyallerini Kullanma Düzeyleri: Amasya İli Örneği. *AÜ Bayburt Eğitim Fakültesi Dergisi*, Cilt 1, Sayı 1, 90-101.

Keller, J. M. (1999a). Motivational systems. In H. D. Stolovitch, & E. J. Keeps (Eds.), Handbook of human performance technology, 2nd Edition. San Francisco: Jossey-Bass Inc., Publisher.

Keller, J. M. (1999b). Using the ARCS motivational process in computer-based instruction and distance education. In M. Theall (ed.), New Directions for Teaching and Learning: Motivation from Within: Approaches for Encouraging Faculty and Students to Excel. San Francisco: Jossey-Bass, (#78).

Kelly, R., & Jones, L. (Writer) (2007). Exploring How Different Features of Animations of Sodium Chloride Dissolution Affect Students' Explanations, *Journal of Science Education and Technology*: Springer Netherlands.

Khalil MK, Lamar CH, Johnson TE. (2005). Using computer-based interactive imagery strategies for designing instructional anatomy programs. *Clin Anat* 18:68–76.

Khalil, M. K., Paas, F., Johnson, T. E., & Payer, A. F. (2005). Interactive and dynamic visualizations in teaching and learning of anatomy: A cognitive load perspective. *The Anatomical Record Part B: The New Anatomist, 286B*(1), 8-14.

Kim, M. C., Hannafin, M. J., & Bryan, L. A. (2007). Technology-enhanced inquiry tools in science education: An emerging pedagogical framework for classroom practice. *Science Education*, 91(6), 1010-1030.

King, C. (2008). Geoscience education: an overview. *Studies in Science Education*, 44(2), 187-222.

Klein, J., & Koroghlanian, C. (2004). The effect of audio and animation in multimedia instruction. Journal of Educational Multimedia and *Hypermedia*, 13(1), 23-46.

Kocasaraç, H. (2003). "Bilgisayarların Öğretim Alanında Kullanımına İlişkin Öğretmen Yeterlilikleri", *The Turkish Online Journal Of Educational Technology*, Vol. 2, No 3.

Kozma, R. (2003). The material features of multiple representations and their cognitive and social affordances for science understanding. *Learning and Instruction*, 13(2), 205–226.

Krajcik, J. S., Blumenfeld, P. C., Marx, R. W., & Soloway, E. (1994). A Collaborative Model for Helping Middle Grade Science Teachers Learn Project-Based Instruction. *The Elementary School Journal, 94*(5), 483-497.

Krajcik, J.,Blumenfeld, P. C., Marx,R. W., Bass, K. M., Fredericks, J.,& Soloway, E. (1998). Inquiry in project-based science classrooms: Initial attempts by middle school students. *The Journal of the Learning Sciences. 7,* 3 13-350.

Krajcik, J.S., McNeill, K. L., & Reiser, B.J. (2007). Learning-goals-driven design model: Developing curriculum materials that align with national standards and incorporate project-based pedagogy. *Science Education*, 92(1), 1-32

Krajcik, J.S., & Sutherland, L.M. (2009). *IQWST Materials: Meeting the Challenges of the 21st Century.* Paper presented at the NRC Workshop on Exploring the Intersection between Science Education and the Development of 21st Century Skills.

Kühl, D.-P. T. (2011). Optimizing Learning with Dynamic and Static Visualizations to Foster Understanding in the Natural Sciences.

Kyza, E. A., Golan, R., Reiser, B. J., & Edelson, D. C. (2002). Reflective inquiry: enabling group self-regulation in inquiry-based science using the progress portfolio tool. Paper presented at the Proceedings of the Conference on Computer Support for Collaborative Learning: Foundations for a CSCL Community.

Jenkins, E. (1997). Towards a functional public understanding of science. In R.Levinson & J.Thomas (Eds.), *Science today: Problem or crisis?* (pp. 137 150). London: Routledge.

Lee, M. N. N. (1989) Science for all: Implications for curriculum efforts. *Journal of Science and Mathematics Education in Southeast Asia, 12* (1), 16-27.

Libarkin, J. C. and C. Brick (2002), Research Methodologies in Science Education: Visualization and the Geosciences. *Journal of Geoscience Education* 50(4):449-455

Limón, M. (2001). On the cognitive conflict as an instructional strategy for conceptual change: A critical appraisal. *Learning and Instruction, 11,* 357–380.

Linn, M. C., & Hsi, S. (2000). Computers, teachers, peers: Science learning partners. Mahwah, NJ: Erlbaum.

Loucks-Horsley, S., Hewson, P., Love, N., and Stiles, K. (1998). *Designing professional development for teachers of mathematics and science*. Thousand Oaks, CA: Corwin Press.

Marbach-Ad, G., Rotbain, Y., & Stavy, R. (2008). Using computer animation and illustration activities to improve high school students' achievement in molecular genetics. *Journal of Research in Science Teaching, 45*(3), 273-292.

Mayer, R. E. (1997). Multimedia learning: are we asking the right questions? *Educational Psychologist*, *32*, 1–19.

Mayer, R. E. (2001). Multimedia learning. New York: Cambridge University Press.

Mayer, R. E. (2003). The promise of multimedia learning: using the same instructional design methods across different media. *Learning and Instruction*, 13(2), 125-139.

Mayer, R. E., Hegarty, M., Mayer, S., & Campbell, J. (2005). When static media promote active learning: annotated illustrations versus narrated animations in multimedia instruction. *Journal of Experimental Psychology*: *Applied*, 11(4), 256–265.

Mayer, R. E. (2005). The Cambridge handbook of multimedia learning. Cambridge, UK: Cambridge University Press.

McClean, P., Saini-Eidukat, B., Schwert, D.P., Slator, B.M., White, A., 2001. Virtual worlds in large enrollment science classes significantly improve authentic learning. In: Chambers, J.A. (Ed.), Selected Papers from the 12th International Conference on College Teaching and Learning, Center for the Advancement of Teaching and Learning, Jacksonville, FL. pp. 111–118.

MEB. (2005). İlk*öğretim 6. ve 7. ve 8. Sınıf Fen ve Teknoloji Dersi Öğretim Programları***.** Ankara: Milli Eğitim Bakanlığı Talim ve Terbiye Kurulu Başkanlığı.

Millar R, Osborne J (1998) *Beyond 2000: Science Education for the Future*. London, UK: King’s College

Moreno, R., & Mayer, R. E. (2000). A learner-centered approach to multimedia explanations: deriving instructional design principles from cognitive theory. *Interactive Multimedia Electronic Journal of Computer-Enhanced Learning*, 2(2).

Morrison, J.B., Betrancourt, M., and Tverksy, B., 2000. Animation: does it facilitate learning? In: Proceedings of American Association of Artificial Intelligence Spring Symposium, Smart Graphics 2000, Stanford, 53-60.

National Science Teachers Association (NSTA). 2003. *Standards for Science Teacher Preparation*: Arlington, Va.: NSTA.

Norris, S. P., & Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education, 87*(2), 224-240.

Novak, J. D. (2002). Meaningful learning: The essential factor for conceptual change in limited or inappropriate propositional hierarchies leading to empowerment of learners. *Science Education, 86*(4), 548-571.

Novak, J. D. & Cañas, A. J. (2006) The Theory Underlying Concept Maps and How to Construct Them, Technical Report IHMC CmapTools 2006-01, *Florida Institute for Human and Machine Cognition*

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academy Press.

National Research Council (NRC). 2000. *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: National Academy Press.

Owens, R. F., Hester, J. L., & Teale, W. H. (2002). Where do you want to go today? Inquiry-based learning and technology integration. *The Reading Teacher*, 55(7), 616-625.

Pane, J. F., Corbett, A. T. & John, B. E. (1996). Assessing dynamics in computer-based instruction. In M. J. Tauber, Ed. Proceedings of the ACM Conference on Human Factors in Computing Systems, pp. 797–804. Vancouver: ACM.

Patrick, M., Carter, G., & Wiebe, E. (2005). Visual representations of DNA replication: Middle grades students' perceptions and interpretations. *Journal of Science Education and Technology*, 14(3), 353-365.

Piburn, M.D., Reynolds, S.J., Leedy, D.E., McAuliffe, C.M., Birk, J.P. & Johnson, J.K.(2002). *The hidden Earth: Visualization of geologic features and their subsurface geometry*. Paper presented at the annual meeting of National Association for Research in Science Teaching, New Orleans.

Pintrich, P. R. (1999). Motivational beliefs as resources for and constraints on conceptual change. In W.

Plass, J., Homer, B., & Hayward, E. (2009). Design factors for educationally effective animations and simulations. *Journal of Computing in Higher Education, 21*(1), 31-61.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*(2), 211-227.

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., et al. (2004). A Scaffolding Design Framework for Software to Support Science Inquiry. *Journal of the Learning Sciences, 13*(3), 337-386.

Raab, T., & Frodeman, R. (2002). What is it like to be a geologist? A phenomenology of geology and its epistemological implications. *Philosophy & Geography, 5*(1), 69-81.

Rapp, D., & Gilbert, J. (2005). Mental Models: Theoretical issues for visualizations in science education. *Visualization in Science Education* (Vol. 1, pp. 43-60): Springer Netherlands.

Reiser, B., Tabak, I., Sandoval, W. A., Smith, B. K., Steinmuller, F., & Leone, A. J. (2001). BGuILE: Strategic and conceptual scaffolds for scientific inquiry in biology classrooms. In S. M. Carver & D. Klahr (Eds.), Cognition and instruction: Twenty-five years of progress (pp. 263–305). Mahwah, NJ: Erlbaum.

Reiser, B. J. (2004). Scaffolding Complex Learning: The Mechanisms of Structuring and Problematizing Student Work. *Journal of the Learning Sciences, 13*(3), 273-304. Songer, Lee & Kam 2011

Reynolds, S., J. Johnson, et al. (2005). Visualization in undergraduate geology courses. *Visualization in Science Education*, Springer Netherlands. **1:** 253-266.

Roberts, D.A. (2007). Scientific literacy/science literacy. In S.K. Abell, & N.G. Lederman (Eds.), Handbook of research on science education (pp. 729–780). Mahwah, NJ: Lawrence Erlbaum Associates.

Roschelle, J. M., Pea, R. D., Hoadley, C. M., Gordin, D. N., & Means, B. M. (2000). Changing How and What Children Learn in School with Computer-Based Technologies. *The Future of Children, 10*(2), 76-101.

Royce, C. & Holzer, M. (2003). What would it be like without. . .? *Science Teacher*, 27, 20–24.

Rudwick, M. J. (1978). Charles Lyell's dream of a statistical paleontology. *Paleontology, 21*(Part 2), 225-244.

Ryoo, K., & Linn, M. C. (Writer) (2012). Can dynamic visualizations improve middle school students' understanding of energy in photosynthesis? Wiley Subscription Services, Inc., A Wiley Company.

Saini-Eidukat, B., Schwert, D. P., & Slator, B. M. (2002). Geology explorer: virtual geologic mapping and interpretation. *Computers & Geosciences, 28*(10), 1167-1176.

Sandoval, W. A., & Reiser, B. J. (2004). Explanation-driven inquiry: Integrating conceptual and epistemic scaffolds for scientific inquiry. *Science Education, 88*(3), 345-372.

Scheiter, K., Gerjets, P., & Catrambone, R. (2006). Making the abstract concrete: Visualizing mathematical solution procedures. *Computers in Human Behavior*, 22(1), 9-25.

Schnotz, W. & Grzondziel, H. (1999). Individual and co-operative learning with interactive animated pictures. *European Journal of Psychology of Education*, 14, 245–265.

Schnotz, W. and T. Rasch (2005). "Enabling, facilitating, and inhibiting effects of animations in multimedia learning: Why reduction of cognitive load can have negative results on learning." *Educational Technology Research and Development* **53**(3): 47-58.

Schwab, J. J. (1962). The teaching of science as enquiry. Cambridge, MA: Harvard University Press.

Scribner, S. (1986). Literacy in three metaphors. In N. Stein (Ed.), *Literacy in American schools: Learning to read and write* (pp. 7-22). Chicago: University of Chicago Press.

Slotta J. (2004) The web-based inquiry science environment (WISE): scaffolding knowledge integration in the science classroom. In Internet Environments for Science Education (eds M. Linn, E.A. Davis & P. Bell), pp. 315–341. Lawrence Erlbaum Associates, Mahwah,NJ.

Sweller, J., van Merriënboer, J. G., & Paas, F. (1998). Cognitive architecture and instructional design. *Educational Psychology*, 10, 251–296.

Tashakkori, A., & Teddlie, C. (1998). Mixed methodology: Combining qualitative and quantitative approaches. Thousand Oaks, CA: Sage.

Trindade, J., Fiolhais, C., & Almeida, L. (2002). Science learning in virtual environments: a descriptive study. *British Journal of Educational Technology*, 33(4), 471-488.

Tversky, B., Morrison, J. B., & Betrancourt, M. (2002). Animation: Can it facilitate? *International Journal of Human-Computer Studies*, 57(4), 247–262.

Trundle, K. C., Atwood, R. K., & Christopher, J. E. (2002). Pre-service elementary teachers' conceptions of moon phases before and after instruction. *Journal of Research in Science Teaching, 39*(7), 633-658.

van Gog, T., Paas, F., Marcus, N., Ayres, P., & Sweller, J. (2009). The mirror neuron system and observational learning: Implications for the effectiveness of dynamic visualizations. *Educational Psychology*, 21(1), 21-30.

Vosniadou, S. (1991). Designing curricula for conceptual restructuring: Lessons from the study of knowledge acquisition in astronomy. *Journal of Curriculum Studies*, 23, 219–237.

Vygotsky, L. S. (1978). Mind in society: The development of the higher psychological processes (A. Kozulin, Trans.). Cambridge, MA: Harvard University Press.

Waight, N., & Abd-El-Khalick, F. (2007). The impact of technology on the enactment of “inquiry” in a technology enthusiast's sixth grade science classroom. *Journal of Research in Science Teaching*, 44(1), 154-182.

Williamson, V.M., & Abraham, M.R. (1995). The effects of computer animation on the particulate mental models of college chemistry students. *Journal of Research in Science Teaching*, 32, 521 - 534.

Wilson, C. D., Taylor, J. A., Kowalski, S. M., & Carlson, J. (2010). The relative effects and equity of inquiry-based and commonplace science teaching on students' knowledge, reasoning, and argumentation. *Journal of Research in Science Teaching, 47*(3), 276-301.

Wood, D. J., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry,* 17, 89-100.

Yarden, H., & Yarden, A. (2010). Learning Using Dynamic and Static Visualizations: Students’ Comprehension, Prior Knowledge and Conceptual Status of a Biotechnological Method. *Research in Science Education*, 40(3), 375-402.

Zhang, Z. H., & Linn, M. C. (2011). Can generating representations enhance learning with dynamic visualizations? *Journal of Research in Science Teaching, 48*(10), 1177-1198.

Zirbel, E. L. (2004). Framework for Conceptual Change. *Astronomy Education*, *3*(1), 62-76.