DESIGN AND DEVELOPMENT OF A WEB-BASED SCIENCE LEARNING TOOL WITH A SAMPLE UNIT ON PARTICULATE NATURE OF MATTER

by

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ABSTRACT

DESIGN AND DEVELOPMENT OF A WEB-BASED SCIENCE LEARNING TOOL WITH A SAMPLE UNIT ON PARTICULATE NATURE OF MATTER

The primary aim of this study is design and development of WEBFEN, a web based science learning tool that follows instructional design guidelines and suggestions derived from current practices of constructivist approach and argumentation method in science education. The tool that is developed and implemented by the researcher using Adobe Flash and ASP.net software platforms includes a variety of interactive learning activities compatible with national science curriculum. It includes three main sections which are student activity, teacher monitoring and administration environments.

This tool is designed to help students develop conceptual knowledge on selected unit and also gain argument building skill which is noted as an important element of science education in the literature. As students explore the WebFen, they try to find out evidences for their claims and build up argument statements. The tool also provides various monitoring features for teachers. A review of previous research highlighted the significance of and students' difficulties on the particulate nature of matter subject. These studies also showed the value of multimedia-based representations in helping students to gain particulate understanding of matter. The particulate nature of matter unit was selected as a sample and learning activities are designed for that topic in the context of present study.

The study also includes a preliminary effectiveness study with teachers in order to get feedback and carry out revisions for the tool and a pilot study with students to get initial data on the WebFen's effectiveness and usability. The results of pilot study showed that students had an improved particulate understanding after using WebFen and that the tool was usable.

ÖZET

MADDENİN TANECİKLİ DOĞASI ÖRNEK ÜNİTESİNİ İÇEREN BİR WEB TABANLI FEN ÖĞRENME ARACININ TASARIMI VE GELİŞTİRİLMESİ

Bu çalışmanın öncelikli hedefi yapılandırıcı yaklaşım ve fen eğitiminde argümantasyon metodunun güncel uygulamalarından elde edilen öğretim tasarımı prensipleri ve önerilerini takip eden web tabanlı bir fen öğrenme aracı (WebFen) tasarlamak ve geliştirmektir. Araştırmacı tarafından Adobe Flash ve ASP.net yazılım platformları kullanılarak geliştirilen ve uygulanan bu araç ulusal fen müfredatına uygun çeşitli etkileşimli öğrenme etkinlikleri içermektedir. Araç öğrenci etkinlik, öğretmen gözlem ve yönetim olmak üzere üç ana bölümden oluşmaktadır.

Bu araç, öğrencilerin seçilen fen ünitesi ile ilgili kavramsal bilgilerini ve literatürde fen eğitiminin önemli bir öğesi olarak işaret edilen argüman oluşturma becerilerini geliştirmeye yardımcı olmak amacıyla geliştirilmiştir. Öğrenciler WebFen'le çalışarak, etkinlikler içinden idialarını destekleyici kanıtlar bulmaya ve argüman cümleleri oluşturmaya çalışırlar. Araç öğretmenler için çeşitli gözlem özellikleri de içermektedir. Önceki araştırmalarda, öğrencilerin maddenin taneikli doğası konusunun önemi ve öğrencilerin bu konudaki öğrenme zorlukları vurgulanmıştır. Bu çalışmalar aynı zamanda çoklu ortam tabanlı gösterimlerin öğrencilerin parçacık kavramını anlamalarındaki önemini de göstermiştir. Maddenin tanecikli doğası konusu, bu çalışmada örnek olarak seçilmiş ve öğrenme etkinlikleri bu konu için tasarlanmıştır.

Çalışma aynı zamanda öğretmenlerden WebFen'in etkinliği ile ilgili geri bildirim almak ve düzenlemeler yapmak için ön değerlendirme çalışması ile sistemin etkinliği ve kullanılabilirliği konusunda ön bilgi almak üzere öğrencilerle yapılan bir pilot çalışmayı içerir. Pilot çalışmanın sonuçları öğrencilerin WebFen'i kullandıktan sonra öğrencilerin tanecikli yapıya ilişkin anlama düzeylerinin arttığını ve sistemin kullanılabilir olduğunu göstermiştir.

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LIST OF ABBREVIATIONS

CLE	Constructivist Learning Environment
CMM	Computerized Molecular Modeling
DIL	Distributed Interactive Learning Environments
DPL	Distributed Passive Learning Environments
ICT	Information and Communication Technology
IDEAS	Ideas, Evidence and Argument in Science Education
KIE	Knowledge Integration Environment
MONE	Ministry of National Education
OLE	Open Learning Environment
SKI	Scaffolded Knowledge Integration
WEBFEN	Web-based Science Learning Tool
WISE	Web-based Inquiry Science Environment
WWW	World Wide Web

1. INTRODUCTION

A major goal of science education is fostering students' understanding of scientific concepts along with a firm understanding of the processes of science. Suggestions coming from past research and theories (Mintzes and Wandersee, 1998) emphasize the role of constructivist principles in fostering a sound understanding of scientific concepts and processes. Science educators try to design learning environments that focus on:

- Active construction of knowledge
- Personal interpretations of the environment
- Multiple representations
- Multiple perspectives
- Student interaction with environment, teacher and others
- Process along with content

According to constructivist views of learning, learners are viewed as active participants of knowledge construction process; they construct their own meaning and reality through experiences and interactions with the learning environment. All learners create their personal interpretations of the environment which provides multiple representations of knowledge (Jonassen, 1991). Mayer (1999) stresses that the instructional designer's role in constructivist approach is to create environments which learners can interact meaningfully with materials and to encourage learners' process of selecting, organizing, and integrating information. Recent studies show that higher order thinking skills can be gained through students' active involvement with information; learners have to be active participants of the learning environment rather than information receivers (Harper and Hedberg, 1997).

Computerized environments can help science educators to design constructivist learning environments, because they offer several means for active construction, interaction, multiple representations, multiple perspectives and an emphasis on process along with the content. Wellington (2004) describes the nature of science and science teaching and explains the relation of information and communication technologies (ICT) with science. He elaborates the ways information and communication technologies can be used to support science learning. He states that school science is a very practical subject that includes doing activities such as observing, measuring, communicating, discussing, trying things out, investigating, watching, observing, recording results, etc. ICT can be used virtually for all of these activities. Besides being a very practical subject, science is also a theoretical subject that includes activities like thinking, inferring, having ideas, hypothesizing, simulating and modeling. ICT can be an effective tool to help these activities as well. Wellington also asserts that there exist two science viewpoints that we see science from, process and content. The content involves scientific facts, theories, laws and the process involves activities like measuring and recording. ICT can help learning in both content and process domains.

It is possible to extend the use of computerized learning environments to a wider range of learners by using the World Wide Web as a science learning medium. Parallel with the improvements in Internet technologies, advantages of web as an instructional support medium becomes more apparent. New teaching and learning models are developed taking advantages of the computer technology and the improvements especially in the Web. Increase in bandwidth and increase in the number of schools and students having access to Internet have lead to numerous innovations in web-based learning activities in many disciplines especially in science education.

The present study is an attempt to design and develop a web-based science learning tool (WebFen) that aims to support middle school students' conceptual learning of selected science unit and to provide interactive learning activities that focus on scientific process skills and argumentation abilities. The learning tool will be shaped by two particular approaches to learning; active construction of knowledge and development of scientific thinking and argument building skills along with scientific content. Primarily the learning environment will be designed to guide and support construction rather than pure reception of scientific knowledge. Secondly the learning environment will be designed to foster both content and process with particular emphasis on the development of scientific thinking.

Therefore, WebFen follows a constructivist approach to learning and will primarily be based on principles that guide successful construction of scientific knowledge. As such, the learning environment will include components that provide multiple perspectives, multiple representations and diverse tasks that are meaningful and interesting. Instructional components that will specifically aim for the development of scientific thinking will be based on suggestions from studies that use "argumentation" as a theoretical base. Design of learning activities are shaped by basic elements of an argumentation lesson where students are expected to create arguments about a science problem by using various evidences.

In WebFen each learning unit starts with a question where students are expected to take sides and choose a claim. Then they are expected to support their claim using evidence embedded in each activity. Further, students are required to build up a decision report that includes their argument statements that are made up of claims, evidences and warrants about the nature of matters.

1.1. Constructivist View of Learning and Implications for Instructional Design

Constructivist approaches describe learning as construction of meanings that is created from experiences and interactions of learner with the environment and this process does not exist outside of human mind (Duffy and Cunningham, 1996). Learners need to be cognitively active to make sense of the information and try to connect it with his existing knowledge (Mayer, 1999). Collaboration is another important aspect of instructional design models that apply constructivist approach.

Implications of constructivist views provide a set of guiding principles to help designers and teachers to create learner centered, collaborative environments that support reflective and experiential processes (Jonassen, Davidson, Collins, Campbell & Haag, 1995). Literature includes major instructional design models and principles of learning environments that are based on constructivist approach of learning. According to Wilson (1996) a learning environment contains at least a learner and a setting or a space wherein the learner acts, using tools and devices, collecting and interpreting information, interacting with others. He also defines constructivist learning environment as "a place where learners may work together and support each other as they use a variety of tools and information resources in their guided pursuit of learning goals and problem solving activities" (p.5).

A number of authors who work on learning and instruction proposed a set of guiding principles for instructional designers and tried to answer the question of how to implement constructivist theories in learning environments especially the environments that includes technology supported practices (Harper and Hedberg, 1997). For example, Duffy and Cunningham (1996) outlined seven key design features of technology supported constructivist learning environments which are:

1. All knowledge is constructed; all learning is a process of construction. Students need autonomy to direct and construct their own understandings, therefore learning environments should provide some control to students to explore the tools and students should have the responsibility to investigate the activities and construct knowledge.

2. Many world views can be constructed; hence there will be multiple perspectives. Learning environments need to encourage learning experiences which encourage students to look beyond their own view and to compare views with alternative views (Lefoe, 1998). In order to achieve this goal, learning environment should provide multiple representations (through text, static and animated pictures) of same concept (macroscopic, microscopic and symbolic representation) to broaden students' views and they need to provide opportunities for communication among students and teacher for sharing and comparing understandings.

3. Knowledge is context dependent, so learning should occur in contexts to which it is relevant. Learning environments need to present a context for the problem or question about the content and the context need to be relevant and authentic for the learners. Providing a context for learning helps students in making sense of the environment as it is encountered. Additionally each learning task in the environment should not be isolated but rather is a part of a larger context in which the problems are relevant.

4. Learning is mediated by tools and signs. All learnings are constructions taken place within a context that uses some form of mediational means, tools, and/or signs. The computer is an example of mediational means that is used as both tool and sign. The computer's role in education is viewed as an instructional tool and to provide a rich and exciting learning environment (Duffy and Cunningham, 1996; Jonassen and Reeves, 1996). Additionally, technology offers a cognitive tool to support cognitive and metacognitive processes supporting a learner for new understandings (Nanjappa and Grant, 2003).

5. Learning is an inherently social-dialogical activity. Group discussion of students is another important element of constructivist learning environments. Through the use of communication tools such as discussion boards, e-mails, chat rooms or video conferencing technologies, students can develop as members of their learning community, develop a shared understanding, and question the issues of the area of study (Lefoe, 1998).

6. Learners are distributed; there are multi dimensional participants in a sociocultural process. Learning should not be an act of a single person, but it needs to include actions of learning communities and learners should participate in and contact with communities.

7. Knowing how we know is the ultimate human accomplishment. Self- awareness in learning is seen as an important goal. Individuals need to be aware of the beliefs that have adopted or created to live, and those beliefs need to be discovered within the learning environment.

Further, Jonassen (1999) outlines the key issues on learning of his instructional model of Constructivist Learning Environments (CLEs). According to that instructional model learning is:

- Active and authentic: Learners are cognitively active while they are mindfully processing information. They should be actively manipulating the objects and tools of the environment, developing skills and knowledge which they then share with other members of the learning community. Mayer (1999) also points on the two kinds of activity learning which only one of them leads to constructivist learning. One is being behaviorally active; students do not trying to make sense out of the material being presented and they are only behaviorally active while working with the materials. The other type is being cognitively active which leads students to process information to make sense of it. Therefore learning environments need to support students with activities in which they are cognitively active rather than only promoting behavioral activity.

- Constructive: Students construct their own meaning by trying to connect new information or ideas with previous knowledge and coming to know the new ideas.
- Collaborative: Learning environments need to provide tools to help students create learning communities and work collaboratively with other students and with teacher, because learning does not occur in isolation but in teams or in groups of people solving a problem. Recent technologies support CLEs with possible collaboration tools such as electronic mails, discussion boards, chats, etc. CLEs should provide conversations about the problem or project that students work in. Students share their notes with teacher and with others about questions or problem and they gain multiple perspectives of the problem.
- Driven by a learning goal or problem owned by the learner: Learning is goal directed, this goal may be complex or simple. In CLEs students think and learn more in order to actively try to achieve a cognitive goal. The focus of learning should be an ill structured question, problem or a project that is relevant to learners' lives and they attempt to solve it. Moreover in the design of CLEs, a question, problem or a case that have controversial answers need to be introduced to the learner to increase engagement of students to the subject and to increase interest.

Most of the recent instructional constructivist design models use opportunities of technological improvements especially the development of World Wide Web (WWW). Another design model developed by Hannafin, Land and Oliver (1999) is "Open Learning Environments" (OLEs) that uses Web as a medium to create a constructivist learning environment. It takes the advantages of technological developments in order to create a learner-centered design employing tools, resources and activities that foster thinking. Similar to CLEs of Jonassen (1999), OLEs of Hannafin, Land and Oliver (1999) support the idea that learning should be in context and start with a problem that will be analyzed by the students. Divergent thinking, promoting multiple representations, providing different resources and tool, guiding and supporting students' learning are some of the key principles of OLEs (Hannafin, Land & Oliver, 1999). They also introduce a tool, ErgoMotion that uses the principles of OLEs model. It is a technology supported interactive science learning tool where students investigate physics laws in the context of designing a virtual roller coaster. It includes graphics, simulations, video and print based materials and also provide tools which participant can seek, sort, collect, organize, integrate and generate knowledge.

1.2. The Design Goals of WebFen

The major design goals which are used as a framework for the design of WebFen were derived from the guidelines and common issues of instructional design models of constructivist learning environments which are highlighted above. These principles can be summarized as:

- Active construction of knowledge: Learning environments need to support active construction of knowledge and instructional activities need to help allow students interpret the incoming knowledge and relate it with existing knowledge. Activities should favor personal active construction rather than passive reception of new knowledge.
- Personal interpretations of the environment: One of the important tenets of constructivist approach is the defining learning as individuals' personal interpretations of the world. Therefore learning environments need to enable students to create personal interpretations of the information which is shaped by their previous and current experiences.
- Multiple representations: Activities in learning environments need to utilize different representations of information such as text, static and animated picture, video and these representations need to supplement each other, does not give redundant information.
- Multiple perspectives: Because learning is personal interpretations of the environments, the environments need to welcome and support development of

different perspectives of the concept or problem. It can include presentation of multiple and alternative views about the problem to learners.

- Student interaction with environment, teacher and others: The researchers in the area of computer supported education identify three types of interaction which affects the learning. They are interaction with content (tools and activities), interaction with instructors, and interaction with other students (Moore, 1989). In order to improve students' learning, all these kinds of interactions need to be provided by the system.
- Process along with content: Learning environment need to focus on both content learning and development of process skills such as investigating, measuring, creative thinking, building and testing hypothesis.

2. LITERATURE REVIEW

The major aim of the present study is design and development of a web-based science learning tool (WebFen) that uses constructivist principles and argumentation as a method to support science learning among secondary school students. The unit of study is chosen from 6th grade science curriculum and covers “particulate nature of matter”. This unit is specifically selected, because an understanding of particulate nature of matter is considered to be a major prerequisite for the development of subsequent topics on matter.

The theoretical and empirical bases that guide the design of WebFen tool can be summarized by the following scheme. The literature is reviewed in four main categories that focus on instructional framework, instructional medium, design and usability principles and finally the content of selected unit for the present study.

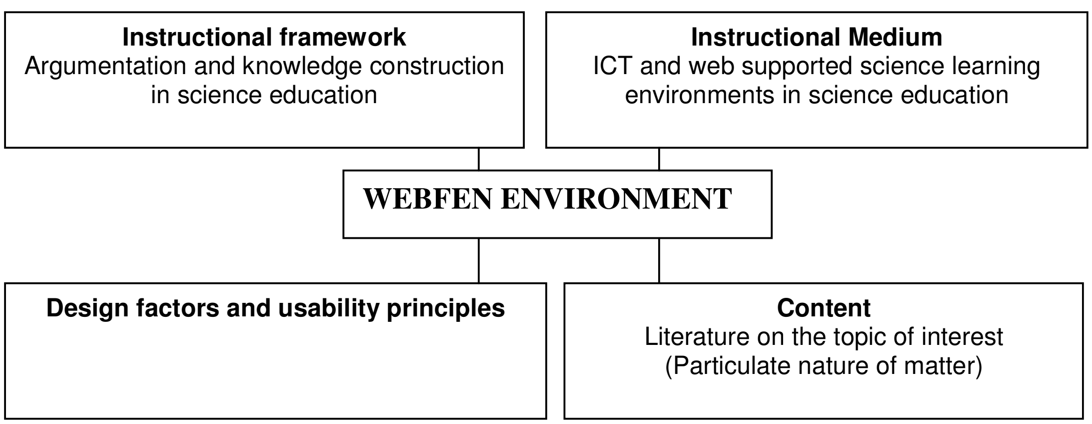


Figure 2.1. Theoretical and empirical basis of WEBFEN

In line with the problem statement, the review of literature will initially introduce the instructional framework that is based on implications of current studies that focus on argumentation method in science education and current design models of constructivist views of learning. Literature will continue with an introduction on use of ICT and Web as instructional medium in science education and then there will be particular focus on web-based learning environments that use both constructivist and argumentation strategies as a means for fostering understanding of scientific concepts and scientific thinking. The literature review will then include research-based suggestions on improving the usability of web-based learning environments. Finally there will be a brief overview of studies on the specific unit “particulate nature of matter”, in order to show the difficulties, remedies and reasons for its selection.

2.1. Argument and Argumentation

Science involves the construction of theories that provide explanations about the natural world. Observation, creative thinking and argumentation are all important in the building of models, theories and explanations. Scientists generate rules and knowledge claims through the use of argumentation. They test these rules and knowledge claims through argumentation, by relating evidences to knowledge claims. However although scientists frequently use arguments to relate the evidence to the claims, this seems to be a very difficult task for students which may partly be due to the content-oriented emphasis given in teaching science. Research indicates that school science provides rare opportunities for these kinds of practices (Newton, Driver & Osborne, 1999) which are important for students to have critical reasoning and arguments to understand the nature of science and natural world rather than accumulating scientific facts about how the world is.

Argumentation had given various meanings in the literature. Miller (1987) defines argumentation process as learners’ coordination of their reasoning about the presented question, or claim and their trials to come up with an agreed answer or solution to the problem. In the study of Jermann and Dillenbourg (2005), argumentation is accepted as a dialectic activity includes justification and explanation of answers to a question and process of convincing others about the answers. Further, Veerman (2003) theorizes the process of argumentation as a type of collaborative, constructive and multi-representational exchange of ideas. Most of the definitions include the view of argumentation as a social practice that involves negotiation of different views.

The common points in approaches of argumentation provided by researchers are explained by Andriessen, Baker and Suthers (2003) as;

- It is about giving reasons,
- It is about trying to persuade or convince someone,
- It is about demonstrating a point of view.

The concept of argument, on the other hand is different from argumentation although they are used interchangeably in the literature. Krummheuer (1995) defines argument as “the intentional explication of the reasoning of a solution during its development or after it” (p. 231). In order to create an argument, there has to be a problem or controversy and people need to be in the process of reasoning that focus on resolution of that problem.

The literature on use of argumentation in education mainly presents two types of argument descriptions which are rhetoric/didactic and dialectic. In the first type, argument is seen as combination of sentences that are used to tell others and to persuade or convince them about the strength of a case or an issue. In that kind of arguments, one person provides scientific explanations for a specific issue and tries to persuade others to see it as reasonable. It is generally used by teachers while explaining the underlying reasons of a scientific fact and it is mostly one-sided. Use of rhetoric arguments has limitations in classrooms, because they occur when teacher gives evidence and construct arguments for their pupils (Driver, Newton and Osborne, 2000). Students are not seen as active participants of knowledge construction process. The second type of arguments is “dialogical” or “multivoiced” argument that utilizes different perspectives to reach an agreement on the topic or problem under discussion. Such dialogical arguments can take place within an individual or within a social group.

Toulmin (2003) has a major contribution to the literature on the explanation of the argument concept. In his book named “The Uses of Arguments”, he describes the structure of an argument as the combination of four main types of statements which are claims, data, warrants, and backings with functional relations between them.

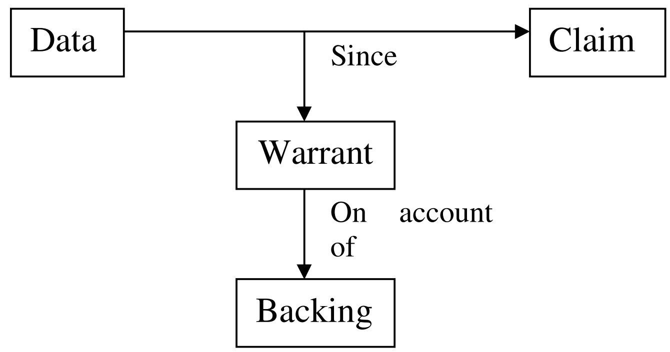


Figure 2.2. Toulmin's model of an argument

- Claim statements involve assertions or conclusions that are stated for general acceptance,
- Data or evidence can be described as the specific facts used to support the claims,
- Warrant phrases justify the logical connection between data and claims, they relate data as evidence to the claim,
- Backings are the basic assumptions and generalizations that provide justifications for warrants (Osborne, Erduran and Simon 2004b).

Toulmin exemplifies his definition with an argument from daily life. He states a claim that "Harry is a British subject"; the data/evidence that supports that claim is "Harry was born in Bermuda"; the warrant statement is "since a man born in Bermuda will generally be a British subject" and the backing statement is "on account of following statutes and other legal provisions…" Some of scientific arguments that are used in studies of argumentation in science classrooms (Osborne, Erduran & Simon 2004a) and parallel with Toulmin's argument definition are presented below:

- We can see things because the light produced by a source enters the eye not because light travels from eye onto objects [claim]. We cannot see when there is no light [data]. We use sunglasses stop something coming in, not something going out [data]. The eye is like a camera with a light sensitive coating at the back, which picks up light coming in, not something coming out [warrant].

- A snowman that is not wearing a coat is melt faster than another snowman wearing a coat [claim]. He (the first snowman) is not wearing a coat [data], so the Sun's rays will touch him directly that makes him to melt faster [warrant].

With the reference of Toulmin's model, Simon, Erduran and Osborne (2006) made a distinction between an argument and argumentation for their studies; an argument refers to the substance of claims, data, warrants and backings statements; whereas argumentation refers to the process of assembling these components. In educational settings teacher engages students in construction of arguments through the process of argumentation.

2.1.1. Use of Argumentation in Science Education

Argumentation has been emerging as an important goal of science education over the past few decades, because it is an important component of scientific inquiry and discourse. Beside teaching scientific content, the need and importance of educating students as scientific literate individuals who think critically, learn about the science, construct scientific knowledge and experiencing argumentation process is highlighted with a number of studies (Boulter & Gilbert, 1995; Osborne, Erduran & Simon, 2004b; Bell, 2000; Linn, 2004). Today's science education pays more attention on what should be believed in and learning scientific facts rather than why something should be believed in, and how to promote justifications or evidences for a scientific claim (Erduran, Ardac & Yakmacı-Guzel, 2006). Science education often ignores the justification and arguments for scientific beliefs and it uses argument created by authorities. If it is asked to people why they believe in fundamentals tenets of school science such as matters are made up of atoms or day and night are caused by earth's spinning, only few will be able to provide evidence and explanation for their scientific ideas (Osborne, Erduran & Simon, 2004b). Even graduates of science programmes have difficulty to support their claims on natural world because of not being able to present evidence and justification for their claims (Erduran, Ardac & Yakmacı-Guzel, 2006). However this approach of science education contradicts with discipline of science, because construction of arguments and its critical evaluation are seen as fundamental reasoning activities of that discipline (Osborne, Erduran & Simon, 2004b). In order to cover this gap, a number of projects such as 'Ideas, Evidence and Argument in

Science (IDEAS) Project' (Osborne, Erduran & Simon, 2004a,b; Simon, Erduran and Osborne 2006; Driver, Newton, & Osborne, 2000), 'Knowledge Integration Environment (KIE) and WISE Projects' (Linn, Davis, & Bell, 2004; Linn, 2004; Linn, Shear, Bell & Slotta, 1999; Bell, 2000) and 'Towards Evidence Based Practice (EPSE) Project' (RatCliffe, 2000) are initiated to help students and teachers learn argumentation and scientific inquiry practices in science courses which traditionally provide rare opportunities for creation of science related arguments and rarely use argumentation as method of science education.

Newton, Driver and Osborne (1999) explains importance of the being active participant of scientific community and being a scientific literate person with the sentences that "It is not enough for students just to hear explanations from experts (e.g. teachers, books, films, computers); they also need to practice using the ideas for themselves. 'The' answers to 'the' questions need to become 'their' answers to 'their' questions. Through practice in posing and answering scientific questions, students become active participants in the community of science rather than just passive observers" (p. 556). Therefore it is suggested that students need to be encouraged to be active in science classrooms, building and testing hypothesis, and achieving their own solution for a science related problem owned by students.

Argumentation is necessary not only as a process skill that leads students to have the abilities such as thinking critically and making justifications for an argument, it is also important for meaningful learning. Andriessen, Baker and Suthers (2003) explain how students might learn in argumentation situations within four categories. Firstly the expression of arguments could itself lead to a reflection and knowledge reconstruction. In other words in the learning environments employing collaborative argumentation methods, students' expressing of views under discussion could lead them to elaborate a more logical discourse about the topic. Secondly, argumentation methods may help students to modify their erroneous beliefs as a result of argumentation (discussing and questioning them). Argumentation can be accepted as a means of eliminating students' erroneous or wrong claims. Thirdly new knowledge can be co-constructed as a means of reaching an agreement from different views of students through argumentation environment that also includes interactive learning activities. Lastly, learning occurs as a result of expression of arguments and justifications using different types of representations such as graphical, textual, or pictorial.

Literature includes studies (Boulter & Gilbert, 1995; Osborne, Erduran & Simon, 2004 a,b; Niaz, Agulera, Maza and Liendo, 2002 ; Erduran, Ardaç, Yakmacı Guzel, 2006) that are initiated to highlight effectiveness of argumentation in conceptual learning, to emphasize the importance and need of argumentation methods in science classrooms and establishing teaching strategies that include argumentation practices. In one of those studies (Niaz et al., 2002) researchers studied the relation between use of argumentation method and learning experimentally. In that study a sample of 160 freshman students of General Chemistry course has participated. 77 of them (experimental group) participated into courses that are given by teachers who are also trained in workshops on argumentation and philosophy of science in the scope of the study and uses argumentation method in their classrooms. The control group consists of 83 students attended courses carried out in traditional manner. Three weeks after, both groups have a monthly exam and after another 3 weeks a semester exam. The results show that students' understandings of the topic could go beyond the simple regurgitation of experiment details for experimental group. And experimental group showed a consistent progressive conceptual change between two measures (monthly and semester exam). The researchers conclude that if students are provided opportunities to build up arguments and carry out discussion on the topic of interest, a more meaningful conceptual understanding can occur and students understand the scientific process and practice.

Another study (Aufschnaiter, Erduran, Osborne & Simon, 2008) was carried out in order to investigate junior high school students' processes of argumentation and cognitive development in science and socioscientific lessons. Using of video and audio records of students' small group and classroom discussions, the quality and frequency of students' argumentation was analyzed using Toulmin's (2003) argument model. The researchers also investigated students' development and use of scientific knowledge, drawing on a schema to find out the content and level of abstraction of students' meaning-making. The results of analysis of student discourse presented that when engaging in argumentation students draw on their prior knowledge, and such activity enables them to consolidate their existing knowledge and elaborate their science understanding at relatively high levels of abstraction.

In the scope of IDEAS project Osborne, Erduran and Simon (2004b) has collaborated with middle- school science teachers in order to develop and establish classroom activities that focus on argumentation and scientific discourse. They identified and developed argumentative instructional activities and strategies that give emphasis on the role of evidence in scientific ideas. They also trained a sample of in-service science teachers to help them learn about the argument and how they could establish argumentation practices in their classrooms. Toulmin's argumentation framework is used as a base to analyze and evaluate students' arguments in the lessons which are guided by the trained teachers.

These projects have ended up with valuable guidelines for teacher educators on how to promote scientific argumentation in the classroom. The present study uses suggestions and some of the instructional strategies coming from studies of IDEAS and WISE studies in helping development of scientific thinking through the use of "argumentation". The following section introduces some of the instructional strategies for argumentation which are also used in the design of WebFen learning tool.

2.1.2. Instructional Strategies in Argumentation Method

In order to initiate and support argumentation and argumentative learning activities, in science classrooms, some instructional strategies are developed by the studies of "Ideas, Evidence and Argument in Science (IDEAS)" project. These strategies are used in the studies of IDEAS projects by teachers and instructional designers to develop learning activities. Some of these strategies are also suggested and used by researchers who study on argumentation, scientific inquiry and constructivist science learning. Some of the strategies can be listed as:

- Competing theories
- Construction of arguments
- Predicting- Observing and Explaining

- Small group discussions

In "computing theories" strategy, students are presented with two or more computing theories or claims in pictorial and/or textual forms (cartoons, story or textual statements) and they are asked to choose one of the claims that they think as correct and expected to provide evidence using their previous knowledge. In some cases they are also presented with text based evidence statements that may support one of the claims and they are asked to organize evidences and justify their claims using those evidences.

In "construction of arguments" type of strategy students are given an explanation of a scientific phenomenon and some data statements. Then they are asked to discuss data statements in small groups and decide which statements provide strongest explanation for the presented event. Then they are asked to build up argument statements explaining the reasons. In one example of this strategy, students are asked to evaluate data statements for the physical event of days and nights are caused by a spinning Earth.

"predicting – observing and explaining" strategy which is also used in IDEAS projects is promoted by White and Gunstone (1992) with the aim of effectively bringing out students' ideas and also promoting discussions of science related topics. In that strategy students are asked to make predictions about the results of an experiment or a demonstration and discussing the reasons. Then they carry out observations and are asked to propose explanations for the outcomes. They are also expected to provide justifications for their explanations.

This strategy is also used in the study of Kearney (2004) within computer-mediated video-based tasks to encourage student discussions about their own ideas on force and motion topic of science and to detect pre-instructional conceptions or misconceptions of high school students. Further, Tao and Gunstone (1999) used computer mediated physics microworld including physics animations to support students in order to co-construct knowledge. The result of the study shows that peer collaboration was taken place and conceptual change was observed in the tasks.

"Small group discussions" strategy is used to foster students' participation in argumentation process which is mainly described as a kind of collaborative process (for dialogical type of arguments) that needs students' interaction with peers, with teachers and with the environment in order to generate, evaluate and resolve arguments (Erduran & Osborne, 2005). Therefore learning environment need to provide opportunities for discussion and collaboration. The strategy of "small group discussions" is not a stand alone strategy; it is mainly used within the some other strategies presented above. For instance in predicting-observing-explaining activities, students could be asked to carry out group discussions for their predictions and explanations.

Moreover, the following design principles that need to be taken into consideration while designing learning environment that fosters argumentation method are derived from the related studies of argumentation and scientific inquiry (Erduran & Osborne, 2005; Bell, 2000; Linn, Davis and Bell, 2004; Linn et al., 1999; Osborne, Erduran & Simon, 2004a, b)

- Students need to be explicitly thought what an argument is, what the sub elements of an argument are, and how students should make use of evidences. Just giving scientific problems to discuss will not be enough for students to create valid arguments. Additionally students need to participate over time in argumentative discussions.
- Argumentation is fostered by a context where student-student interaction is permitted. Therefore environment needs to provide opportunities for students to communicate with each other.
- As a starting point, students need to be presented with a problem, question or a scientific phenomenon that have controversial answers. For instance in competing theories strategy students need to be presented or generated more than one theory and alternative theories that include common student misconceptions on the selected topic.
- Evidences can be presented in textual, pictorial and multimedia format. Multimedia format can include multiple diverse representations, animations and some other visualization tools.
- Learning environment needs to encourage small and large group discussions.

2.2. Information Communication Technologies and Web Supported Science Learning Environments

For the last twenty-five years there is a significant growth in implementing and using information and communication technologies at all levels of science education from primary to tertiary level in order to facilitate science teaching and learning (Holliman & Scanlon, 2004). Technological developments provide new ways for researchers to design technology rich learning environments which aim to increase science understanding. Literature provides a number of different uses and effectiveness of ICT in facilitating science learning.

The most recent technological innovations for classrooms are the uses of Web which offers opportunity for enhancing the teaching and learning process. It can change the nature of learning with increasing access to instructional materials, providing network collaborations (Hoffman, Wu, Krajcik, & Soloway, 2003) and enabling small group discussions through synchronous (e.g. chat options) and asynchronous (e.g. online discussion boards and forums) communication tools.

Web is a very popular and useful instructional medium because of easy access, flexible storage and display options and incorporating different media elements (Oliver, Herrington & Omari, 1997). It has a graphical interface and information can be presented in a variety of formats such as text, video, audio, and static and animated pictures. Research on the use of web for science learning varies from use of educational web sites to web-based activities developed by the researchers as support tools of classroom activities or use of Web-based material without any class meeting. The literature does not provide a strict distinction or classification of the methods or uses of World Wide Web for science learning. Web as information resource tools, Web-based tutorials, interactive Web-based science activities, simulations, applets are some examples of web-supported learning materials found in the literature.

Several research studies (Frailich, Kesner & Hofstein, 2007; Ng and Gunstone, 2002; Sandberg and Bellamy, 2004) are conducted to examine the outcomes of these applications on students' learning. The results of the studies that take place in the literature, show that together with carefully designed instructional methods web can be used to increase students' inquiry skills, achievements and awareness. Some of these studies are presented in the following paragraphs. Majority of studies that are included in this survey are selected from work that focuses on chemistry topics due to its relevance to the present study.

Frailich, Kesner and Hofstein (2007) investigated the influence of web-based chemistry learning on 10th grade students' perceptions, attitudes and achievements. They developed, implemented and evaluated a set of web-based activities for the topic of chemical bonding. The study was conducted with two groups of students (experimental and control group). They used both qualitative and quantitative methods in order to evaluate the variables. A 40-item likert type scale is developed and administered to measure students' perceptions about their chemistry studies. Students' attitude was measured using a feedback questionnaire and their achievement was also measured by achievement tests. The results indicate that experimental group who learned using web site had more positive attitudes toward chemistry studies than students in the comparison group. The achievement tests also show that students in experimental group had significantly higher scores than those of the comparison group.

Another study is performed by Barneal and Dori (1999) about the effect of computer-based molecular modeling and visualization software on high school students' chemistry performance and achievements. The tool named computerized molecular modeling (CMM) which includes 3-dimensional simulations was used in a high-school with five heterogeneous classes (N=169) of tenth graders. The experimental group (N=97) worked on the molecular geometry, chemical bonding and molecular structure subjects with the molecular modeling software and with a dedicated working booklet, while a control group (N=72) studied the subject in the traditional instruction. The result of the achievement test that was administered to both experimental and control group showed that experimental group students scored significantly higher than the control group students. Experimental group students also gained better insight into the molecular model concept than the control group and could explain more chemical phenomena with the aid of a variety of models. Additionally, it is reported that feedback taken from participant teachers and students on

CMM learning environment was positive and they thought that CMM helped students to understand the subjects.

Literature also includes studies that highlights the positive effect of ICT supported educational practices on learning for other topics of science such as biology. In the study carried out by Ng and Gunstone (2002), web is used as a research and teaching tool in promoting self-directed learning of science. Twenty two 15 years old students used WWW in their learning of photosynthesis and respiration topic. The perceptions of students on the effectiveness of the WWW in assisting them while constructing of knowledge were analyzed. The findings showed that the students found that the WWW had a number of positive effects on their learning including motivation for independent learning. However, because WWW includes unedited and unstructured nature, many of the sites they visited had information that was too difficult to understand.

Another study by Philips, Baudains and Keulen (2002) examines the effectiveness of a botany unit about plant diversity which is supported by online materials at Murdoch University, Australia. WebCT software is used to organize materials such as pictures, videos and texts and provide online access to them. The participants were second year university students taking the biology unit, plant diversity course. Researchers collect qualitative data about the effectiveness of web; they carry out interviews with teaching staff and students. They found that providing flexible access and overcoming students' time constraints are important characteristics of the Web support. Additionally online materials allow students to check their work and used as a powerful revision tool.

Khalifa and Lam (2002) studied relative effectiveness of two different types of web based environments which are distributed passive learning environments (DPL) and distributed interactive learning environments (DIL). In DPL environments, web is used only to present linear study materials such as text files, presentation slides or videos and rooted from objectivist approach of learning whereas in DIL, the materials are in hypertext format supporting exploration and students can use of materials according to their needs. 32 undergraduate students participated to the study and they are asked to evaluate the environment in terms of effectiveness, support of exploration, degree of interactivity and enjoyment. In order to measure the effect of web environment on students learning, quizzes are applied. Result shows that students use DIL environment had more active and explorative learning than students work in DPL environment. Students also perceive DIL as more effective and more enjoyable.

2.2.1. Simulations in Science Education

Simulations are one of the most widely researched web-based support environments for science learning. Many science educators (Kulik, 1994; Nakhleh, 1994; Welmar, 1996) state that simulation programs to be a real advantage because simulation programs seem to focus on higher-level instructional objectives. They can help students to understand invisible conceptual worlds of science through animation, which can lead to more abstract understanding of scientific concepts (Hwang & Esquembre, 2003) Most of the findings about the effect of simulation in achievement indicate that they are moderately effective in increasing achievement, but students gain positive attitudes toward the related science topic after use of simulations.

In the study of Geban, Askar, and Ozkan (1992) two hundreds ninth grade students were introduced with three treatments: an experimental group of 60 students who worked on simulation environment for nine weeks; a control group of 70 students who studied with a traditional instruction; and a third group of 70 students who used a problem-solving approach. At the completion of the nine-week study, the achievement of students on related chemistry concept, students' scientific process skills, and attitudes toward chemistry are measured. Findings showed that students who used simulation environment outperformed the control group on tests of chemistry knowledge and scientific process skills.

A study by Sandberg and Bellamy (2004) examined how students learn chemistry using simulated experiments. They developed two simulations about the concept of chemical equilibrium in introductory chemistry which is stated by the researchers as a difficult topic and students have misconceptions on the topic. The subjects who were university students used the web-based chemical equilibrium applets during the class activities. Researchers followed two different ways in utilization of the simulations. In first method, applet was projected on a screen in the classroom and students were asked to predict the changes in the chemical system under different conditions. After students explained their predictions, the results were calculated by the applets and again presented to the class. If students make wrong predictions, teacher guides a discussion about why the predictions are incorrect. In the second method, an exercise booklet was given to each student to perform the activities from the Internet. As students working on activities on the course web site, immediate feedback is provided by the system. After students' completion of the web-based tasks, the topic was reviewed and discussed in the classroom. The qualitative results indicate that students found the applets as useful and have no complain.

The studies presented above and other studies included in the literature that use advances of Web and simulations pay little attention on the argumentation method in science education. The main themes in those studies are development of conceptual (scientific) knowledge and, or students' development of positive attitudes toward the discipline. However the researchers and educational specialist who also study in argumentation method highlight the need and importance of argumentative learning practices and materials in science classrooms besides supporting students in gaining scientific knowledge. One of the main contributions to the literature on the argumentation, scientific inquiry that also uses the promises of ICT is made by Knowledge Integration Environment and WISE Projects which will be discussed in the following section.

2.2.2. Knowledge Integration Environment and WISE Projects

Studies that examine the effect of web-based environments on learning science are not limited to simulations, animations, applets, web-based science activities and web-based tutorials. Other projects invest on the development and evaluation of more extensive and elaborated web-based environments that are founded on specific instructional models. These web-based science learning environments have a wider range that they are designed for a wider range of audience using a wider range of topics. Following paragraphs will include two such web-based science learning environments. These examples were specifically selected, because the principles they used were similar and relevant for the design of the WebFen environment. Both of these examples place specific emphasis on the use of constructivist principles and use the argumentation method in science teaching as a means to develop scientific thinking.

The first example is titled as "Scaffolded Knowledge Integration and Knowledge Integration Environment". Scaffolded Knowledge Integration (SKI) is an instructional design model to support science learning in classroom. This framework is created as a result of long term science project, computer as learning partner, directed by Prof. Marcia Linn at the University of California at Berkeley. This project involves the partnership of science teachers, scientists from different disciplines, technologist and science educators. SKI framework has 4 main principles which are;

- Making science accessible principle: focuses on knowledge integration by building on students existing knowledge. Therefore design materials need to be connecting with students' existing ideas and learning environment need to provide personally relevant examples to students.
- Making thinking visible principle: is related to modeling and evaluating how ideas are connected and making alternative models accessible to students. Inquiry instruction where new ideas are represented in multiple ways like models or simulations is effective way to make students' thinking visible.
- Helping students to learn from each other principle: is another principle of SKI framework. Learning environments need to promote collaborative learning that students discuss ideas.
- Promoting autonomous learning principle: is created to encourage and support students to be lifelong learners gaining investigatory skills. These skills can be developed by working on inquiry projects (Linn, Davis & Bell, 2004).

Knowledge Integration Environment (KIE) is an internet based science learning suite designed according to SKI principles. KIE includes software such as Speakeasy, web-based discussion tool, online scaffolding system called Mildred, argument building software, SenseMaker and web-based evidence database. All of these tools support each principle of SKI framework.

A number of research projects were carried out to design, implement and evaluate KIE effectiveness on students' science learning. Bell (2000) explains design studies aimed to create web-based K-12 science curriculum materials that supports lifelong learning and increase science understanding. He describes the goal as engaging students in collecting and evaluating scientific evidences on web and according to these evidences and students existing knowledge, they create scientific arguments related to a specific topic. "How far does light go?" debate project is one of the curriculum projects of KIE researches. In this study a total of 172 middle school students carried out web-based and classroom activities about propagation of light. Researcher explored relationship between students' view of the nature of science and argument construction, change in students' conceptual understanding as a result of this project and type of arguments that students construct.

As starting point, two opposite theories were introduced which are "Light goes forever until it is absorbed" and "Light dies out as you move further from the source". Students started with choosing one of these theories and try to make personal explanations first. Then they explored evidences in KIE which are in text, video or graphic formats. KIE also provides links to related web sites where students may collect more evidences. Students were also encouraged to develop evidences from their own lives that may support one of the competing theories about the light. At this step SenseMaker tool was used by students to categorize the evidences and making their thinking more visible. According to students' collected evidences, they created arguments which were used in class debate at the last steps of the research. In debate part, students presented their arguments in classroom discussion and answered the questions from other students and class.

During this project SenseMaker tool was used by students to construct and revise evidences. It also provides opportunity to group and segment the evidences from highly related to unrelated in the topic of light. This software serves as a knowledge representation tool that corresponds the "making thinking visible" principle of SKI framework. It models expert thinking because students examine scientific arguments of science experts. It also promotes collaborative exchange of ideas, group work and communication with others which is another principle of SKI framework.

Mildred guidance and note-taking tool is another component of KIE that is used in "light propagation" projects. As students collected data and evidences, they were expected to create explanations for each of the evidences. They took notes of their explanations or request hints.

Another KIE research is one-year "Deformed Frog Partnership" project. The project topic was selected from US 7th grade curriculum focusing on genetics and simple organisms. Students were introduced two competing hypothesis about the possible causes of deformed frogs. One is about a type of parasite that can interfere with natural development of frogs and the other is about the influence of environmental chemicals. They spent three weeks with classroom and computer lab activities. Pre-test and post-tests were used to measure students' science understanding. Results shows that more than 50% of students articulated understanding of the mechanism of parasite hypothesis to some degree and 25% are able to describe complete model of hypothesis. Another important result is the behaviors of students who are unsuccessful in traditional classroom activities. At typical classroom activities 65% of students complete assignments but in this project all students completed KIE assignments (Linn et al., 1999).

Another web-based science learning environment that specifically invests on constructivist principles and the use of argumentation as a means for learning science is "Web-based Integrated Science Environment (WISE)". It is another partnership project built on the KIE. It has the same goals and same design framework which is SKI framework and both utilizes web-supported materials. WISE is an open science learning environment for 4-12 graders. It contributes creating learning communities for teachers or students all over the world because it includes flexibly adaptive curriculum materials and each teacher can organize materials according to students' needs. Similar to KIE, WISE supports knowledge integration and inquiry approach that students design solutions to scientific problems, create predictions before conducting online experiments, use scientific evidence to support theories or conclusions, collaborate and discuss ideas with others.

In WISE, "Plants in Space" curriculum project is designed to improve students' understanding of the plant growth. Fifth grade students and a fifth grade teacher from the US participated in the study. In the design of learning activities students use both Internet-based materials and carry out classroom activities. To measure the effectiveness of the method, a parallel form pre- and post-subject matter assessment were administered. Researchers also used qualitative methods to clarify the results. Overall, students show significant gains in understanding plant growth science concepts including photosynthesis.

2.3. Design and Usability Principles of Web-based Learning Environments

Since design and development of an interactive Web-based learning tool is the main aim of the present study, literature on design and usability principles of such environments and tools have an important role in present study. This section involves research based suggestions and principles which need to be taken into consideration to create effective technology supported learning tools.

Usability is defined in ISO 9241-11 (Jokela, Iivari, Matero and Karukka, 2003) as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”. Software need to be easy to learn, easy to remember and allow users to accomplish their task in a reasonable amount of time (Wahl, 2000). Graham (1998) asserts that user-friendly documents need to let the user read or play with the content at anytime, should have unambiguous interactive controls and should have a clear navigation scheme.

However usability of the Web-based education sites including multimedia technologies needs special usability design principles. In a comprehensive literature review of Stemler (1997), he outlines educational multimedia features used for instructional purposes. Stemler describes the effects of screen design, learner control and navigation, use of feedback, student interactivity and video and audio elements on the effectiveness of educational multimedia. A short summary of his views on usability design principles concerning each of these elements is presented below.

- Screen design: It is defined as coordination of textual and graphic elements in the content to facilitate learning. Each instructional screen should provide effective instruction, navigation tools, and visual aesthetics. Screen design is a critical element of web design in order to gain attention of the users. Researches show that users read text from computer screen 28% slower than from printed materials (Hannafin, 1989). Therefore designers should not fill the screen with texts. It is also suggested that there should be maximum two or three type and sizes of fonts on a screen.

- Interaction and feedback: Interaction is one of the key principles of learning environments that focus on knowledge construction. The learning system need to interact with students and allow them to interact with others. Hannafin (1989) explains that cognitive engagement in interactive multimedia can be achieved with the use of real-time responding, note taking, predicting or hypothesizing, hypertext and cooperative dialogue. The system also provides feedback for students' actions. Orr, Golas and Yao (1994) propose guidelines for feedback as:
- Keep feedback on the same screen with the question and student response.
- Provide feedback immediately following a student response.
- Provide feedback to verify the correctness. For incorrect responses, give the student a hint and ask the student to try again.
- Tailor the feedback to each learner's response.
- Provide encouraging feedback; however, do not provide the type of feedback that may encourage a student to make an incorrect response on purpose just to see the feedback.
- Navigation: Interfaces need to be designed with some cues about the placement of the user in the system. Navigational items such as menus need to be consistent in the system and a screen design template including navigational menus should be created and used consistently in order to increase learnability of the system.
- Control: Learner control is an important issue in design of interactive learning environments. Students need to have to control over the interaction with multimedia content; they should be able to explore and navigate through sub sections of the system according to their own pace and ability level. Orr, Golas, and Yao (1994) have outlined the following learner control guidelines for instructional designers:
- Provide the learner control of the sequence when there is no specific order of instructional activities, when students are familiar with a topic and are able to

make appropriate sequence choices, and when the aim of system is for higher order problem solving tasks.

- Do not provide sequence control to students in a situation where the materials have a specific prerequisite order.
- Provide learner control of content when students have significant previous knowledge of the content, when they have higher ability, when cognitive strategies and higher order problem solving are being taught and when the skills are not critical, the training is optional, and student motivation is high.
- Do not provide full learner control of content when all topics in the instructional presentation are required for successful completion of the program and there is a hierarchical order to the materials.
- Color: Color must be used carefully and consistently in multimedia design. Some suggestions on the use of color are: (a) colors should be used for cueing and highlighting; (b) use maximum three to six colors per screen; (c) use neutral gray or pastel colors for background color to increase readability of the text; (d) use dark text colors on light background; (e) use accepted colors for specific actions, for example red to stop, green for action; (f) avoid to use bright colors.

Further, Twomey and McNutt (1998), outline guidelines for developers of educational websites. These guidelines are presented as technical and design issues:

Technical Issues:

- Give meaningful, but short instructions.
- Provide easy navigational strategies.
- Allow the user to return to homepage from every screen (no dead-ends).
- Use graphics sparingly and only when fully justified.
- Use standard fonts.
- Make sure all links work.
- Use plain backgrounds, or a small set of simple backgrounds, which do not interfere with the color of the text.
- Ensure there is good contrast between text and background.

- If large graphics are essential, provide a thumbnail image which links to the full sized one.
- Ensure that the site is tested on many browsers.
- Only use features that enhance the product.
- Keep the interface simple.

Design Issues:

- Use meaningful titles and links.
- Use consistent layouts which help the user navigate through the site.
- Use friendly language and colors.
- Use icons that are recognizable and appropriate to the users and the subject.
- Keep the screens uncluttered and simple.

Findings of the Internet Science Institute project carried by Keilson, King and Sapnar (1999) on the students' usability preferences for web-based learning environments corroborate the principles described in the guidelines above. In the scope of the project, Web was used to make the lab-based learning attractive and accessible for university students. They support the idea that designing educational materials for Web-based learning requires careful consideration of usability factors. They created web site modules for the motion of the pendulum experiment. The site consists of three major sections which are also the three main levels of the experiment. First is a 'hands on' lab that use readily available materials, the 'refine' lab with images and video of a lab experiment that also focuses on data collections, test and measurement issues. The last section includes simulations and mathematical models. Web usability study was carried out with a small group of university engineering students who had not used the system before. A usability survey was applied to each participant. The results of the observations mainly indicate that:

- Students usually prefer watching pictures or videos to reading
- Students often want to "wing-it" not spending too much time to read text or instructions
- Pop-up windows may be confusing

- Even if the videos are preferred to text, they should not be too long and boring.

Studies that examine design factors that support the usability of a web-based environment particularly focus on principles for the design of multimedia environments. The term multimedia refers to an environment that includes multiple representational sources.

Wellington (2004) defines multimedia as involving at least three of the followings:

- Speech or other sound
- Drawings or diagrams
- Animated drawings or diagrams
- Still photographs or other images
- Video clips
- Text

Mayer (2003) focuses on promise of multimedia as fostering deeper learning in students. He states that multimedia messages can be designed parallel with the mechanism of how people learn and a number of studies (Ardaç & Akaygün, 2004; Williamson & Abraham, 1995; Sanger, 2000; Frailich, Kesner & Hofstein, 2007) indicate that students can learn better from well-prepared multimedia presentations than from traditional verbal-only instructions. Some principles that Mayer explains in his article indicate that multimedia instructional messages which are defined as a presentation involving words and pictures that are designed to increase learning, would not include teaching arbitrary list of facts or laws but it needs to explain how something works.

2.4. Unit of Study- Particulate Nature of Matter

The instructional environment of the present study focuses on the particulate nature of matter. Particulate nature of matter is chosen as the unit of study, because it is considered to be essential for accurate conceptualization of several related topics such as chemical change, matter and energy. Studies analyzing students' conceptual knowledge of chemistry indicate that particulate nature of matter is one of the core concepts of chemistry that students have difficulties in understanding (Gabel, Samuel & Hunn, 1987; Boz, 2006; Lee, Eichinger, Anderson, Berkheimer & Blakeslee, 1993).

Researches show that students experience difficulties in understanding particulate nature of matter (Novick & Nussbaum, 1981; Nurrenberg & Pickering, 1987), because they tend to attribute macroscopic properties to individual atoms and molecules (Ben-Zvi, Eylon & Silberstein, 1986), they use symbols without understanding what they represent at macroscopic and molecular levels (Friedel & Maloney, 1992; Pickering, 1992).

One of the most significant studies in this line is carried out by Johnson (1998) who studied particulate models of students over a 3-year period from ages 11 to 14. According to Johnson, particulate ideas form part of a progression towards a scientifically acceptable particle model, the development of which can be fostered through appropriate instructional decisions. Johnson (1998) describes four different categories. These categories specify four distinct particle models that constitute possible steps towards the more scientifically acceptable model. The first model (Model X) refers to an understanding where particle ideas have no meaning. Students don't understand that substances are made of particles and use continuous forms to represent the substance. In the second model (Model A) particles are drawn, but they are seen as something separate from the substance. The third model (Model B) includes particles that are seen as making up the substance but with macroscopic character. Individual particles are perceived as small bits that have the same quality as the macroscopic sample. In this model, although students can view the model as particulate, they tend to attribute all of its properties to the nature of the particles rather than the movement of particles. Fourth model (Model C) which is the accurate model refers to an understanding where particles are seen as the substance, and properties of state are seen as collective properties of the particles. The study tried to identify the models that are frequently used by 11-13 year old students on the basis of these four different categories:

- Model X - perception of matter as continuous substance,
- Model A - perception of matter as having particles in a continuous character,

- Model B - particles are substance but with macroscopic character and
- Model C - where particles are substance and the properties of the state are collective.

The results of the study indicate that majority of the students has a perception of matter as continuous substance (Model X) where there is no understanding on particle ideas, or perception of matter as having particles in a continuous character (Model A) and a perception with particles are substance but with macroscopic character (Model B).

Another study is carried out by Boz (2006) to analyze Turkish pupils' conceptions of the particulate nature of matter. A total of 300 students from grades 6, 8 and 11 participated in the study. Open-ended questions and semi-structured interviews are conducted to measure samples' understanding of arrangement and movement of particles in solid, liquid and gas states. The results show that 82.5% of 6th grade, 71.7% of 8th grade and 53% of 11th grade students have problems in understanding the movement of particles. Interviews indicate that majority of the students thought that particles in solids do not have any movement. Boz also reported that some pupils of 6th grade associated the concept of particles as small pieces of matter rather than chemical compositions such as atoms, molecules.

Most of the chemistry concepts include three levels of conceptual understanding which are macroscopic (observable), molecular (microscopic, particulate) and symbolic levels (Gabel, Samuel and Hunn, 1987). Students' understanding of chemistry concepts is dependent on their ability to represent and translate the concepts in those three levels. In order to provide a sufficient understanding of a chemistry concept, they need to understand the relationship among these levels. However at the present time most chemistry courses pay more attention to the symbolic level. Little emphasis is given to the microscopic and the macroscopic levels and to the connections between the three levels (Gabel, 1993). This may causes insufficient understanding. Gabel (1993) proposed that this weakness can be overcome with teachers' emphasis on the transitions between the symbolic, macroscopic, and microscopic worlds so that students will develop their own mental models of particulate nature of matter on these three levels. Moreover, Johnson (1998) claims that it's the "teaching" rather than students' capabilities that restrict successful progression from continuous and macroscopic views towards a scientifically accurate understanding of particle ideas. Similar research indicates that students will develop an accurate understanding of chemical phenomenon when molecular representations are linked to the observable and symbolic representations of chemistry. Similar to Gabel's assertion and Johnson's assertions, Johnstone (1993) suggests that instruction must link the three levels of chemistry so that students work with a combination of the macroscopic, molecular and symbolic representational modes.

A number of studies indicate improved performance following instruction that encourages students to make connections between the macro-molecular-symbolic levels (Hinton & Nakhleh, 1999; Tasker, Chia, Bucat & Sleet, 1996). Gabel (1993) used visual material to help visualization of matter at molecular level. Following instruction, students were observed to show improved chemistry achievement in terms of both symbolic and particulate scores.

Computer-based technologies open up new ways to overcome the learning difficulties and misconceptions highlighted in previous paragraphs. They have the capacity to support molecular level representations of chemical phenomena that is not directly observable (Ardaç & Akaygün, 2004). A number of studies (Ardaç & Akaygün, 2004; Sanger, 2000; Williamson & Abraham, 1995; Geban, Askar & Ozkan, 1992) also include computer-generated visual materials that are used in instruction and results shows a positive effect of multimedia supported instruction on conceptual understanding of particulate nature of matter unit. For example, Sanger (2000) used computer-generated graphics to improve students' conceptions of pure substances and mixtures. The results indicated that students who received instruction that used molecular representations were better able to answer conceptual questions that were particulate in nature. Similarly, Ardaç and Akaygün (2004) studied on the effects of using a multimedia-based instruction that integrates macroscopic, microscopic and symbolic representations of chemical phenomena with forty-nine eight grade students. Students in treatment group received instruction based on computer software that includes films, pictures and simple animations and control group attended regular instruction. The results of the achievement test that is administered at the end of two weeks period showed that students in treatment group outperformed from the control group.

The present study uses findings from past research when designing content of the sample unit of WebFen, which is particulate nature of matter. Special interest is given to microscopic (particulate) representations in order to help students visualize particulate nature of matter. In the light of past research it is possible to say that microscopic representations at molecular level are of prime importance particularly when trying to establish an understanding of particulate nature of matter.

However unlike the tools that are used in the past research on the selected unit, WebFen is not only a collection of multimedia materials that present molecular level demonstrations of chemical phenomena. One of the main tenets that guide the design process of WebFen is the argumentation methods and strategies and providing learning activities that support scientific process skills. Therefore the present study differentiates itself from the previous studies that focus on the use of multimedia tools for topic of particulate nature of matter.

3. METHODOLOGY

The methodology section of the present study is organized around 6 sub-sections which are:

- (Section 3.1) Aim and significance of the study
- (Section 3.2) Statement of the problem
- (Section 3.3) Design, development and implementation of WebFen
- (Section 3.4) Preliminary study with teachers
- (Section 3.5) Revisions of WebFen based on the results of preliminary study with teachers
- (Section 3.6) Pilot study

Methodology section starts with the statement of aim, significance of the study and the research problem which is design and development of WebFen. The second section includes detailed information on design, development and implementation issues of the revised version of WebFen and sub-parts including sample screenshots from activities of the tool. After the main design and development process of WebFen, a preliminary study with in-service science teachers was carried out to get initial data on the effectiveness of the tool and suggestions for revision. Section 3.4 presents the details of that preliminary study with teachers. According to data and results of the preliminary study, some revisions such as clarifications of textual or pictorial information presented in the software were carried out and those revisions are explained in Section 3.5.

Since the main aim of the study is not to evaluate the effectiveness of the tool, a comprehensive evaluation study was not carried out in the scope of present study. However, in order to gain initial data on the usability of the tool and possible effects of WebFen on students' conceptual learning and development of argumentation skills, a pilot study with a small number of samples was carried out. The results of preliminary and pilot studies are also presented in the methodology as sub-sections, because the main focus of the study is the design, development and implementation of WebFen and the results of these studies are not the results of overall study. Additionally, a summary of the results of preliminary and pilot study with a discussion of possible reasons and implications of the results will be mentioned in the chapter 4, “Results and Discussion”.

3.1. Aim and Significance of the Study

The aim of this study is primarily to design and implement an interactive Web-supported science learning tool (WebFen). Design of WebFen is based on current approaches to science learning and takes its principles from major instructional design models of constructivist views and argumentation as a method for science learning. It is aimed to provide web-based tools and activities to support students’ creation of science related arguments and develop students’ content knowledge and argumentation and process skills. In order to design and implement a set of sample activities for WebFen, the topic of ‘Particulate Nature of Matter’ from 6th grade science national curriculum is selected. Most of the learning activity is parallel with the suggested activities of new curriculum described by the Ministry of National Education (MONE).

After the design and implementation of the system, a preliminary study with 3 in-service science teachers and a pilot study with a group of 8 students are carried out to obtain initial results about the effectiveness and usability of the system.

Web is a powerful environment to provide easy access to effective multimedia supported interactive learning materials, discussion boards that facilitate students’ discourse, on-line assessment tools and all kinds of other documents. Today a number of schools have broadband Internet connection and access to educational materials. According to the data provided by MONE, the broadband internet connection is established in 45% of overall primary schools and 86% of state high schools. If the number of the students who have Internet connection at their schools is considered, 95% percent of overall high school students along with 82% of primary school students (10 million students in total) have the internet facility in their schools (MONE, 2007).

In order to make use of advantages of Web to support students’ learning, appropriate instructional tools and designs guided by recent learning theories and models need to be implemented. The learning environment designed for this particular study (WebFen) attempts to provide means to meet this need. The study also tries to provide a learning environment with distinctive features that may differentiate it from other attempts with the same goal. The following section tries to outline the distinctive features of WebFen with respect to similar environments.

Today there exist a number of web sites that are developed to transmit scientific information having different quality, effectiveness, validity and content. Some of these web sites are even like electronic textbooks with a very few pictorial representations. Therefore teachers have difficulty to evaluate the effectiveness and validity of the educational web sites and to find out web sites that pay attention on multiple knowledge representations in order to use them in their classrooms (Linn, 2004).

In the study of Mioduser, Nachmias, Oren and Lahav (1999), they found that only 28.2% of the educational web sites include inquiry-based activities, and more than three-quarters were highly structured and give the control of learning to the computer . Most sites support processes of retrieving information (52.5%) or rote learning (42%), fewer focuses on analysis and inference processes (32.6%) and less on problem-solving and decision-making (5%). Only a few sites include student-modeling and adaptation mechanisms.

WEBFEN is a comprehensive learning tool in which students can reach interactive learning activities that support scientific process and argumentation skills, discussion board, assessment tools, educational games, videos or other documents.

The vision of science and technology curriculum is described as educating all students as science and technology literate individuals. The documents provided by MONE focuses on the significance of technology and relationship between science and technology. The MONE also states the main philosophy and characteristics of new curriculum as:

- Structure of the curriculum is appropriate for active learning and scientific learning process.

- New knowledge and skills are constructed on already learned skills and knowledge.
- Communication-including language- is the main unit of science and technology education.
- Students learn best when they are actively participating in learning process.
- Students learn best when open-ended activities, discovery, using initiative and self-assessment practices are provided.
- The effective learning takes place when educational practices and students' real life match with each other.

These principles are parallel to the WEBFEN principles and WEBFEN includes activities that are similar or same as the suggested learning activities of the national science curriculum of 6th grades. Therefore this system will be a useful support tool for science education for both teachers and students.

To sum up, when considered in relation to other similar web-based learning tools and environments, the significance of WEBFEN is mainly based on its close relevance to national curriculum standards which is assumed to be an advantage in terms of usability and practicality. Moreover, the literature does not include similar studies Web-based tools that use the main argumentation principles among the studies carried out in Turkey; so it opens up new research areas especially for Turkish researchers.

3.2. Statement of the Problem

The main research problem is the design of a web-based science learning tool namely WebFen and development of the system and instructional materials about 'particulate nature of matter' topic of 6th grade science curriculum as a sample unit. The tool is designed to develop students conceptual knowledge on the selected unit as well as engaging students in activities that scientific processes and argumentation method are taken place as testing a claim, building hypothesis, predicting-observing-evaluating a scientific phenomena, building up arguments with related evidences and justifying scientific claims about the topic under discussion. The study also aims to provide initial data on the effectiveness and usability of WebFen with preliminary study with in-service teachers and pilot study with students.

3.3. Design Development and Implementation of WebFen

Design, development and implementation phase of WebFen tool can be grouped into four main categories which are:

- Student activity environment and activity rooms
- Learning activities for selected topic
- Teacher monitoring and administration environment
- Implementation of the WebFen

There are mainly three types of users, students, teachers and administrator, who have different tasks and different system interfaces. Each user signs in to the WebFen with a unique ID and password. Figure 3 represents the homepage of WebFen learning tool. Students have permission to enter each activity room. Teachers can enter the activity rooms (in student activity environment) and they also monitor students' responses to each task or question, get reports about students' scores and number of correct and incorrect responses for each question or task. The last type of user is site administrator who can assign teachers, define activity rooms and define the tasks in those rooms.

Figure 3.1. Homepage of WebFen

Design guidelines of WebFen that are derived from current constructivist design models, suggestions coming from argumentation studies and usability principles of interactive learning environments. The following paragraphs describe the guiding design principles which are used as a framework for the present study and were derived from the common issues of constructivist design as mentioned in introduction chapter and how those principles were used in the WebFen;

Active construction of knowledge: WebFen environment includes learning activities that will help students interpret the incoming knowledge and relate it with existing knowledge. An example for this principle is that learners have already covered the topic of matters in different states and with the present study they build and test hypothesis about the nature of matters in different states using the interactive tools and activities provided by the environment.

Personal interpretations of the environment: The tool needs to welcome and support students' personal interpretations of the information. In WebFen, students are encouraged to create a hypothesis according to their previous knowledge and test and revise these hypotheses by making personal interpretations of the evidences provided by related activities and tools. The different learning activity rooms and tools in them serve as cognitive tools to help learners to create interpretations of the problem or hypothesis.

Multiple representations: In WebFen, different learning activities provide different representations of the particulate nature of matter concept. Students can observe both microscopic and macroscopic representations of matters in solid, liquid and gas phases. For instance in one experiment activity students observe the matter and the particles while the matter is being compressed; in other activity, they observe the matter while dissolving in other matter.

Multiple perspectives: Another important principle of the WebFen environment is providing and supporting multiple perspectives. In WebFen, students use the tools and activities in order to create their own answers to the main question, they organize multiple evidences in activities and they can demonstrate their own solutions (perspectives) to the problem; activities provide multiple ways to solve the problem. The tool also provides different perspectives on the history on structure of matter in expert room in WebFen. Students also supported to collaborate with each other to share their views and see how other students use evidences; therefore they bring different perspectives to the discussion.

Student interaction with environment, teacher and others: In this study, when working with WebFen, students can interact with

- Content by using tools, and activities provided by the environment,
- Teacher in discussion room and by using e-mail (asynchronous messaging) options of the system,
- Other pupils using discussion options. Collaboration between students is also enabled with discussion room facilities.

Process along with content: An important goal of WebFen tool is to emphasize the development of scientific thinking along with an understanding of related concepts in science. This study uses "argumentation" method as a means to support scientific thinking.

3.3.1. Student Activity Environment and Activity Rooms

The main design principles of the WebFen are guided by the current instructional models of constructivist learning approach. It integrates instructional practices that foster the development of scientific thinking, which is an important goal of the "Science and Technology Course" of national curriculum for science education. WebFen also uses basic suggestions and principles of argumentation method in education.

Main characteristics of WebFen can be listed as:

- Each topic/unit includes a set of content learning objectives.
- Each topic/unit starts with a question or problem having controversial answers. Students choose an answer (build up a claim) according to his/her previous knowledge about the topic.
- Environment includes activities that are used to support students' starting claims/ answers.
- Activities include multiple representations of same concepts such as macroscopic and microscopic representation of different matters.
- Activities probe students' existing knowledge. In the experiment activities students need to be first asked to make a prediction about the experiment using their previous knowledge.
- Help menu is provided for student who might need information regarding aim of that learning activity, how to manipulate screen objects (e.g. buttons, texts, experiment materials such as syringes, magic lens, beaker) and how to complete tasks.
- System has collaboration features to allow students share and discuss their claims or solutions to the problem.

- Students are guided and informed during the activities about what they are expected in each task.
- System provides help features to explain the aim of each task also needs to be explained in help section.
- A user can terminate the activity at any step.
- Students' responses to each task are recorded by the system and monitored by the teachers.

The "content" part of WebFen includes interactive learning activities and rooms (activity rooms). The layout of topics section of WebFen with introduction screen (at the main activity environment) is presented in Figure 3.2. The navigation menu group at the left side of the screen provides easy access to introductory screens and activity rooms while the user is exploring the system. The title of each activity screen such as introduction, investigation room and which one can be compressed is presented at the top of the screen. Each activity screen is opened in the main activity environment as presented in Figure 3.2.

Figure 3.2. Introduction screen of the selected unit

Topic introductory screens (introduction and question screens) and activity rooms are the main components of student activity environment. Initial screen starts with introduction of the agents and aim of the topic. Agents are used to convey the instructions to complete the tasks and convey the feedback about users' actions. After the introduction screen, the main problem of the topic is introduced to students.

Rooms are the sub systems of WebFen. There are seven rooms which are investigation room, video room, discussion room, decision room, game room, competition room and expert room. As students follow activities in the rooms, they try to collect evidences to support their choice for the main problem to create an argument on presented question. Activities aim to develop both conceptual understanding about the topic and scientific process skills such as predicting, observing, explaining, building up hypothesis/claims, testing claims and building up science related arguments that are justified with scientific evidences. Students investigate simulations and online experiments, observe video demonstrations, read additional textual and pictorial documents, take notes, discuss with other students and with the teacher, complete educational games and other assessment activities and they analyze their collected evidences to decide on a solution for the problem and to build up arguments relating with collected evidences. Each room is designed to accomplish a content knowledge or process skill objective. The following paragraphs explain the rooms and their functions.

Investigation room includes educational simulations which are interactive flash activities (experiments) related to the given problems. Activities mainly use predict-observe-explain strategy in order to reinforce students to generate tentative answers (build hypotheses), by making predictions, testing their predictions, and thinking about their observations. This strategy is helpful to support students' development of scientific process skills and it can also be used to get students' previous knowledge and detect possible misconceptions about the topic. For the activities that use predict-observe-explain strategy, students are asked to make a prediction for the experiment (flash activity/simulation), then they complete experiments and they are expected to answer questions related to experiment observation. At the end of each experiment they explain their observation and collect evidence from each experiment. Students' responses to each task are recorded by the system and can be monitored by the teacher.

Video room contains video based activities which are embedded into interactive flash documents. Activities in video room are video demonstrations of laboratory experiments that follow predict-observe-explain strategy similar to the investigation room, and 3-dimensional video demonstrations of substances.

According to Toulmin's argument model, a claim need to be supported with some evidences and activities in investigation and video room and these serve as sources of evidences to support students' answer to initial problem/question/claim. Students' explanation statements of interactive activities in those rooms are presented in decision room to support their argument building process.

Discussion room is designed to provide students and teachers a platform where they can communicate and collaborate online (in asynchronous way). Students and teachers read and send notes under a topic created by teacher after they login to the system. Collaboration is an important element of argument building and knowledge construction process. Argumentation studies that are taken as reference suggest arranging small and large group discussion sessions for students to share their claims and evidences, explain their justifications to each other. Teacher is responsible to guide and monitor flow of discussions and provide feedback about students' understanding of topic and quality of their arguments (whether they provide any evidences for their claim or whether they explain the relationship between evidences and claims).

Decision room is the place where students view their answers for initial question/problem/claim, their responses to predict-observe-explain questions in the activities of investigation and video room and a list of explanation statements (that are the responses to explain questions). These explanation statements that are created by students serve as evidences that may either support or oppose the main problem. As student observes his/her responses presented in that room, he/she is expected to decide on the final answer/ final argument. There is also an online decision report that needs to be filled by students in a scientific argument form; claim statements that are supported by related evidence statements including warrant statements that explains the relationship between the evidences and claims. Students' decision reports are also saved by the system.

Game room includes educational games such as crossword, matching and puzzle type of games that related to the topic. These games help to keep students' attention and keep them motivated. They get scores as they complete the games correctly. For the present study a matching game is developed on the particulate nature of matters in solid, liquid and gas phases (details of the game is presented in "Learning Activities for Selected Unit" part of this chapter).

Competition room serves as the assessment module where students answer text based multiple choice questions and they get points to be the winner of the competition. Wheel of fortune type of competition is included into that room. In the competition, the aim is to get the highest score by answering maximum number of questions correctly.

Expert room includes text-based and pictorial information related to the topic. New technologies and developments, scientific facts and information that are not highlighted in activities of other rooms are included into the expert room. A brief summary of selected topic is also added into that room to help students reorganize presented information and have conceptual understanding on selected topic together with other activities.

3.3.2. Learning Activities for Selected Unit

The instructional content is based on curricular objectives of the section emphasizing "The Building Blocks of Matter" within the unit titled "The Particulate Nature of Matter". The unit is designed for 32 hours of instruction and covers 22% of the 6th grade science curriculum with 26 objectives. The section chosen for the present study, the building blocks of matter covers eight of the 26 objectives specified for the unit on "The Particulate Nature of Matter". The unit consists of four parts. The first part includes an introduction to particulate nature of matter and concludes with the idea of atoms. The second part covers, atoms, molecules, elements and compounds. The third part is on physical and chemical change while the last part includes states of matter.

The major aim of the unit is to help students recognize that matter is made up of invisibly small moving particles with empty space between them using the properties of compressibility and expansion. The students are expected to use these notions to conceptualize atoms and molecules in relation to elements and compounds. Moreover students are also expected to understand changes in matter using the particulate nature. The unit is designed to form a basis for 7th grade topics that aim for an understanding of the structure of an atom. The unit also focuses on the development of scientific thinking skills such as observing, comparing, making inferences, predicting, and building up scientific arguments while helping conceptual development of the particulate nature of matter.

Content of learning activities are designed to accomplish conceptual learning objectives which are compatible with 6th grade science curriculum objectives that are included in the first part (building blocks of matter) of the unit on "particulate nature of matter". The conceptual learning objectives that highlighted through various activities in different rooms of WebFen can be listed as:

- Objective 1: Compare the compressibility and expansion properties of liquids and gases.
- Objective 2: Use the compressibility and expansion properties of gases to explain the empty space between particles of a gas.
- Objective 3: State that matters can be broken down into smaller particles through experimentation
- Objective 4: Specify that all matters are made up of invisibly small moving particles
- Objective 5: State that the empty space between particles of a matter in gaseous phase is greater than the empty space between particles of a matter in liquid and solid phase.
- Objective 6: State that the arrangement of particles made up matters is getting more disordered as it moves from solids to gases.
- Objective 7: Question how far one can go on dividing matter into consecutively smaller pieces.
- Objective 8: Use the term "atom" to specify building blocks of matter.

Supporting students' argument building process is another goal in design of learning activities. In order to accomplish that goal, activities include implications of studies that use argumentation as theoretical base. The following paragraphs explain the learning activities and underlying content and scientific process goals.

In argumentation studies and current instructional models that follow implications of constructivist approach suggest starting learning activities with a main problem that have controversial answers. Students follow activities to solve that problem or to support their answers (claims) using evidences provided by multiple sources in activity rooms. Learning activities in WebFen start with introduction of topic and main problem/question.

The main problem of the sample unit is stated as "If you have a magic lens and we are able to observe the matters in details, how do you think we could observe evaporating water having chalks in it?" Students are provided with sample student drawings that are adapted from the study of Ardac and Akaygün (2004) as alternatives to the main problem and they are asked to choose the best particle representation of evaporating water with chalk. Students' responses are accepted as their claims about the nature of matters that need to be justified with evidences and they build up arguments including claims, evidences and warrants.

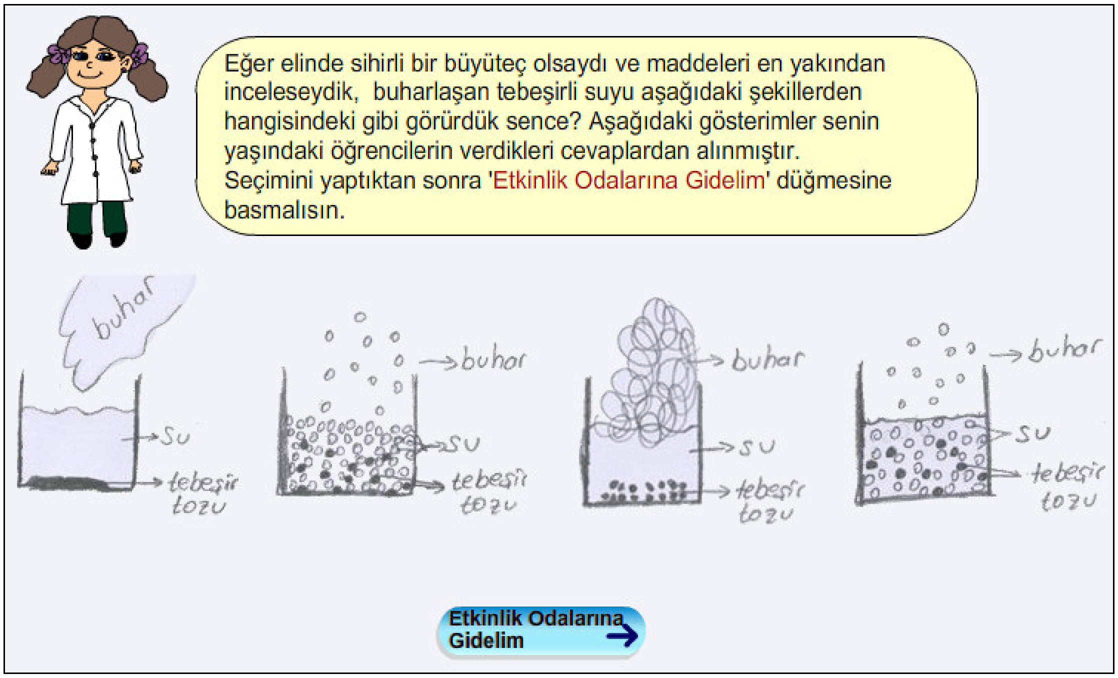


Figure 3.3. Question screen

In the first claim/alternative, matter is perceived as continuous substance with macroscopic properties. The second alternative represents matters in particulate form which is the accurate representation. The third alternative is similar to the first alternative but the solid (chalk) is represented in particulate form whereas liquid and gas are seen as continuous substances. The third alternative represents solid and gas in particulate forms whereas the particle representation of liquid includes macroscopic interference; liquid borders are shown and particles are seen as one of the components of liquids.

After choosing a claim about nature of matters from four alternatives, students are introduced with a map of rooms which are:

- Investigation room
- Video room
- Discussion room
- Decision room
- Game room

- Competition room
- Expert room

Each room includes a set of learning activities that is designed to accomplish one or more learning objectives. There is no strict sequence to follow activity rooms, however decision room need to be studied after completing activities in investigation and video room. That is because the content of decision room (evidence/explanation statements placed in decision room) is created according to students' responses to tasks in investigation and video rooms. Moreover, it is suggested to work on competition room at the final steps of instruction, because it serves as measurement tool for conceptual learning on selected topic. Figure 3.4 presents suggested sequence of activity rooms. A more detailed instructional sequence and sample instructional plan can be seen in Appendix A.

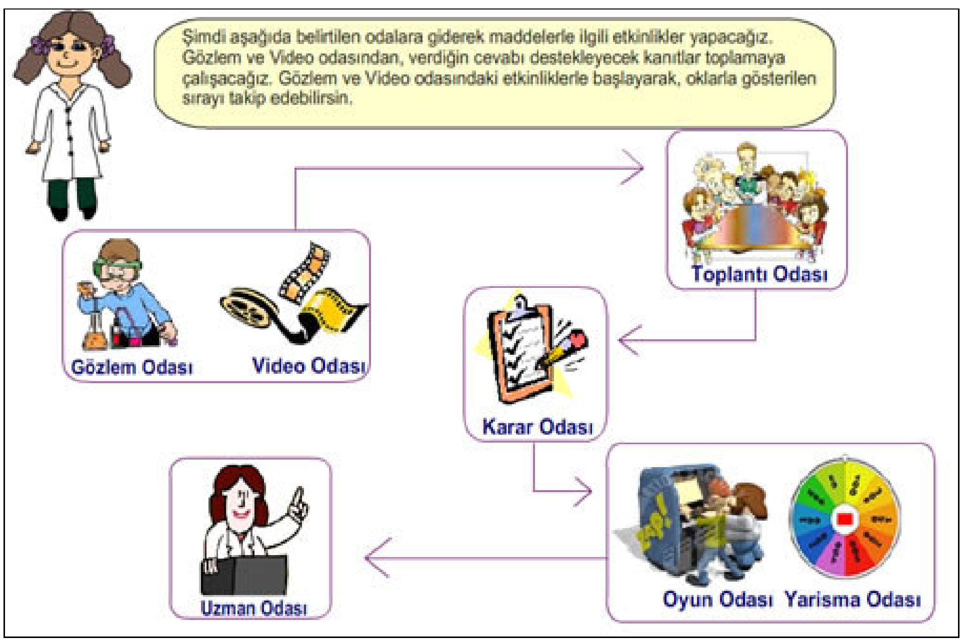


Figure 3.4. A screenshot from activity rooms

The investigation room includes three interactive flash activities which are also recommended activities of the new Turkish science curriculum. The titles of activities are "Which one can be compressed?", "Salty water" and "Look into matters". There is no rigid sequence of activities in investigation and video room; student can start working any of those three activities.

Figure 3.5. A screenshot from investigation room

"Which one can be compressed?" experiment activity which uses predict-observe-explain strategy focuses on compressibility differences of liquid and gas matters. This activity supports objective 1 and 2; students compare the compressibility and expansion properties of liquids and gases and use those properties of gases to explain the empty space between particles made up of gas. Objective 4 which states students specify that all matters are made up of invisibly small moving particles is also partially included in this activity. Here, students analyze the particulate nature of pure water (as a substance in liquid phase) and oxygen gas (as a substance in gas phase) by using magic lens which will be described in the following paragraphs.

Activities in both investigation and video room start with introduction of experiment including the aim of the activity. Before students start to use the interactive lab materials, they are asked to make a prediction about the compressibility properties of water and oxygen gas. The prediction, observation and explanation questions are presented in multiple-choice format and in a notebook figure as presented in Figure 3.6.

As a student chooses one alternative, she or he can go on to work with the activity. All of the students' answers are saved by the system during the activity.

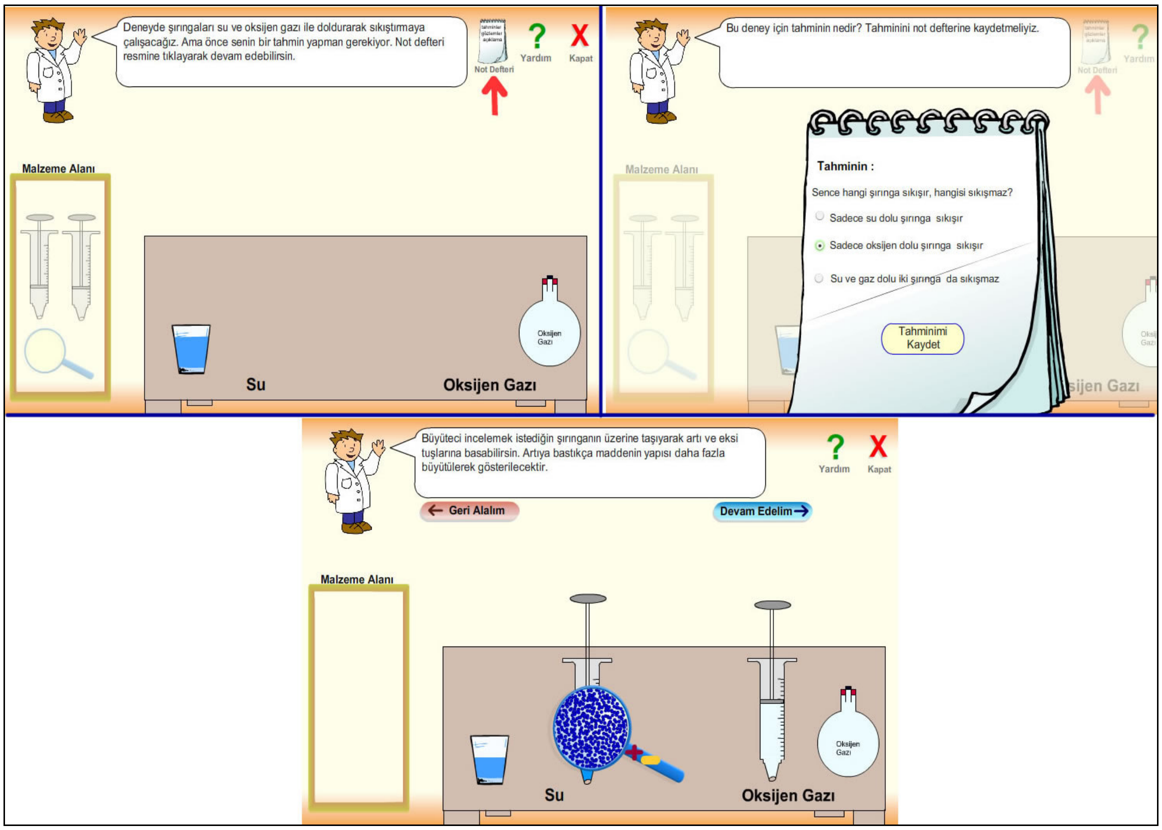


Figure 3.6. Screens from "Which one can be compressed?" activity in the investigation room

After deciding on prediction statement, they manipulate the interactive lab equipments (flash objects) which are syringes, water and oxygen gas to carry out the experiment. Students need to drag the syringes to fill them with water and oxygen gas and tries to compress each of them, then they are asked to note observations. In order to make an explanation for the observation which then will be used as evidences he uses special molecular magnifier tool to look into the water and oxygen gas as shown in Figure 3.6. The special magnifier has 4 different enlargement scales starting from small particle images of the matters to molecular or atomic images. After the second enlargement scale user can observe the atomic demonstrations of matters (two hydrogen and one oxygen atoms for pure water and two oxygen atoms for oxygen gas). The magnifier also shows the movements of particles of liquid and gas. This cognitive tool plays an important role to help students understand differences of the movement of liquid and gas particles and the spacing of particles.

In the second part of the activity, if a student wants to continue to study the same activity in details, she/he can use magnifier to observe the water and oxygen particles during the compressing process and can revise his/her explanation. Selected phases from the second part of compressibility activity that demonstrate particle representations before and after compression are presented in Figure 3.7.

Students drag the magnifiers and weights on the syringes and then choose an enlargement level by clicking plus and minus push buttons. By clicking "release weights" push button, s/he can observe the difference in the arrangement of particles made up of oxygen gas and observe no change (a negligible amount of change) in the arrangement of particles made up water.

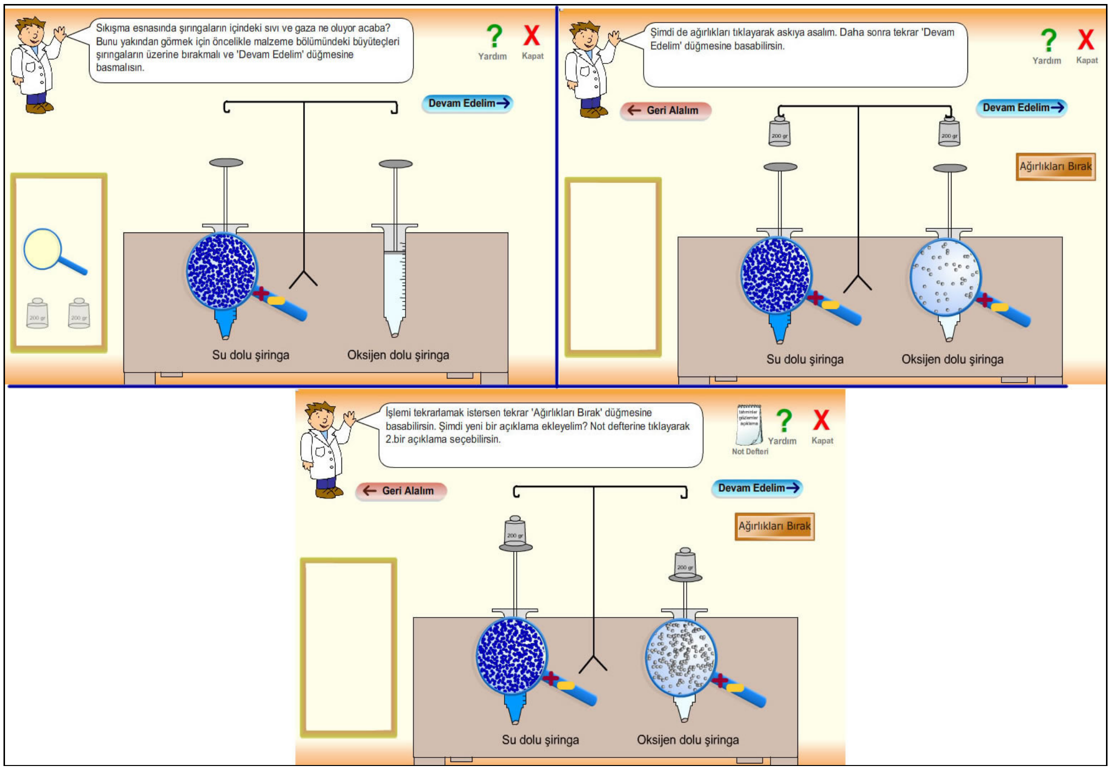


Figure 3.7. The molecular views of water from “Which one can be compressed ?” activity

At the end of each activity in investigation room, feedback about students’ answers to observation and explanation questions is provided by the tool.

In “Which one can be compressed” activity both macroscopic and microscopic representations of liquid and gas matters are provided to the students. Before students use the magic lens, they can compare the compressibility property of liquid and gas using macroscopic properties, after that they use magic lens to analyze those matters before and during the compression process to explain the empty space between particles made up of gas.

“Salty water” is another interactive experiment activity that focuses on molecular representation of dissolving salt in pure water. It is designed to accomplish objective 3; students recognize that matters can be broken down into smaller particles through experimentation. The task that students are expected to follow is adding salt into pure

water and observing the macroscopic and microscopic properties of salty water. They observe salt is broken down into smaller particles which are not visible with naked eye (macroscopic representation), but using the magic lens particles made up of salt and water can be observed in a detailed way during the dissolving process of salt in water (microscopic representation). The flow of tasks in that activity is similar to the compressibility activity; students are first asked to fill the beaker with pure water and make a prediction about the appearance of salt added to pure water. After that step students drag the salt and observe whether the salt dissolves and disappears in the water. They also use magic lens to investigate dissolving process at particle level. Figure 3.8 shows the selected phases of salty water activity.

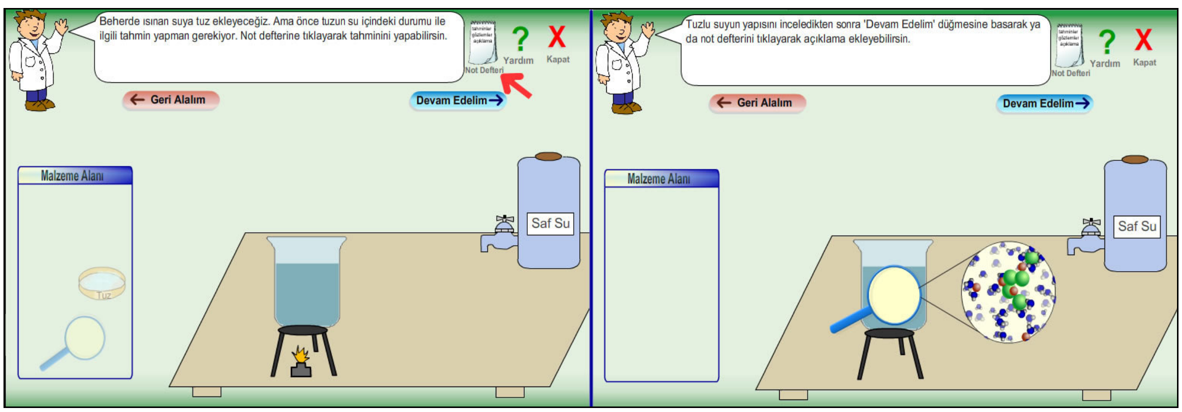


Figure 3.8. Screens from "Salty water" activity in investigation room

"Look into matters" activity is the last activity of investigation room designed to accomplish the objectives 4, 5, and 6 which state that students specify that all matters are made up of invisibly small moving particles, students recognize that the empty space between particles of a matter in gaseous phase is greater than the empty space between particles of a matter in liquid and solid phase, and students recognize that the arrangement of particles made up of matters is getting more disordered as it moves from solids to gases respectively. The particulate nature of different matters (iron screw, olive oil and helium gas) from each phase (solid, liquid and gas) are analyzed using special lens in that activity. Unlike the other two activities in investigation room, look into matters activity is not an experiment-based activity and therefore does not include prediction and observation phases. Students are expected to investigate the matters presented on the screen using

magic lens and they are asked to compare the movement of particles as explanation statement of the activity.

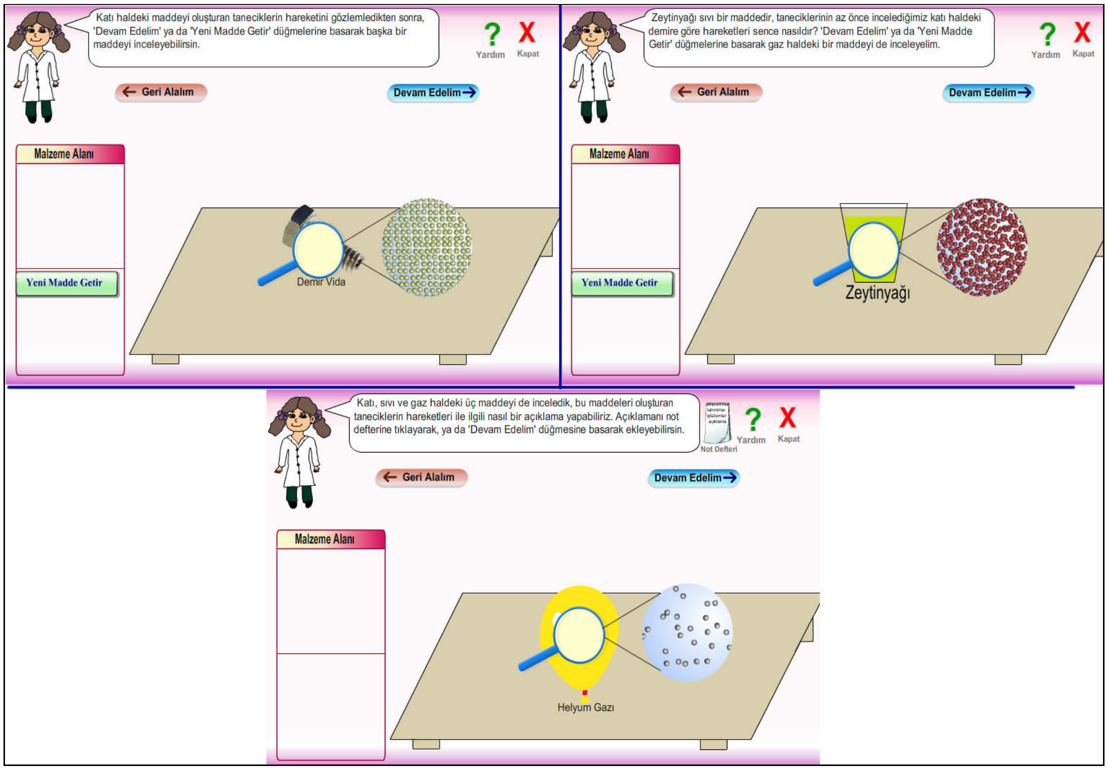


Figure 3.9. Screens from “Look into matters” activity in investigation room

The video room includes three video-based activities, one is the video demonstration of laboratory experiments that follows predict-observe-explain strategy and two are 3 dimensional particulate video demonstrations of evaporating water and salty water.

The first activity is “ink in water” activity which is a demonstration of the laboratory experiment. It shows the macroscopic representation of water after a small amount of ink is added into it. This experiment focuses on the macroscopic characteristics of matters. Students make predictions about the behavior of ink substance in water, observe the experiment and explain the results. The main content learning objective of ink and water activity is objective 3 which states students recognize that matters can be broken down into smaller particles through experimentation. Ink is broken down into small particles in water and ink disperses homogeneously in water. Ink particles are not seen separately from water, because it is broken down into smaller particles. The figure below (Figure 3.10) displays consecutive screens captured from the clip on the dispersion of ink in water.

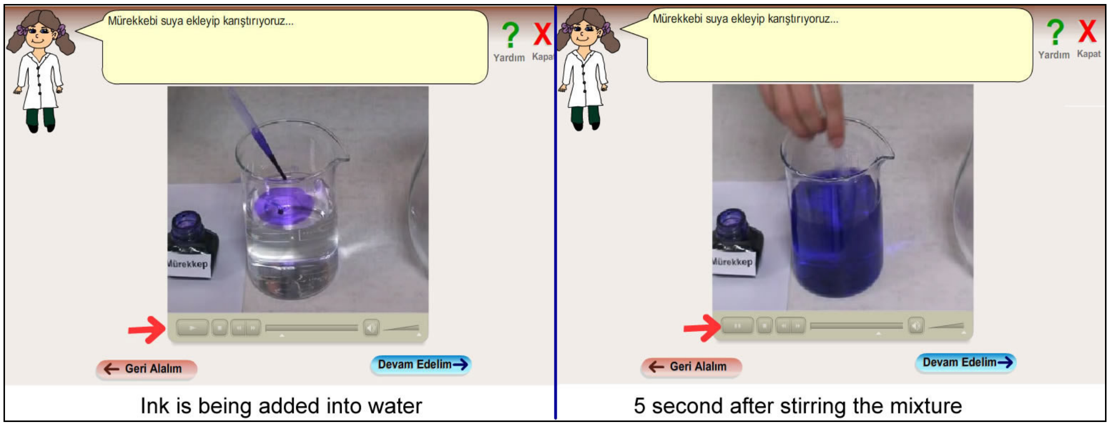


Figure 3.10. Screens from the “Ink and Water” activity in video room

Figure 3.10 presents the views before and after the ink spreads homogenously in water. This activity also uses the predict-observe-explain strategy. In between the two phases, students are asked to predict the behavior of ink (degree of dispersion) in water. After observing the results, students are expected to explain their observations. The video clip is thus introduced with occasional breaks in order to include questions on the observed scenes.

Evaporating water activity is a three dimensional demonstration of evaporating water particles which aims to support objective 3 and 4 (students recognize that matters can be broken down into smaller particles through experimentation and students specify that all matters are made up of invisibly small moving particles). Figure 3.11 shows an example frame captured from the video clip which is created in The VisChem Project (Tasker, et al., 1996) and embedded into evaporating water activity in video room of WebFen.

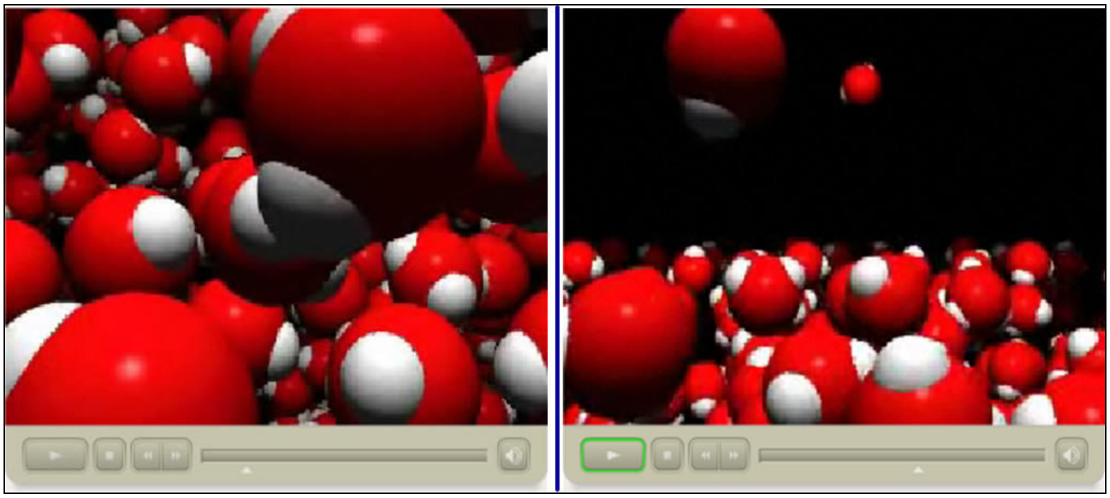


Figure 3.11. 3-D demonstrations of water molecules from “Evaporating water” activity in video room

The main aim of this activity is helping students to notice that water (liquids) are completely made up of small moving particles and there is no macroscopic property such as lines or borders on the surface of liquid. As mentioned in the literature review part, the results of studies that focus on particulate nature of matters and students’ perceptions of matters (Ben-Zvi, Eylon & Silbestein, 1986; Ardaç and Akaygün, 2004; Johnson, 1998) shows that students tend to attribute macroscopic properties to atoms and particles. They tend to draw lines in particle representations of solids or liquids. At the end of the evaporating water activity students are asked to choose an explanation statement about the liquids in particle form. The explanation screen is shown in figure 3.12.

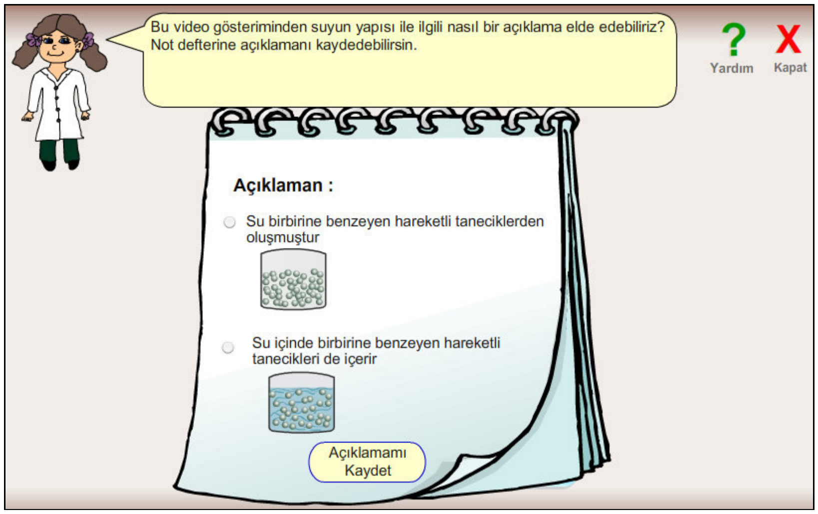


Figure 3.12. Explanation screen of “Evaporating water” activity in video room

Similar to the evaporating water activity, “Salt and water” activity of video room represents dissolving of salt particles in water in three dimensional video form which is created in The VisChem Project (Tasker, et al., 1996) and embedded into WebFen. “Evaporating water” and “salt and water” video based activities are designed to emphasize the main misconception which is “all matter has also small particles in it”. The correct claim is “all matters are completely made up of small particles and there are no borders or any macroscopic signs in the nature of matters”.

All of the activities in investigation and video room also have “help” section that includes the aim of the activity, instructions and animated demonstrations on how to manipulate and use screen objects including push buttons. Figure 3.13 shows a screenshot form help section of which one can be compressed activity.

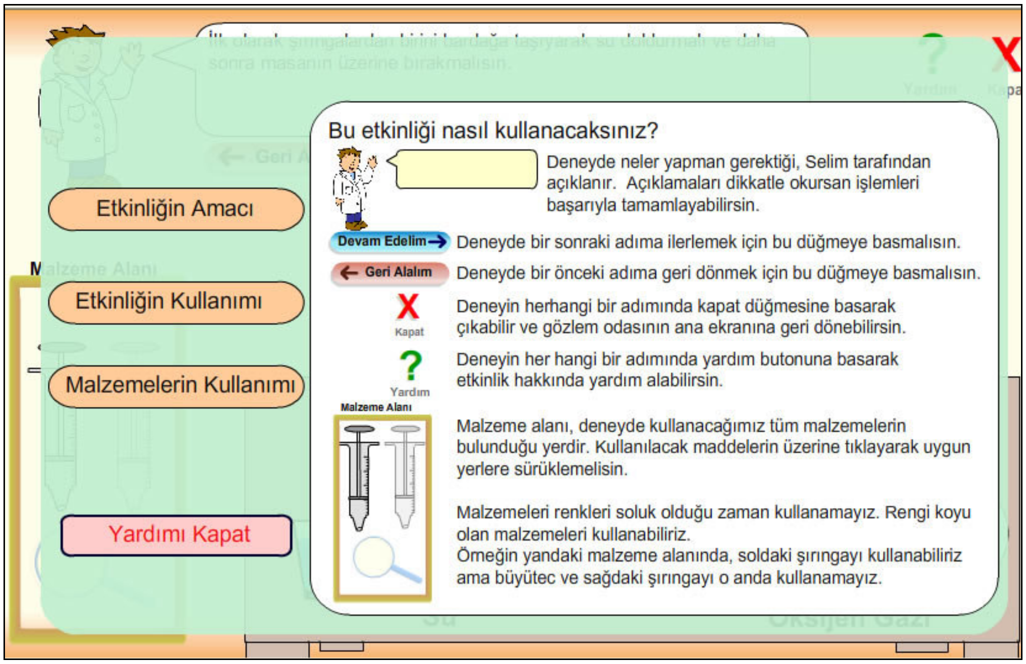


Figure 3.13. Help section of “Which one can be compressed ?” activity

The discussion room is the place where students are expected to share their finding which is collected from activity rooms with other peers and teacher provides feedback for them. A forum like discussion board for the use of teachers and students are designed to support collaboration and group work in argument building process.

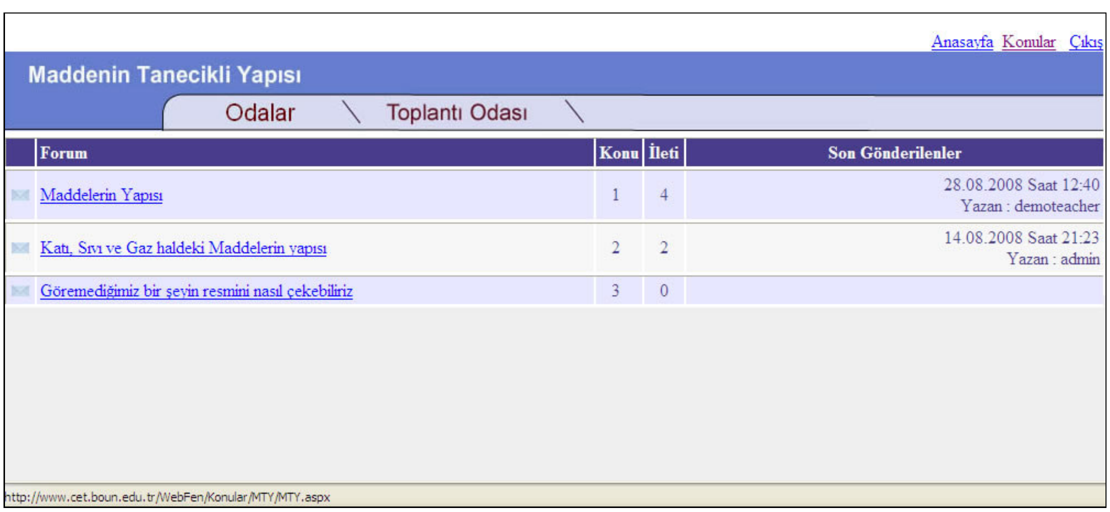


Figure 3.14. Discussion room

The decision room is designed to help students bring together and reflect on the information presented in the investigation, the video and the expert rooms. The students are expected to bring together the explanations they have gathered from different experiments and observation as evidence to support or reformulate their initial claims. In this room, students can see their starting claim, the notebook that contains their records from the experiments and observations (their evidences). They are expected to reconsider their starting claim with reference to existing evidence, and complete an exercise that requires them to check the consistency between their claim and gathered evidence and reach a conclusion.

The second part of decision room, students are asked to create a decision report that include arguments about the matters (solids, liquids and gases). According to Toulmin's argument model (which is the argumentation model used in this study) an argument consists of at least a claim statement, data/evidence statements to support the claim and warrant statements to explain how data/evidence support the claim. In this study, claims are students' answers to main problem which is the representation of water and chalk; evidences are the explanation statements (of experiments) that are created in the activities of investigation and video room, and warrants are students' statements that describe the relation between claim and data/evidence. Students are presented a sample argument statement about the particulate nature of solids and they are asked to write similar arguments using their collected evidences in the template of decision report. The decision room and its components are shown in Figure 3.15.

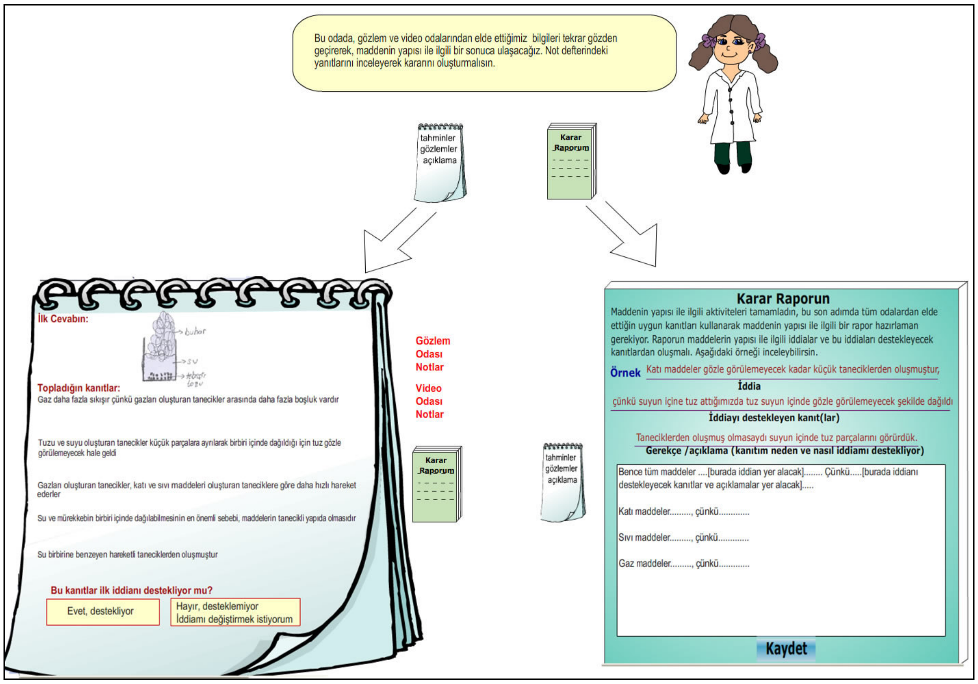


Figure 3.15. Decision room and its components

The game room includes a matching game that students are asked to drag appropriate particulate representations of matters in solid (ice), liquid (water) and gas (water vapor) phase. The correct and incorrect actions of students while they are dragging the particulate representations in front of the substances are counted and recorded by the system. The following figure (Figure 3.16) represents the game activity.

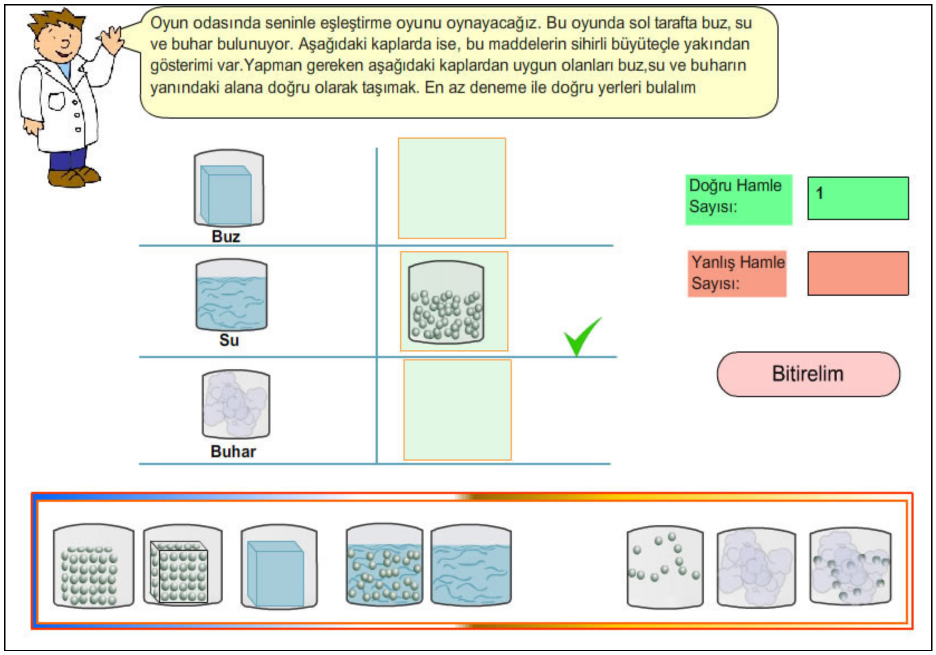


Figure 3.16. "Matching" game in game room

The competition room serves as assessment tool for the content knowledge and it is designed to evaluate students' knowledge as they complete the activities in previous rooms. The assessment tool is presented as a competition and the format is selected from the popular competitions of typically broadcasted in television channels. There is an object similar to wheel of fortune which shows the point of each question as student run it. As students answer the question correctly, s/he gains points in the competition and go on with another question. Immediate feedback is provided by the system as students answer a question. The general layout of game room is given in Figure 3.17.

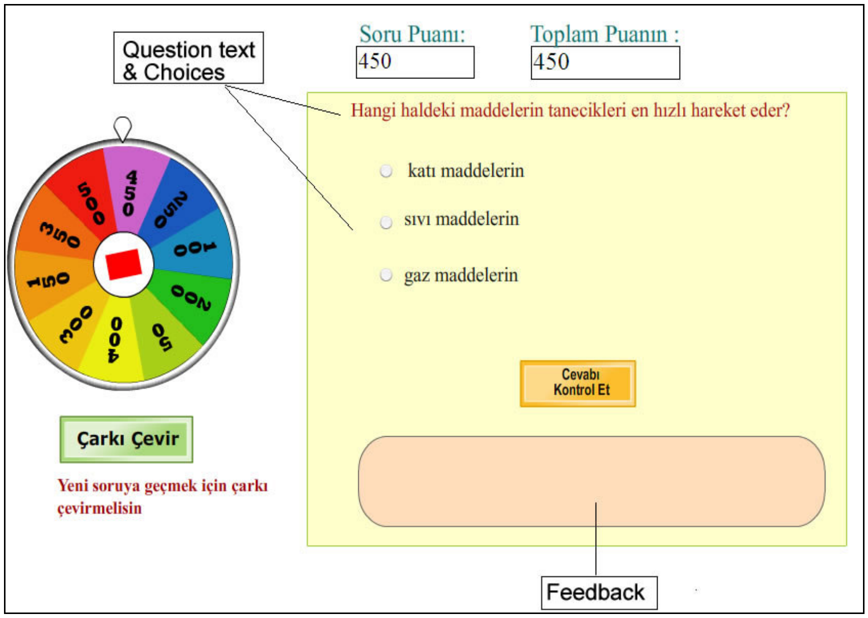


Figure 3.17. Competition room

The expert room includes text and pictorial materials about the historical development of ideas on particulate nature of matters and idea of atom, invisibility of atoms and ways to get pictures of atoms and molecules, and a summary of content covered in activities of investigation and video rooms. Objectives 3, 4, 5, 6, 7 and 8 are covered in the expert room. Selected screens from expert room are presented in Figure 3.18.

Figure 3.18. Expert room

All the activities and rooms except discussion room are placed into the main activity environment as presented in Figure 3.2 and users can easily navigate between rooms using navigation menu.

3.3.3. Teacher Monitoring and Administration Environment

Teachers have a significant role to guide students to accomplish conceptual and process skill goals while studying with WebFen. The system allows teachers to check students' responses to all questions or tasks in the system. As a teacher sign in the system, she or he can access students' activity environment and teacher monitoring environment. In teacher monitoring environment, they can observe whether the students provided correct answer to any question and could detect possible student misconceptions before the instruction and analyze in which tasks students have difficulty or complete correctly. Teachers also create discussion topics for selected unit in teacher environment of WebFen.

Reports section allows teachers to get question statistics and student answers reports. In question statistics report teacher gets a list of number of correct and incorrect answers of each question in activity rooms. With this report, teachers can analyze that how many correct answers are given to a question in an activity room. The other report is student answers report which shows answers of each student to any question. Figure 3.19 represents student answers report in teacher monitoring environment. As teacher chooses a student name from a drop down list, the name of the activity, type of question, question text, that student's answer text, correctness of answer and score of the question (if the question belongs to competition room) are displayed in a table format.

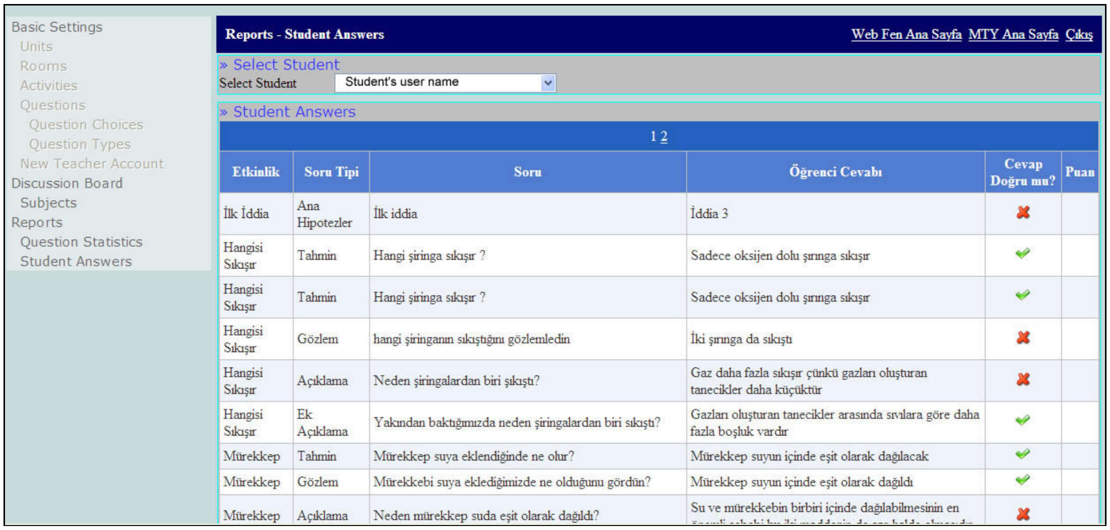


Figure 3.19. Students' answer report in teacher monitoring environment

Site administrator is the third type of user which is responsible to assign teachers (assign user name and passwords for teachers), define the rooms, activities in each room, and define tasks or questions and alternatives (choices). According to those definitions, the database is arranged to keep students' response records. Site administrator signs in WebFen with a unique username and password. S/he also has the permission to enter the teacher monitoring and student activity environment of WebFen.

3.3.4. Implementation of WebFen

In the implementation phase of WebFen two main software applications were used. First one was Adobe Macromedia Flash (version 8) with ActionScript 2.0 (script language of Flash) which was employed in order to construct student activity environment for selected unit. Flash is professional authoring software and is capable of designing and implementing interactive visual applications. Flash movies can consist of graphics, text, animation, imported video and sound. It also allows users to provide input and with ActoionScript language, users' inputs can be used to modify the application and increase interactivity in flash movie.

Teacher monitoring environment, administrator environment, login controls, discussion board and other web programmings were created within .net platform (Ms Visual Studio .NET, ASP.net) with C# (pronounced see sharp) programming language. The system works in Sql server 2000 database. The Figure 3.20 shows the WebFen database structure and relations.

Unit table was used to collect data of the main science topics from curriculum. For the present study "particulate nature of matter" topic was chosen as a sample unit. A unit has properties of name, grade level, subject matter category (e.g. chemistry, biology, and physics), a brief description and a unique unit ID. There are also rooms (e.g. investigation room, video room) in each unit and several activities (e.g. which one can be compressed, salty water, matching game) in each room. In some activities students are expected to give answers to a question or a task. For those types of activities, details of questions such as types (e.g. predict, claim, competition question), descriptions are described in questions table. Question choice table in the database is used to define the alternatives of multiple choice questions.

Decision and discussion room have separate tables from room table, because they include different data types. In decision room, students are expected to complete a decision report which is a long text entry type of response and can not be included in room table that has no such properties. Discussion room which has a form based structure is defined in two data tables, discussion subject and discussion entry. Discussion subject table is used to define and store data of discussion subjects. Each subject in discussion room has some properties such as subject headers, texts, creation date, user name of the person who created the subject and status (is the subject active or inactive).

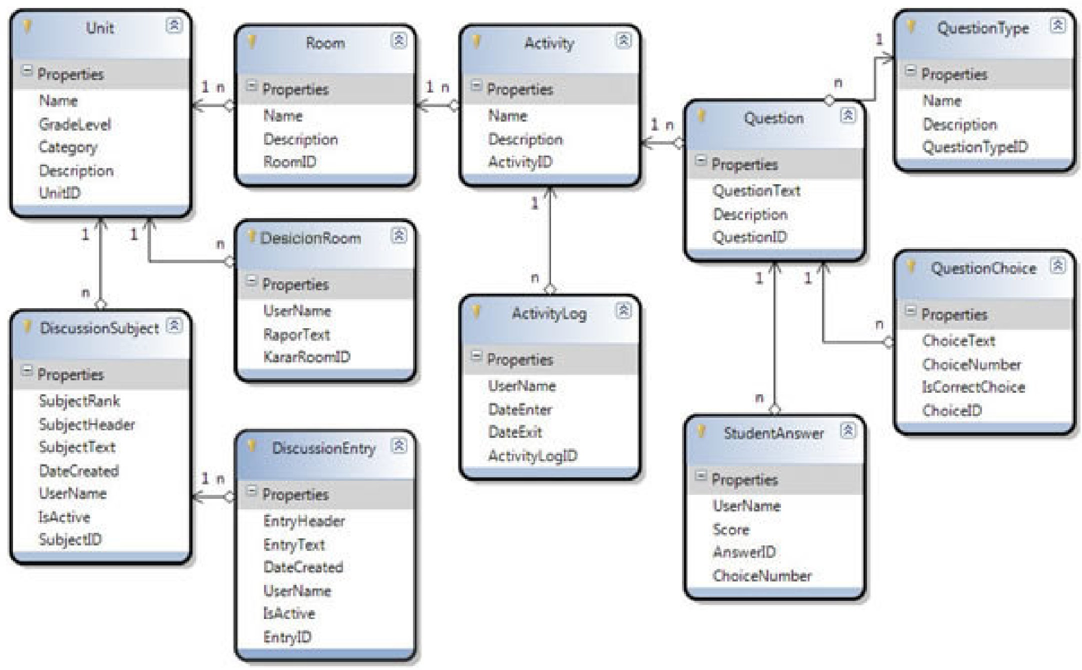


Figure 3.20. WebFen relational database structure

Flash is not capable to communicate with a relational database directly, it must work with a server-side technology such as ASP.NET that also capable of database access. By using ASP.NET, it's possible to retrieve data from database, including Microsoft SQL, MySQL, Access, and Oracle, to display in a Flash-based interface. Additionally, ASP.NET can be used to update or insert data coming from a Flash interface into a database. Therefore ASP.NET acts as an intermediary and handles any database connectivity issue. However because Flash and ASP.NET are separate systems, there are (former executing on a client system, the latter on a Web server), mainly four methods to build up a connection between those systems which are:

- Flash Vars: This method uses tags embedded in HTML to exchange data. FlashVars only allow for one-way communication which is from the server to the Flash Movie.
- LoadVars: The LoadVars object is capable of either sending data to the server for processing, loading data from the server. It uses name-value pairs to exchange data between the client and the server. The LoadVars object doesn't require large

amounts of data to be passed. The main handicap of that method is that the .NET developer havs to handle the formatting of the exchanged data.

- XML Object: The XML object is very similar to the LoadVars object; it can both send data to the Web server and get data from it. The difference between the XML object and the LoadVars object is the formatting of data. LoadVars object expects a name-value pair as a response; the XML object sends and receives a well-formatted structured XML document.
- WebServices: Web Services are the newest method for communicating between Flash and ASP.NET. They use SOAP (Simple Object Access Protocol), an XML-based format, to transfer data between the client and server (Moore, 2006).

For the present study a WebService created in ASP.net platform was used as a method to build up the connection between the Flash movies and SQL database through ASP.NET. Figure 3.21 demonstrates the connection between Flash Movies, database and Web.

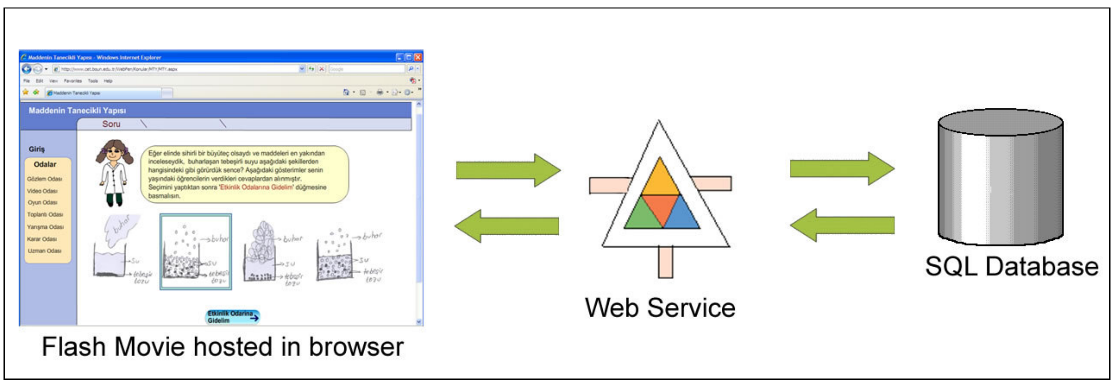


Figure 3.21. Connection between flash and database

WebService created for the present study includes six public functions used in WebFen system (see in Appendix E). These functions are:

- Get Current User: returns the username of current user.
- UserEnteredActivity: used to record the date and time of a user's entrance of an activity.

- UserExitActivity: used to record the date and time of a user's exit of an activity.
- NewDesicionRecord: used to record a user's decision report text.
- StudentResponseToQuestion: used to get a user's response to a question.
- StudentResponseToQuestionWithScore: used to get user's response to questions that has scores (questions in competition room).

3.4. Preliminary Study with Teachers

This part of the study was carried out with teachers during the late development phase of WebFen tool. The main aim of this part was to collect data from in-service science teachers on the effectiveness, strengths, weaknesses of the system, and suggestions for revisions. According to results of the preliminary study with teachers, revisions of the system were carried out by the researcher and development phase was completed at the end of the revisions phase.

3.4.1. Participants

The sample of the preliminary study consisted of 3 female in-service science teachers working in private schools and having different characteristics. School type, teaching experience and academic degrees are presented in the Table 3.1. Teachers were selected according to their accessibility.

Table 3.1. Participant teacher characteristics

Teacher	**Type of School**	**Experience (in years)**	**Academic Degree**	**Teacher**
T1	Private School	2	MS in Science Education	T1
T2	Private School	10	BS in Science Education	T2
T3	Private School	14	PhD in Science Education	T3

All of the teacher participants had completed their undergraduate degree in Secondary School Science Education (T1 and T3 have completed their Bachelor of Science degree in Chemistry Education). T1 and T3 also had graduate degrees (MS and PhD respectively) in Secondary School Science Education.

3.4.2. Data Collection Tools

To collect data in preliminary study with teachers, a semi-structured interview was conducted with each of the participating in-service science teachers. The main aim of interviews with teachers were to collect data on system's effectiveness, strengths, weaknesses, scientific accuracy, usability, how to use the system before/during/after instruction and to carry out revision study. Interview sessions included three main phases, which are:

- researcher's introduction of WebFen and underlying goals
- teachers' investigation of the system
- questioning-answering

Interview meetings were started with introduction of WebFen, its conceptual and scientific process goals, sample unit and main activity rooms. Then each teacher was asked to explore the system and carry out the activities. At the final phase of interview meeting, 6 open-ended questions were asked to each teacher. The main interview questions were:

- Does this tool appear to be scientifically accurate? In what ways does it not?
- What are WebFen's weaknesses and misleading aspects, if any?
- Do you think the tool is good to be used before/during/after instruction? And how should it be embedded in instruction to increase effectiveness?
- Do you think the tool is usable for target teachers and student?
- Dou you have any other comment about the system?
- What do you think are the strengths of this tool?

3.4.3. Procedure

Two days before the interviews with teachers, the Internet address and an introduction on how to use the system had been e-mailed to each of the teacher participants. They were also asked to explore the activity rooms to be familiar with the system before the interviews. Meeting sessions included three main phases which are introduction of WebFen and underlying goals, investigation of the system and questions.

In the introduction phase, aim of the system, conceptual knowledge goals and scientific process skill goals were explained briefly. As teacher started to investigate the system, they provided feedback on usability of screen objects, strengths and weaknesses of the system. At the final step teachers answered six open-ended questions about the effectiveness of the system. During the interviews, teachers' feedbacks and verbal responses to the questions were audio recorded by the researcher. Each interview session had lasted approximately 50-70 minutes.

3.4.4. Data and Results of Preliminary Study with Teachers

In order to analyze the results of the interviews with in-service teachers, audio records of teacher interviews were transcribed and translated by the researcher. Teachers' feedback, comment and answer statements were analyzed and data were classified into six main groups which are:

- Scientific accuracy of WebFen content and related suggestions
- Weaknesses or misleading aspects of WebFen and suggestions
- When (before/during/after instruction) and how to use WebFen
- Comments on usability and design of the system
- Other suggestions or comments
- Strengths of the tool

The following table (Table 3.2) includes main points of students' responses that are classified into the categories listed above. The similarities, connections and details of the teachers' data are explained in following paragraphs.

Table 3.2. Teacher's data

	T1	T2	T3
Scientific accuracy and related suggestions	• The need for correction in definition of matter in expert room (suggestion). • The tool includes scientifically accurate demonstrations of particle movement and arrangements. • For the demonstrations of oil particles in the matters activity of investigation room, teachers should use the term 'particles' instead of 'atoms' (suggestion for sample instructional plan).	• The tool includes scientifically accurate demonstrations of particle movement and arrangements. • The tool includes accurate textual information.	• The tool includes scientifically accurate demonstrations of particle movement and arrangements • The particles should be in same size in the starting question which is about demonstrations of evaporating water with chalk.
Use in instruction	• The tool can be used during instruction. • Teacher makes an introduction, state introductory and triggering questions. • Starting question is presented and students' answers are recorded. • They work on investigation room. • They carry out experiments in classroom. • They carry out online experiments in investigation room. • They complete tasks in decision room. • Teacher guides the flow of activities.	• The tool can be used during instruction. • Teacher asks questions like "what do you think about the nature of matters? What can be they made up of?". • To find answer to such questions, the system is used in class. • Teacher guides students' works with the system.	• The instructional program is so heavy, and teachers are so busy to complete the program, it is also difficult to arrange computer lab sessions in science courses. • Students investigate the tool at home one or two day before starting the unit in class to gain a prior knowledge about the unit.
Comments on usability	• There is no problem on usability of the tool.	• No need for 'continue' button after dragging the materials the next screen can be presented (for the activities in investigation room).	• No need for 'continue' button after dragging the materials the next screen can be presented (for the activities in investigation room). • The interface and icons are easily predictable. • Design and arrangement of screen objects are clear and easily predictable. • Design and arrangement of screen objects do not make the eyes tired.

Weaknesses and related suggestions	• It is necessary to state the term 'pure water' instead of "water" in activities (suggestion). • It is better to use a different container for pure water, instead of tap (suggestion). • It is better to use a different container for oxygen gas, instead of tube (suggestion). • The 3rd explanation choice of compressibility activity is not challenging and need to be revised (suggestion). • The explanation choices of evaporating water and ink in water video activities are not so clear and need to be revised (suggestion). • There can be text entry option for predict, observe and explain questions (suggestion).	• It is better to have an instructional plan for teachers (suggestion). • A brief description about activities can be provided before entering that activity (suggestion).	• It is better to have an instructional plan for teachers (suggestion). • It is better to present the aim of the tool (WebFen) at the introduction screens (suggestion). • It is better to use an arrow like symbol for notebook icon at the prediction steps (suggestion). • A brief descriptions about activities can be provided before entering that activity (suggestion)
Other suggestions or comments	• Instead of olive oil, alcohol can be used in matters activity (suggestion).	• For matters activity, it is better to follow the sequence of solid, liquid and gas to present matters (suggestion). • Feedback about students' responses can be provided at the end of each activity (suggestion). • In 3D demonstrations, water molecules are not moving randomly, there are bounds. But it is difficult to explain bounds at this level.	
Strengths	• The tool includes visually rich particle demonstrations. • Choice statements for predict/observe/explain tasks are good and useful to detect possible misconceptions. • Scoring students' correct and wrong actions in game room can minimize chance factor. • The tool is useful in supporting students' scientific process skills. • The features like tracking and recording students' responses are helpful to monitor learning and identify any misconceptions.	• The tool includes visually rich particle demonstrations. • Teachers are familiar with activities such as compressibility of gases, ink and water. • 3rd level of magic magnifier for water and oxygen (in which one can be compressed activity) that shows the molecular demonstrations of water and oxygen is helpful to build up connection with following topic of the same unit.	• The tool includes visually rich particle demonstrations. • Game room can attract students' interests. • Good to be able to see the list of responses to predict, observe and explain questions in decision room. • The interface and icons are easily predictable. • Design and arrangement of screen objects are clear and easily predictable. They do not make the eyes tired. • Teachers and students are familiar with such virtual environments.

3.4.4.1. The Scientific Accuracy of WebFen Content and Related Suggestions: The data in this category were gathered from teachers' responses to the interview question of "Does this tool appear to be scientifically accurate? In what ways does it not?" and from their additional feedbacks, comments and related suggestions during the investigation phase of interview meetings. Data of this group were about the scientific accuracy of visual materials, textual information (presented in the system) and suggestions on how to improve scientific accuracy.

Teacher 1 provided data on the movement and arrangement of particles in different states and definition of matter within this category. She stated that the movement and arrangement of particles were scientifically accurate and it was also parallel with what they were teaching in their classrooms. Another comment was about the demonstrations of oil particles in the matters activity of investigation room. She said that “If we talk about the scientific accuracy of this demonstration in detail, there is a problem about particles of oil. Because oil is not an element; it is made up of molecules and has a very complex molecular structure. However, for this age group and within the selected topic of matter unit, we can represent particles like that.” She also added that it is important that teacher should use the term particles instead of atoms while describing the particles that made up of matters.

Additionally, she pointed out a problem on textual information that takes place in expert room. In the definition of matter, there was a statement that “Matter is everything that has a volume in space, mass and things that we can see and touch”, however she stated that there were also matters especially in gas phase that we cannot see and touch. Therefore she made a suggestion to omit this part from the definition of matters.

Similar to teacher 1, teacher 2 mentioned the accuracy of particle movement animations, and found no problem on presented textual information in the tool. She stated that the movement and arrangement of particles were accurate for the target group.

Teacher 3 also made similar comments with teacher 1 and teacher 2 about the accuracy of particle arrangement and movement in animations. However she also expressed that only in the starting question which is about demonstrations of evaporating water with chalk, the particles were not in the same size, and this could cause a misconception such as same kinds of particles may not be in same size. Then, the researcher explained that these demonstrations were taken from answers of students within same age group in a different study and they represented the possible student conceptions about matters.

All of the teachers agreed that the arrangement and movement of particles in animations were scientifically correct, and suggestions of participating teachers for improvement of scientific accuracy can be listed as:

- Teachers who want to use the system in their classroom should be informed not to use term “atoms” but use the term “particles” at the beginning of the unit, because the difference between atoms and molecules is the subsequent topic and teachers should focus on the molecular representations of water and oxygen gas in “Which one can be compressed?” activity of investigation room at the final steps of the instruction. This suggestion is used for the development of “sample instructional plan for teachers” part of this study.
- Definition of matter in expert room need to be revised.
- Additional information about the starting demonstrations of evaporating water with chalk question should be added. System should emphasize that these demonstrations are sample students’ drawings.

<u>3.4.4.2. Weaknesses or Misleading Aspects of The Tool and Related Suggestions</u>: Qualitative data on this category were made up of teachers’ answers to the question of “What are WebFen’s weaknesses and misleading aspects, if any?” and their additional comments and suggestions made during investigation phase of interviews. The weaknesses of the system that was mentioned before revisions can be grouped as:

- unclear, insufficient textual information for predict/observe/explain statements,
- insufficient information on the aim and description of each activity,
- missing sample instructional plan and sequence,
- unclear screen objects that may cause misunderstanding

Teacher 1 emphasized on the textual information especially for the predict/observe/explain statements and images of some materials in activity rooms. She analyzed the predict/observe/explain statements in investigation and video rooms, and then she explained that some of these statements need to be revised because they were not so clear or not challenging. For instance she said that students did never choose the third explanation choice of compressibility activity, because they saw that the liquids and gases are not compressed in same amounts. Therefore she suggested revising explanation statements of compressibility activity, in order to increase clarity and make them more understandable. The Figure 3.22 represents explanation statements of compressibility activity before revision.

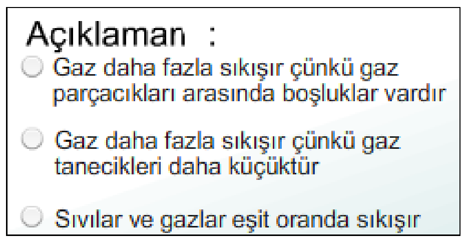


Figure 3.22. Explanation statements of compressibility activity before revision

Similarly she explained that the explanation choices of water-ink and evaporating water activities need to be clearly stated for the target group for better understanding the purpose (More detailed explanation on this suggestion is presented in revisions part of this chapter).

In the activities, the molecular representations belonged to the pure water (only H_2O molecules were presented), but the term "water" was used. Therefore she explained that it was better to use term of "pure water" to prevent any possible misunderstanding. She stated "In our lessons, we are continuously saying that the water coming from the taps in our kitchens and drinking water were not pure water, so it is better to focus on this term". She also suggested using a different image for container of pure water in salty water activity instead of ordinary tap for the same reason. She also added that using a container like gas flask for oxygen gas instead of oxygen tube in the compressibility activity, because in daily life, it was not possible to fill the syringe with gas from a gas tube and it was better to simulate the real life in the system.

The last suggestion of teacher 3 was about implementing an additional text-entry option for students' predict/observe/explain responses. She said that it could be better if students built up their own sentences during online experiments. However because of database structure of WebFen, it was not possible to make such revision in the scope of this study, therefore this suggestion was not put into practice during revision process.

Teacher 2 and teacher 3 focused on absence of a sample instructional plan, expected sequence of activity rooms and additional descriptions for activities. They explained that students and teachers who have not used the system before might have difficulty in deciding on which rooms and activities need to be visited firstly.

For instance, teacher 2 said that "I think the instructional plan and sequence need to be described. I should know from which point teacher or students will start? Where will I put the system into my lesson plan? How should it be used to get maximum effectiveness?" She added: "when I first entered the activity rooms, I could not understand that whether I will only see the atoms and elements or the system will present compounds".

Similarly teacher 3 stated the necessity of a sample instructional plan, introduction statements that present the aim of the tool and a brief description of activities before starting to carry out the activities in investigation room. She also explained that for the first activities which were the online experiment activities in investigation room, an arrow like symbol could be used to show the notebook icon on the screen to help students easily notice that they need to make a prediction to continue.

Data in weaknesses and misleading aspects of WebFen category highlighted the issues that need to be revised before pilot study. These issues can be summarized as:

- It is necessary to state the term "pure" for water in activities of investigation room,
- The container images for pure water and oxygen gas need to be changed,
- The explanation choices need to be revised to increase clarity of statements,

- A sample instructional plan is necessary for teachers to get maximum effectiveness,
- A brief description for activities in investigation and video room needs to be added,
- The aim of the tool needs to be emphasized at the introductory screen,
- An arrow like symbol can be used to emphasize the notebook icon for the first activities.

3.4.4.3. When and How to Use The Tool: In order to guide teachers on how to use WebFen in instruction, a sample instructional plan was created in the scope of this study. Data in this category were also used as one of the sources of guideline during the development phase of sample instructional plan (see in Appendix A). Teachers' answers to the question of "Do you think the tool is good to be used before/during/after instruction? And how should it be embedded in instruction to increase effectiveness?" constituted the data for this category.

Teacher 1 responded to this question in a detailed way including a possible sequence of actions. She said that the tool could be used during the instruction, and listed a sample instructional sequence as follows:

- Teacher makes an introduction with a few sentences about the topic,
- Then teacher and students run WebFen, and students answers the first question which is about the demonstration of evaporating salty water,
- They enter the investigation room, but before carrying out the online experiments, students conduct experiments in class (She explained that they also carry out in class experiments having same or very similar content to the ones in WebFen. This is because most of the activities in WebFen are also suggested activities of Ministry of National Education).
- After finishing class experiments, students carry out the same/similar experiments using WebFen,
- Students complete the tasks in decision room,
- Teacher guides and monitors the flow of activities

She also stated that there was only one teacher computer and one projector in their science labs, therefore according to her plan, one student can manipulate the WebFen activities using teacher computer and the others observe the activities from the presented screen. At the steps where students are expected to answer a question or make a response, the student using the teacher computer stops and waits for the others to note their answer on a paper. However it is not the recommended way of using WebFen, it is better to have sufficient number of computers that have Internet connection and getting each of the students carry out online experiments alone or with a small group of students.

Similar to teacher 1, teacher 2 stated that the system could be used during the instruction. She said that, teacher starts the lesson with introductory questions like "What do you think about the nature of matters?, What can they be made up of?" and in order to find out answers to such questions, the system is used in class. She also added that teacher guide the students during the activities.

Teacher 3 suggested using the system out of class. She explained that the expected instructional program for science courses was so heavy and there is not much time for teachers to complete the instructional program, therefore it is difficult to arrange computer lab sessions frequently. For these reasons she suggested using the system out of class. She stated "One day before I started to study the topic in class, I say students 'We will study the topic of particulate nature of matters, reach the WebFen tool from that address and try to do the activities at home and get some prior knowledge' I want students to think about the topic and also I can find out students' misconceptions before the lesson". She added "I can also say 'explore the system at home and I will check the list of your decision reports' Then student create a product".

3.4.4.4. Comments on Usability and Design of The System: During the investigation phase of interview meetings, teacher 2 and teacher 3 made comments about WebFen's ease of use and made some suggestions to improve the usability of the system.

Teacher 2 and teacher 3 pointed out the functionality of continue button in compressibility and salty water activities. In these activities, as user drags the objects on targets, the message appears in agent's speech bubble saying to click on continue button to go on with next step. Teacher 2 and teacher 3 explained that there was no need to click that button; it disturbed the flow of those activities. They suggested that instead of clicking this button to continue, the screen should automatically appear as user drag the objects to correct place. That suggestion was taken into account at the revision phase. Additionally, as mentioned in the strengths category, teacher 3 also made positive comments on the clarity and predictability of the interface which are important elements of usability.

3.4.4.5. Other Suggestions or Comments: Beside the qualitative data categorized and presented above, there were also additional suggestions and comments of participating teachers. For instance teacher 1 suggested using alcohol as a sample liquid instead of olive oil in matters activity of investigation room, because olive oil has a very complex molecular structure, and the molecular structure of alcohol is much simpler. This suggestion was not carried out at revision phase, because the main focus of the selected unit was not about the molecular structure of compounds, but the particulate nature of matters, and the olive oil was presented as a matter made up of small moving particles. These particles were not named as atoms or molecules in that activity, therefore olive oil could be used as a sample liquid for the matters activity.

Teacher 2 made two additional suggestions which are also used in revision phase and one comment. She suggested designing the matters activity in a way that presents the matters in the order of solid-liquid-gas to help students notice the movement differences step by step. The second suggestion was providing feedback on students' responses to predict/observe/explain questions at the end of each activity. She said "Students wonder whether their responses are correct or incorrect. So the system can provide feedback".

Lastly teacher 2 made additional comments on the movement and bonds between water molecules. She said "In three dimensional demonstrations of water molecules, students may think that they are moving randomly, but it is not the case; there are bonds between molecules. However it is difficult to explain bonds for this age group, and this video can stay same".

3.4.4.6. Strengths of The Tool: While using the system, teachers shared their opinions about the strengths of the tool. The question of "What do you think are the strengths of this tool? In which way, can students get benefit from this?" was also asked to teachers at the final phase of interviews to get further data on this category.

All of the teachers mentioned the importance of 3D and animated particle demonstrations and they stated they liked the richness of multimedia and visual materials of the tool. They explained students at this level could have difficulty in visualizing the things that are not easily observable and they need such tools. For instance Teacher 1 said: "We can draw the arrangement of particles on blackboard or present a static picture, but it becomes difficult to explain the movement of these particles. After we say that all particles are moving, they say that if particles are moving and if all the matters are made up of these particles, then why the matters do not move without touching or pushing them? They think that all the particles move in the same direction at the same time. Therefore these demonstrations are very helpful for students' learning." And she also added: "Our students carry out similar experiments in class, but they cannot observe the matters at particle level, and so they cannot understand properly. Therefore we need such tools for particulate nature of matter unit."

Teacher 1 also provided feedback on the textual content of the system. She focused on the choices of predict, observe and explanation statements that are placed in online experiment activities in investigation rooms. For instance she found that the answer choices of explanation question in salty water experiment activity were very useful to detect students' possible misconception. The question was: "How the salt becomes invisible in water?" The answer choices were "Salt has evaporated with water, and so it became invisible", "The particles that made up salt have dissolved in water, and it became invisible" and "The color of salt and water is similar to each other, so we could not see it". The question and explanation statements are presented in Figure 3.23.

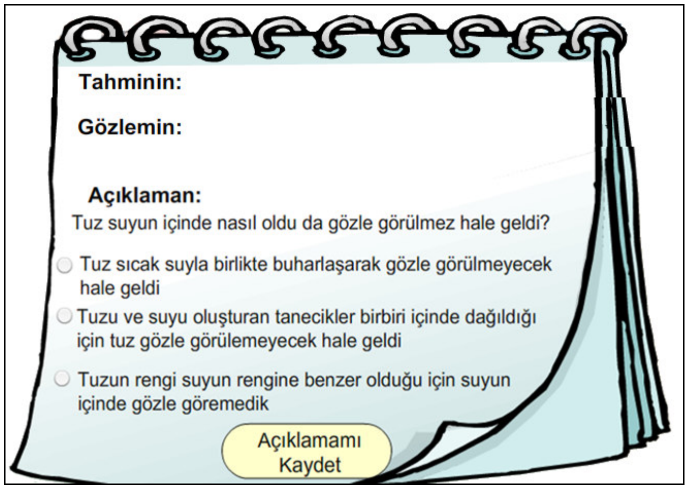


Figure 3.23. The question and explanation statements of salty water activity in the investigation room

One other comment of teacher 1, which was evaluated as a strength of the tool, was about the game room. She explained that they also used such game-like activities in their learning activities and counting the correct and wrong trials were very useful to minimize completing the game by chance.

One of the major aim of creating WebFen tool was designing and developing such a tool that can be used to enhance students' scientific process skills and that supports students' creation of science relating arguments on selected topic. Teacher 1 also mentioned the strength of tool on supporting scientific process skills. She explained that "The tool is also useful to improve students' scientific process skills, especially the steps in investigation and video room. Asking to make a prediction before an experiment, observing the results and then building up an explanation are some important scientific process skills and this method helps students to gain and improve such skills".

Additionally, after the researcher's explanation of WebFen's technical capabilities, such as recording each student's answers and getting data about how many correct and incorrect answers are given to each question, teacher 1 and teacher 3 said that it was very useful to monitor learning, and detect students' misconceptions and learning difficulties;

which in turn, could enable teachers to identify the points where students need additional support or conceptual revision.

The answers and comments of teacher 2 on the strength category were generally about the strength of visual materials and familiarity of activities. Like the other two teacher participants, teacher 2 also mentioned the strength of visual materials. She said:

"The tool includes visually rich animations. These are important, because students can never make strong predictions about the things that they are not actually seeing. While I'm preparing my instructional materials, the thing that I look for from the Internet mostly is such animations. We cannot present the movement of particles with only drawing on board. Such educational animations are not found in Turkish web sites, so I try to find from sites that are in foreign languages". She added that 3rd level of magic magnifier for water and oxygen (in which one can be compressed activity) that also shows the molecular demonstrations ($H_2O$and O_2) could be helpful for teachers to create a connection with the subsequent topic (elements and compounds) in the curriculum. Additionally, she pointed out that the experiments like "Which one can be compressed?", "Salty water" and "Ink and Water" were very common activities and most of the teachers would not have any difficulty about the aim and content of these activities.

Teacher 3 focused on the effectiveness of visual materials, the format of competition and decision room, and usability issues on screen design. Similar to the other teachers, she said that the videos and animated flash movies could be very effective for students' learning. Moreover she stated that the format of competition room and game room could catch students' interests, because they like game activities where they can collect scores and they try to reach the highest score. Similarly the format of decision room that students' responses to predict, observe and explain questions are presented, was helpful to recall their answers and complete the decision report.

She also made some comments on usability of WebFen, which were also in the strengths category. She explained that the interface was easily understandable and predictable, the colors and screen objects were clear. She said "I can understand what to do when I saw the screen; the screens do not made my eyes tired. It is very good and very important. This is one of the most common problems in most of the web sites". She also added that most of the teachers in their school were familiar with such web-based tools, because they use virtual labs in their lessons.

Results of qualitative data of preliminary study with teachers showed that the following issues about the system must be revised or re-designed before the pilot study with students:

- Textual information such as definitions, explanation statements of online experiments need to be added or revised,
- A brief information for activities and aim of the tool need to be added in introduction statements,
- Some of the images of screen objects in activities of investigation room need to be re-designed,
- In order to increase usability, functionality of some control buttons need to be revised,
- The suggested sequence of rooms (starts from investigation and video room, then follows a sequence of video, discussion, decision, game, competition and expert room) need to be presented at the introductory screens,
- The order of tasks in matters activity need to be re-designed (tasks need to follow a sequence of investigating solid, liquid and gas matters respectively),
- Feedback for students' responses to observe and explain questions need to be provided at the end of each activity.

3.5. Revisions of WebFen Based on the Results of Preliminary Study with Teachers

Revision phase was the final step of WebFen development process. This phase was shaped and carried out according to the results of the preliminary study with teachers.

In order to increase the effectiveness, scientific accuracy and usability of the system the revisions were made according to suggestions of teacher participants. The revisions are explained below.

- In order to increase scientific accuracy of the tool, in the definition of matter (in expert room) "things that we can see and touch" part omitted from the definition of "matter is everything that has a volume in space, mass and thing that we can see and touch" and changes in the following way: "matter is everything that has a volume in space and mass ". Because (as teacher 1 also mentioned that) there are also some kinds of matters, especially the ones in gas phase, that can not be touched or seen easily.
- In the starting demonstrations of evaporating water with chalk, the particles were not in equal sizes with each other, because they were the sample drawings of students at target level. However in order to increase scientific accuracy and to prevent students from accepting these drawings as completely true, additional information was added into the agent's speech bubble (of introduction screen that presents main evaporating salty water question) to emphasize that these demonstrations are taken from drawings of students with same ages. Screen captures of speech bubbles of the agent before and after revision is presented in Figure 3.24.

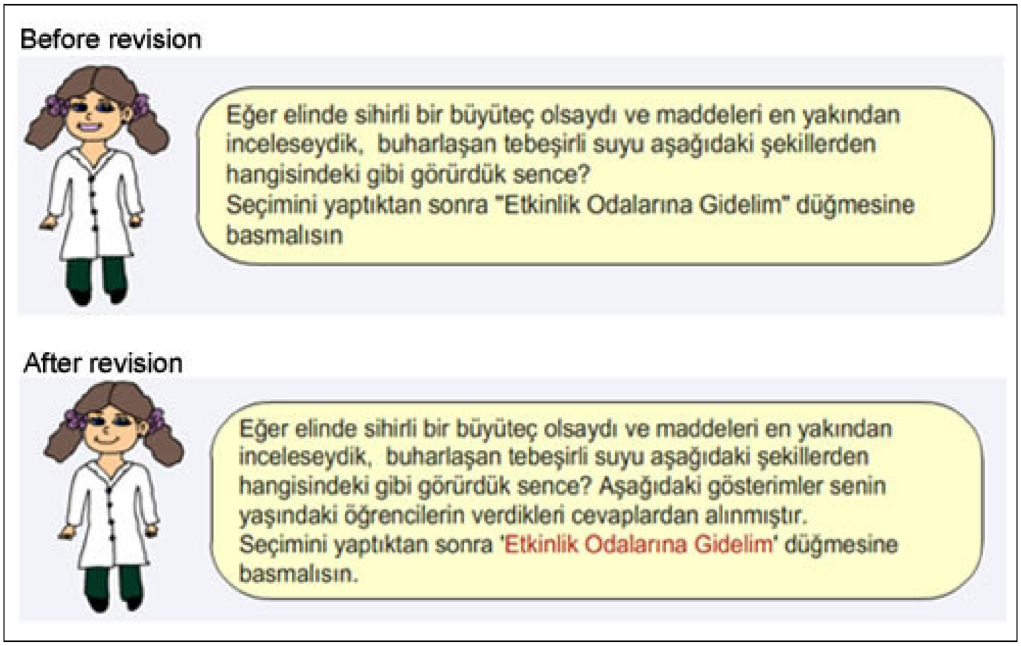


Figure 3.24. Speech bubble of the agent before and after revision

- In the "Which one can be compressed?" and "Salty water" activities of investigation room, the term "water" was replaced with "pure water". Because these activities focus on the molecular demonstrations of pure water (only H_2O molecules).
- In the "Salty water" activity, the image of tap object that user drag the beaker on to fill pure water was replaced with a container having a small tap and a label on it. This revision was important to prevent students from having a misconception that pure water is not the same as the water coming from an ordinary tap water in our kitchens or is not same as drinking water. The previous and new object images are represented in Figure 3.25.

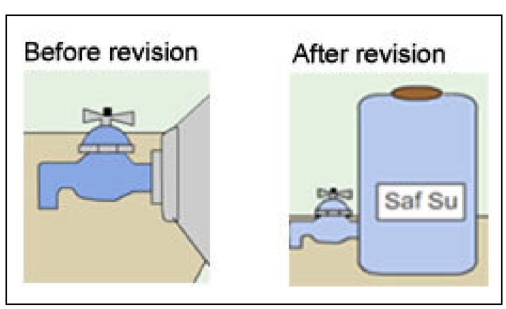


Figure 3.25. The image of tap before and after revision

- In the “Which one can be compressed?” activity, the image of oxygen container object, which was an oxygen tube image, was changed into a gas flask. Figure 3.26 represents the images before and after revision.

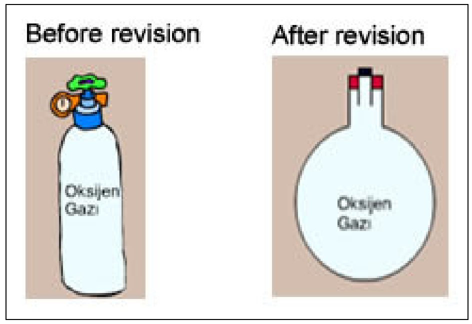


Figure 3.26. The image of oxygen container before and after revision

- The 3rd alternative of explanation question in “Which one can be compressed?” activity was rewritten, because it was not a challenging alternative. Additionally, the sentences were redesigned to increase clarity. The statements before and after revision are presented in Figure 3.27.

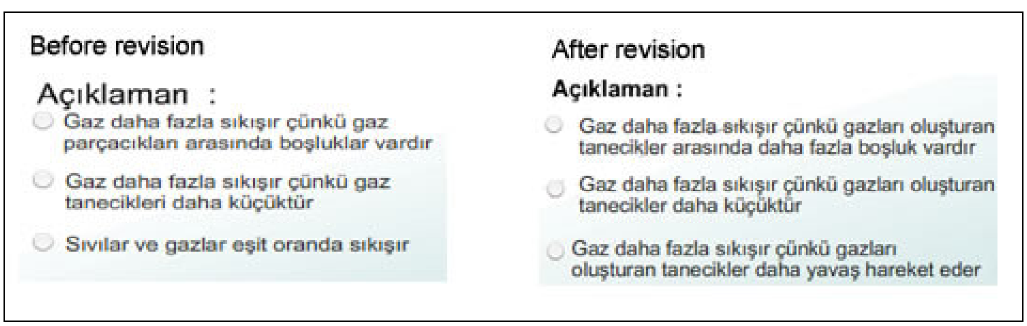


Figure 3.27. The explanation statements of “Which one can be compressed?” activity before and after revision

- The explanation statements of “Ink and Water” and “Evaporating Water” activities in video room were revised to increase clarity. Figure 3.28 represents the explanation statements in “Ink and Water” activity before and after revision.

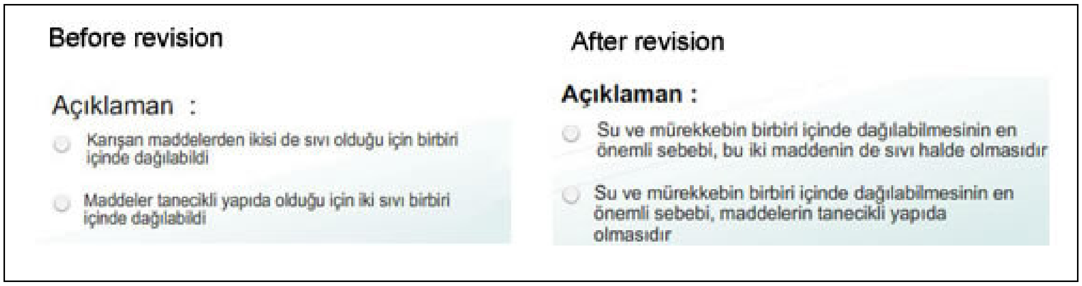


Figure 3.28. The explanation statements of “Ink and Water” activity before and after revision

- A brief description for activities in investigation and video room was added to the introductory screens of video and game room. Before revision, there were only the names and icons of each activity in video and investigation rooms, but after revision, if the user moves the mouse on an activity name or icon, a brief description is presented on the screen as seen in following figure (Figure 3.29).

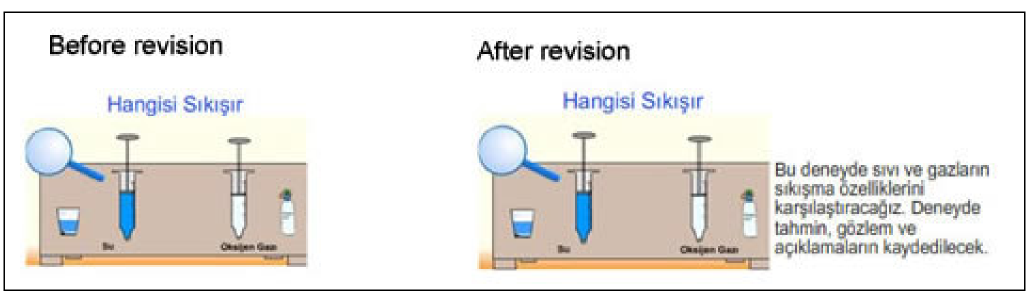


Figure 3.29. The icon image for “Which one can be compressed?” activity before and after revision

- The aim of the tool was explained at the welcome screen.

- A suggested sequence for activity rooms was presented symbolically with arrows at the rooms' introduction screen. Figure 3.30 shows the suggested sequence of activity rooms of WebFen.

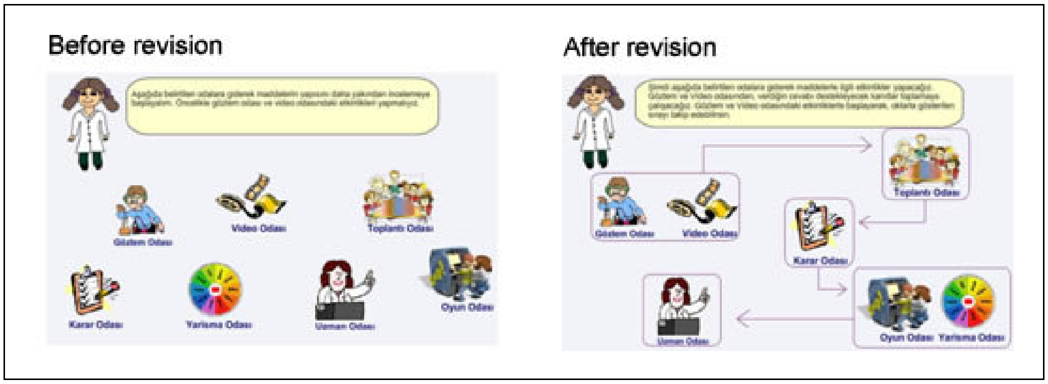


Figure 3.30. The activity rooms before and after revisions

3.6. Pilot Study

After the revision phase which is the final phase of WebFen development process, a pilot study was carried out with a small group of students. The aim of the pilot study was to carry out a formative evaluation study to detect the effectiveness of WebFen in improving students' conceptual knowledge on the topic of particulate nature of matter and to detect possible gains of students in terms of scientific process skills and argumentation skills.

3.6.1. Participants

The participants of the pilot study consisted of 8 primary school students, 4 girls and 4 boys, who had completed 5th grade (11 years old) and had basic computer skills to be able to use the system. The system was designed with a content of Particulate Nature of Matter, which is a topic of 6th grade science curriculum. However 5th graders were used as participants of the study because 6th graders have already covered the topic in the beginning of the semester (during the first weeks of November) and thus it was assumed that the contribution of WebFen would be more apparent when working with students who were not familiar with the topic. The sample students of pilot study were selected conveniently according to their accessibility.

3.6.2. Data Collection Tools

In data collection phase of the pilot study, three tools were used. The first one was pre and posttests which are used to collect data for possible conceptual learning gains on the selected topic after students used the WebFen. The second data collection tool was voice records of students' answers and researcher's prompts to the third open-ended question in posttest. The last data collection tool was WebFen usability questionnaire which is used to get data on system's usability.

3.6.2.1. Pre/Post-tests: In order to analyze possible conceptual learning gains of sample students on particulate understanding of matters and compressibility property of gases after they study WebFen, parallel form pretest and posttest were administered. Both tests include two same open-ended questions that require student drawings. Following paragraphs include the pre and post test questions and brief explanations.

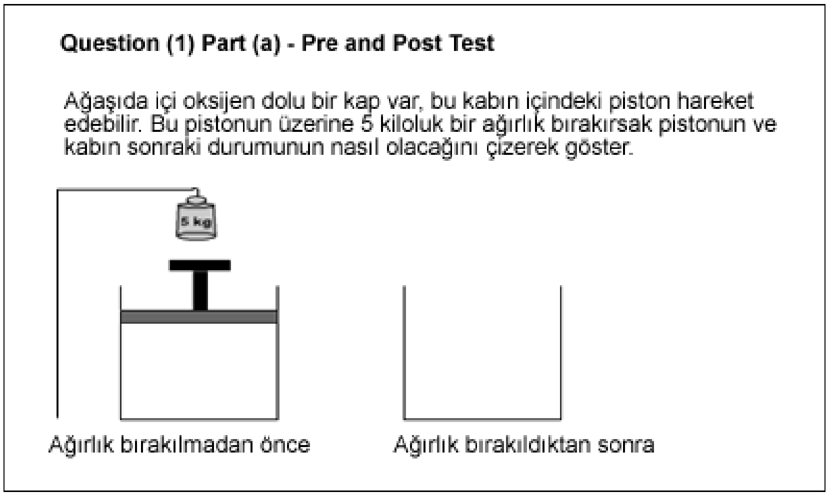


Figure 3.31. Part a of first question in pre and post-test

First question consists of two related parts, part a and part b. Question in part a aims to measure students' understanding of the compressibility properties of gases. Students were given two flasks with some oxygen gas as presented in Figure 3.31. The first flask showed the placement of weight and piston before the weight is released onto the flask. Students were expected to draw how the gas would behave (what would be the final placement of piston and weight) after the weight was released onto the movable piston.

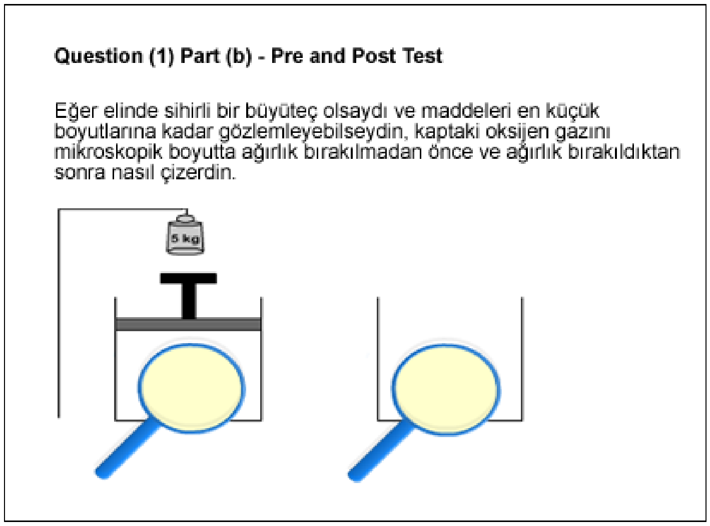


Figure 3.32. Part b of first question in pre and post-test

The second part, part b; seen in figure 3.32, is related to the first part of the same question. In that part students were asked if they had a magic magnifier and they were able to see the smallest part of the oxygen gas, how they would draw the gas before and after compression.

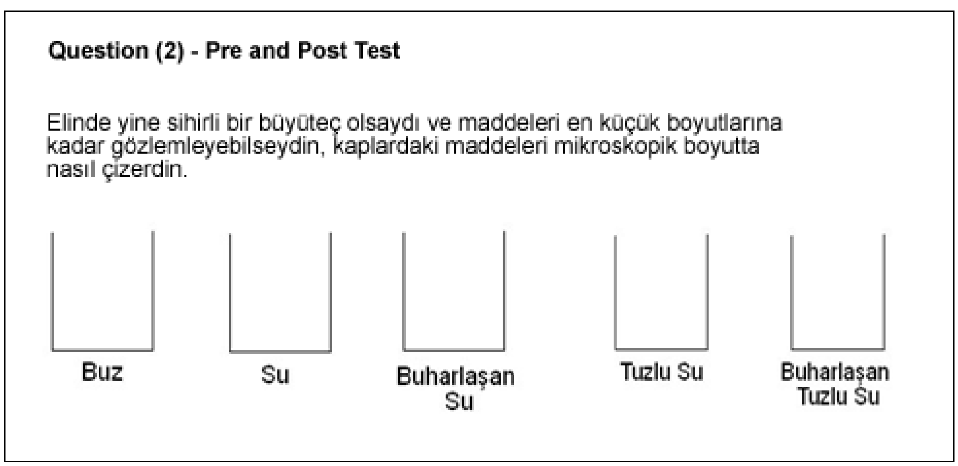


Figure 3.33. Second question in pre and post-test

The second question aims to measure students' conceptual understanding of solid, liquid and gas matters at particle level and arrangement of particles of matters in different states. The question includes five empty flasks with labels of substances that need to be drawn into them. Figure 3.33 presents the flasks and labels of the second question. Students were asked to draw demonstrations of water, salty water, evaporating water and evaporating salty water at particle level.

Question (3) -Post Test only

3) Tüm maddeler aralarında belli miktarlarda boşluk olan ve gözle görülmeyen taneciklerden oluşmuştur" iddiasi sence dogru mudur yanlış mıdır? Neden ?

Doğrudur / Yanlıştır
Çünkü……………………………………………………………………………………

……………………………………………………………………………………………

Figure 3.34. Open-ended question in post-test

Besides two questions that were used to assess students' conceptual understanding on the selected topic, the post-test include one open-ended question ("Do you think the claim that all matters are made up of invisibly small moving particles with some empty space between them, is a correct statement or not? Why?) that required students to determine whether they consider the claim that "all matters is made up of invisibly small moving particles with some empty space between them" to be "True" or "False" and give their reasons. Figure 3.34 represents the question text of open-ended question in post-test.

3.6.2.2. Semi-Structured Interview Elaborating The 3rd Question of The Post-test: The additional 3rd question included in the post test was elaborated using a semi-structured interview. The interview was carried out in order to determine whether students could provide any evidences to support a claim and if they do so, whether they also could provide any warrant or explanation statements to clarify the relation between claim and evidences (This is argument building process in the framework of this study). Two main claim statements were presented by the researcher for students to provide evidences and explanations for the claim. The first claim replicated the 3rd question of the post test and required an elaboration on why the students did/did not think that "all matters are made up of invisibly small particles with some empty space between them". The second claim required students to explain why they did (or did not) think that the earth was spinning around.

Student answers were audio recorded and analyzed in order to determine whether students could provide any evidences to support a claim and if they do so, whether they also could provide any warrant or explanation statements. The data obtained from the semi-structured interview will be explained with a different sub-heading in "results" section.

3.6.2.3. WebFen Usability Questionnaire for Students: The questionnaire was used in order to collect data from students about the usability of the system. The instrument was adapted by the researcher from original version that is prepared and used by Bal (2004). The scale (see in Appendix B) consists of 10 items, 9 of them are Likert-type with 5 points and one question is an open-ended question about suggestions for the programmer. The items were mainly designed to understand the ease with which users can manage to work with the system. Specific questions direct attention to the ease with which users could understand the questions, use the system, use the materials in observation room, run video clips, and manage textual information.

3.6.3. Procedure

After revision step which was the last step of WebFen development phase, 8 participating students used the system in different sessions. Before starting to use the system, the aim of the study, procedure and student's tasks while using the system were explained by the researcher. Then, each student was asked to take the pretest and answer all of the questions. Each student completed the pre-test in 8-10 minutes. Following that, the researcher organized the necessary hardware and typed the Internet address of WebFen (For the pilot study the WebFen tool is uploaded to the server of Computer Education and Instructional Technologies Department, Boğaziçi University and the temporary address was assigned as http://www.cet.boun.edu.tr/WebFen). Then each student created a username and password to login the system and started to investigate the system. Each of participating students completed activities in each room, except discussion room, (because discussion room is designed for classroom use with teacher) and created decision report in decision room. Working with WebFen session was completed in 35-50 minutes. Compared with other activities, students spent highest amount of time (10-15 minutes) in decision room working on completing the decision report with argument statements. While working with WebFen, students had no difficulty in controlling and manipulating the WebFen environment, because they had reported themselves as having good computer skills. All of the participating students have Internet connection at home, have basic computer skills and have their own e-mail accounts.

After completing the WebFen session, usability questionnaire and post-test were administered to students. It took 25-30 minutes for students to complete these two instruments. The semi-structured interview sessions were made just after the completion of post-test and each interview took nearly 5-8 minutes. The interviews were audio recorded by the researcher.

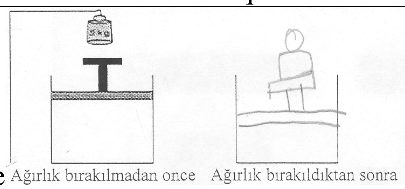
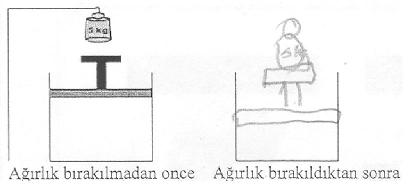
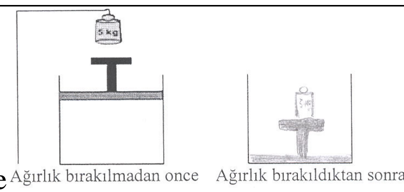
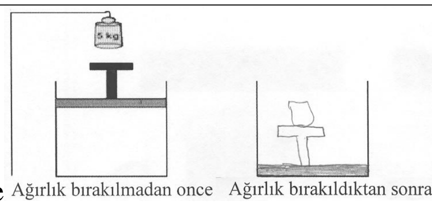
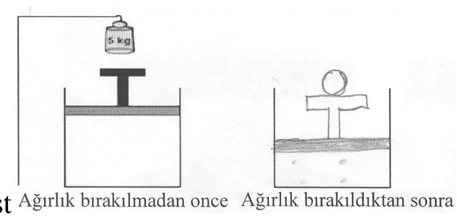
3.6.4. Data and Results of Pilot Study

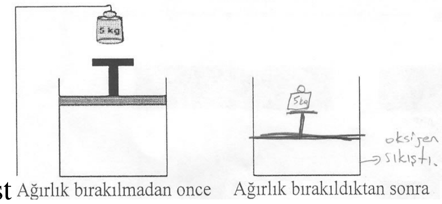
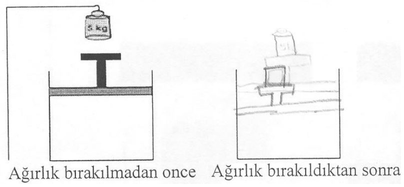
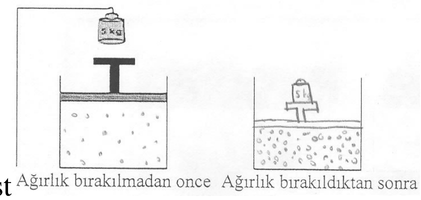
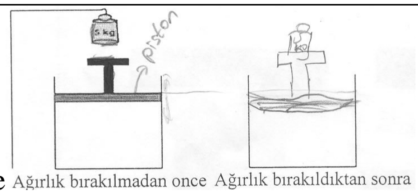
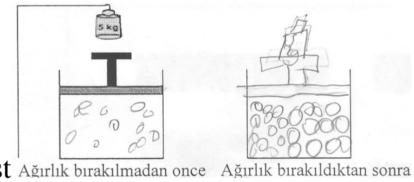
Students' data obtained from pre-post tests, audio recordings of the semi-structured interview (elaboration of the third question in post-test) and usability questionnaire were analyzed in data analysis phase of pilot study. The following sections explain data and results obtained from pre-posttests, voice records of the semi-structured interview, and WebFen Usability Questionnaire.

3.6.4.1. Pre-Post Tests: Data obtained from specific questions of the pre and post tests were analyzed to identify the change in students' particulate understanding of matter in different state and understanding of compressibility property of gases.

In question 1a (question 1, part a), students were presented with a picture of a flask with a piston filled with oxygen gas. The question asks what happens to the piston if some amount of weight is released on it. Students were expected to draw the final position of the piston and weight. This question aims to identify students' understanding of compressibility property of gases. Drawings were considered as accurate if the volume of oxygen gas decreased after compression process. Drawings were considered as inaccurate or erroneous if the volume of gas is increased or stayed the same after releasing of the weight. Students' pre and post test responses for question 1a and observed changes in representations are presented below.

Table 3.3. Students' pre and post test responses for question 1a and observed changes

	Pre/Post Measures for question 1a	Observed Changes in Representations
S1 and S5	Pre  Post 	No change; accurate representations both in pre and post measures.
S2	Pre  Post 	Change towards more accurate understanding of compressibility of gases.
S3 and S6	Pre  Post 	Change towards more accurate understanding of compressibility of gases.
S4	Pre 	Change towards more accurate understanding of compressibility of gases.

	Post 	
S7	Pre  Post 	Accurate representations both in pre and post measures. Post measure includes representation of oxygen particles even though not asked.
S8	Pre  Post 	No change in the volume of gases; erroneous understanding on compressibility property of gas in pre and post measures. Post measure includes representation of oxygen particles even though not asked.

The results of students' responses to question 1a in pre-post measures showed that all of the students except S8 (S8 present erroneous understanding in both pre and post measures), had presented accurate representations for the volume of oxygen gas in post test; they drew the volume of flask filled with oxygen gas smaller after compression. 4 of the students (S2, S3, S4, and S6) who had drawn accurate representations in posttest presented a favorable change in understanding of compressibility property of gas after using the tool. 3 of the 7 students (S1, S5, and S7) who had provided accurate representations in posttest had also presented accurate representations on compressibility of gases in pre measures (before treatment). They seemed to have accurate understanding on the compressibility property of gases prior to the treatment. Additionally 3 of the students (S2, S7, and S8) presented particulate representations for oxygen gas in question1a of posttest although they were not required to do so. The figure 3.35 presents the results of students' representations for question 1a categorically.

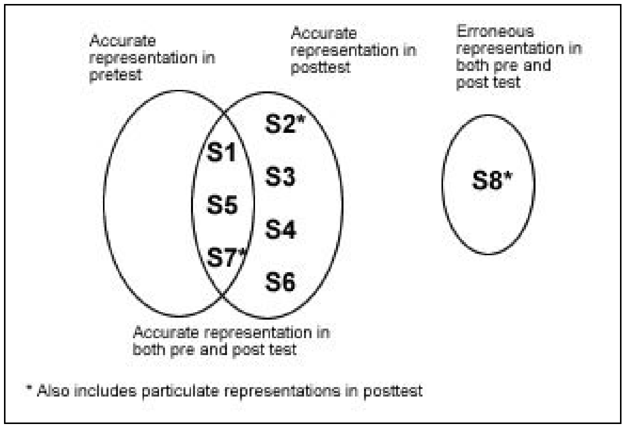


Figure 3.35. Students' response schema for question 1a

Question 1b aimed to identify students' particulate understanding of matter at gas state. Students were expected to draw the microscopic representation of oxygen before and after the compression. The question was "If you have a magic lens and be able to observe the matter in very detailed way, how could you draw the oxygen gas at microscopic level before and after the compression?" Drawings for this task were considered to be accurate representations if;

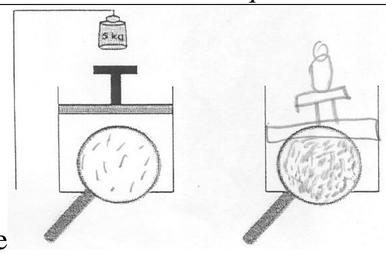
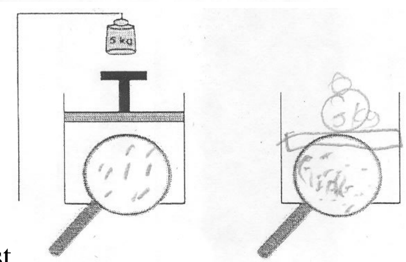
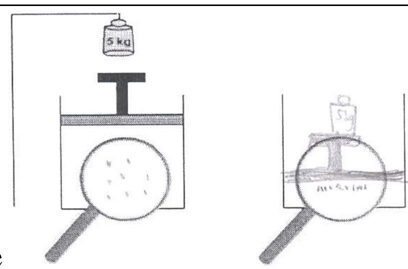
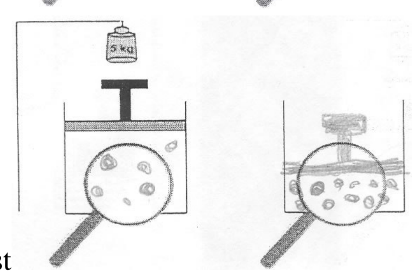
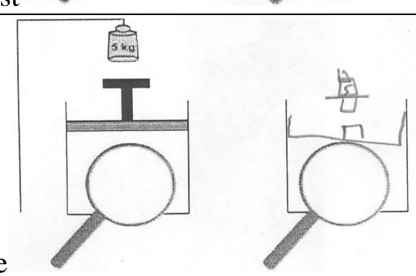
- there is a decrease in the volume of gas but not zero volume after compression,
- the gas is represented in particulate form,
- there is no macroscopic interference; students' particle drawings do not include any macroscopic signs or properties such as drawing borders, adding fumes or smokes for gases.
- the distance between particles decreases after compression,
- the particles are distributed randomly,

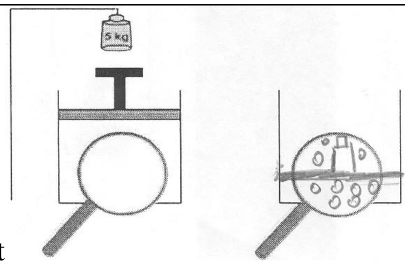
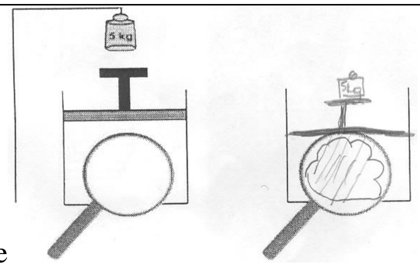
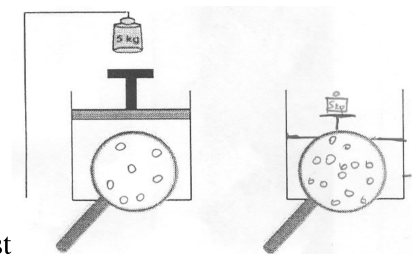
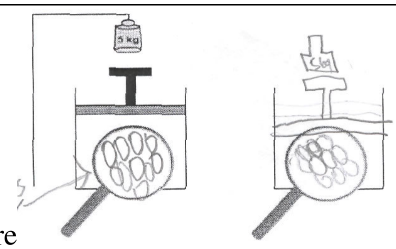
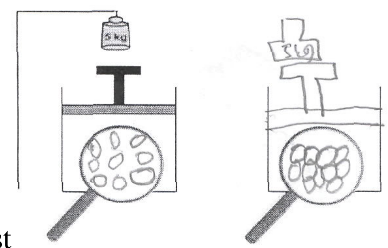
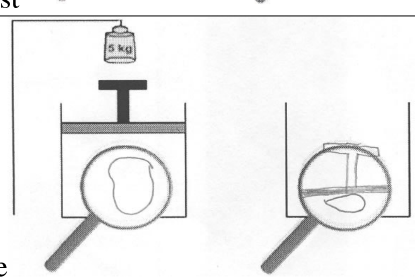
Drawings were considered as erroneous or inaccurate if;

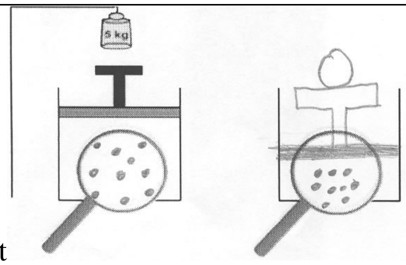
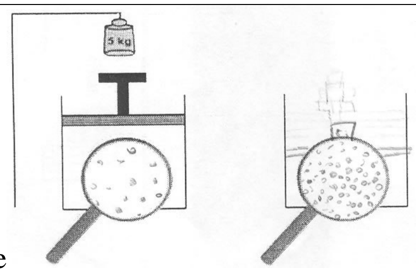
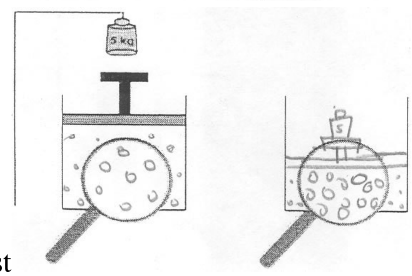
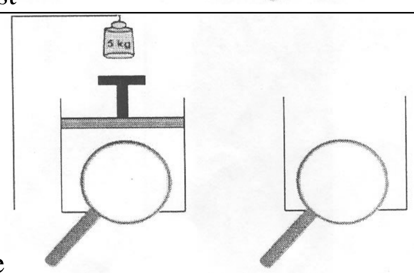
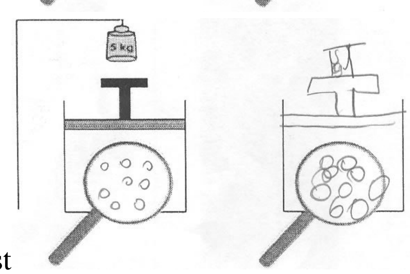
- there is no decrease in the volume of gas after compression,
- the gas is represented in macroscopic form,
- there is no decrease in the distance between particles.

Additionally the dot, point and circle like drawings for gases were considered as particulate form representations, but use of circle like shapes instead of dots and points for gases were accepted to be more refined forms of particulate representation. The pre and post test responses of each student for question 1b and observed changes in representations are presented below in Table 3.4.

Table 3.4. The pre and post test responses of each student for question 1b and observed changes

	Pre/Post Measures for question 1b	Observed Changes in Representations
S1	 Pre  Post	Accurate but not refined particulate form of representations in both pre and post measures. No change in particulate representations of oxygen gas between pre and post measures.
S2	 Pre  Post	More accurate and more refined particle representations in posttest. A change between pre and post measures toward more accurate particulate understanding. (Particulate representations in both pre and post-tests; but there is a change toward more accurate particulate understanding and more refined representations)
S3	 Pre	More accurate representations in post-test.

	 Post	
S4	 Pre	Erroneous representations (macroscopic representations) in pretest, accurate particulate understanding in posttest. A change toward accurate particulate understanding between pre and post measures.
	 Post	
S5	 Pre	Particulate representations in posttest include macroscopic interference in pretest. More accurate and refined representations in post measure.
	 Post	
S6	 Pre	Erroneous representations in pretest but accurate particulate understanding in posttest. A change toward accurate particulate understanding between pre and post measures.

	Post		
S7	Pre		Accurate particulate representations both in pre and posttest, but more refined representations in posttest.
	Post		
S8	Pre		More accurate particulate representations in posttest.
	Post		

The results showed that all of the students had presented particulate understanding in post measures. Additionally when we move from pre to post-test there was a positive change in students' representations which was observed as a shift from either erroneous to accurate representations or towards more refined forms of representations in posttest. Figure 3.36 presents students' responses to question 1b categorically.

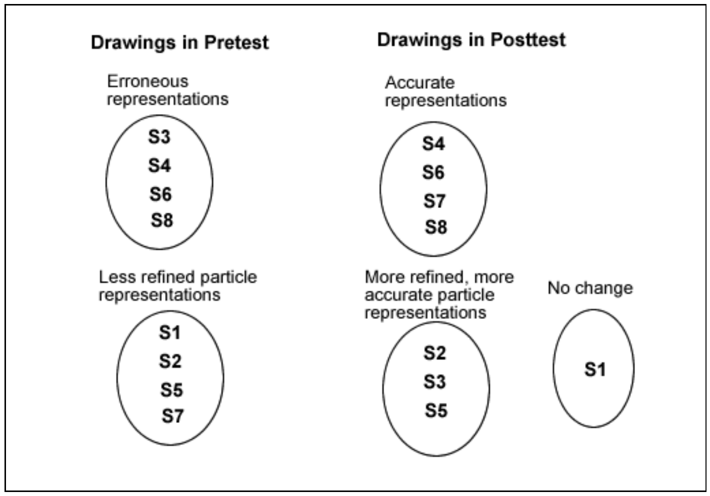


Figure 3.36. Students' response schema for question 1b

Question 2 in pre and post-test aimed to identify students' particulate understanding of matter in different states. Students were expected to draw the microscopic representations of ice (solid), water (liquid), evaporating water (liquid and gas), salty water (solid and liquid), evaporating salty water (solid, liquid and gas). The question was "If you again have a magic lens and be able to observe the matters in very detailed, how could you draw the substances in the beakers at microscopic level?"

Drawings for question 2 were considered to be accurate representations if;

- the matters are represented in particulate form,
- the particles are distributed randomly,
- there is no macroscopic interference; student's particle drawings do not include any macroscopic signs or properties such as drawing borders, adding fumes or smokes for gases. For the specific case; due to the dust like macroscopic appearance of salt, dots and points (rather than circular forms) are considered to indicate macroscopic interference.

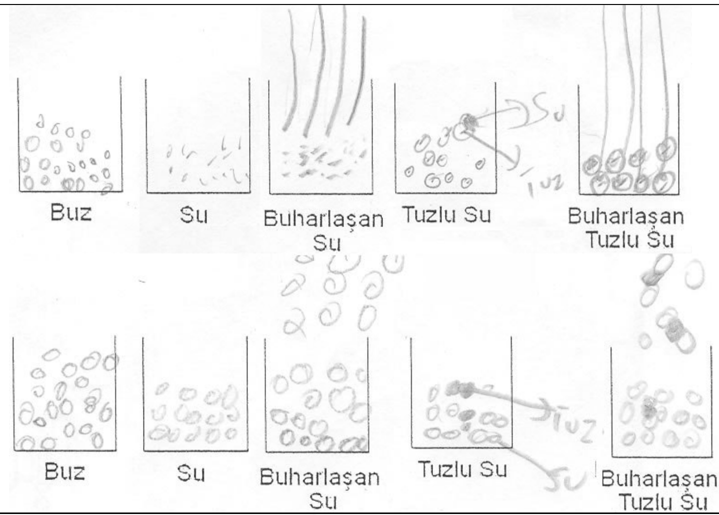
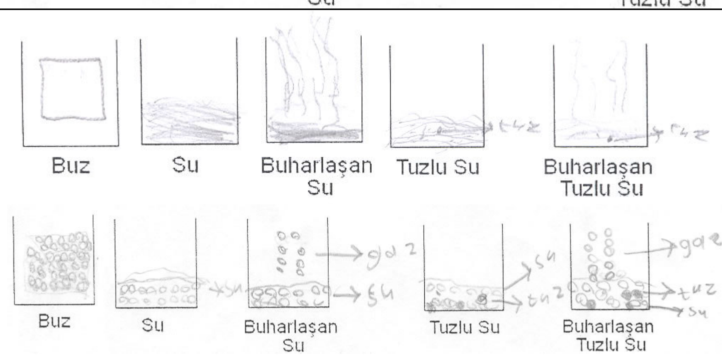
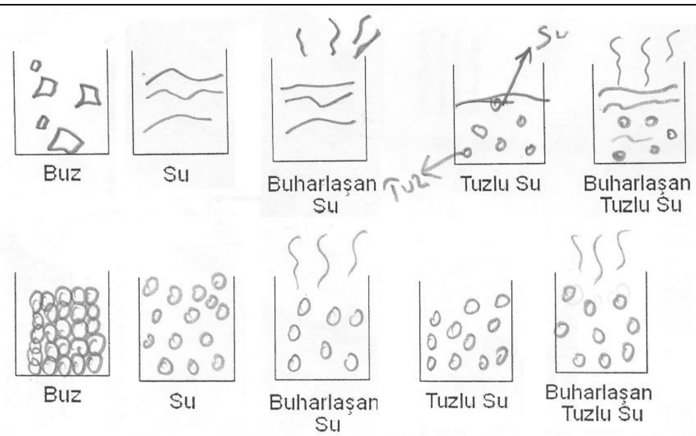
Drawings were considered as erroneous or inaccurate if;

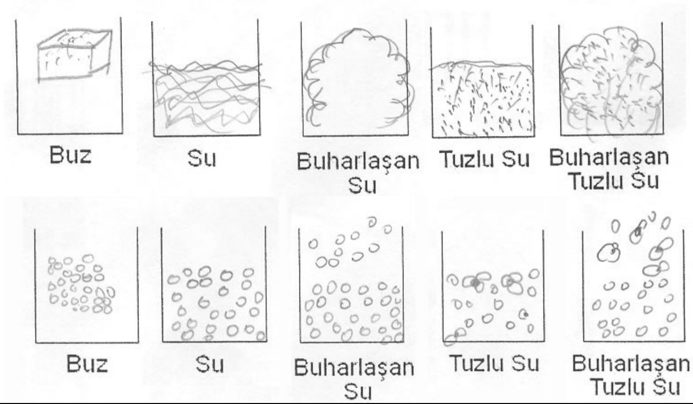
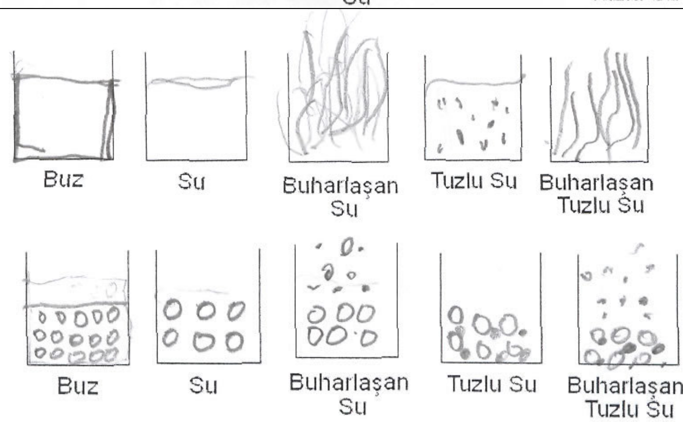
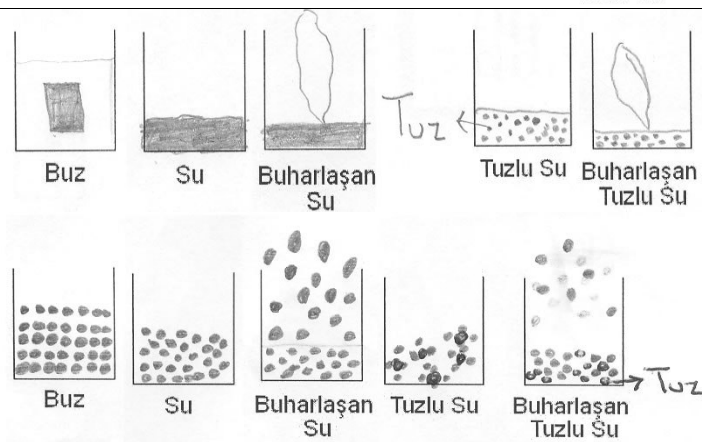
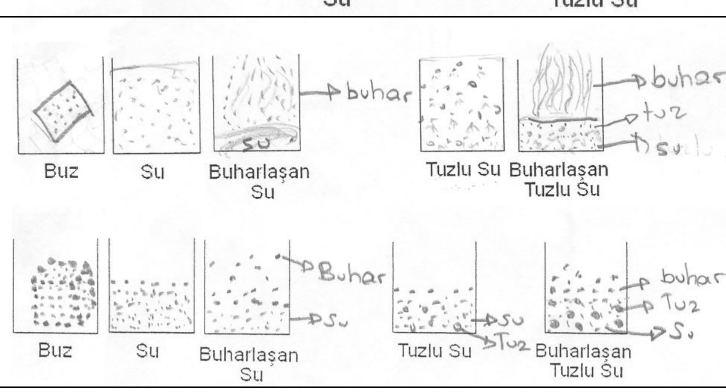
- the matters are represented in macroscopic form,
- the particles are not distributed randomly,
- there are macroscopic interference in representations.

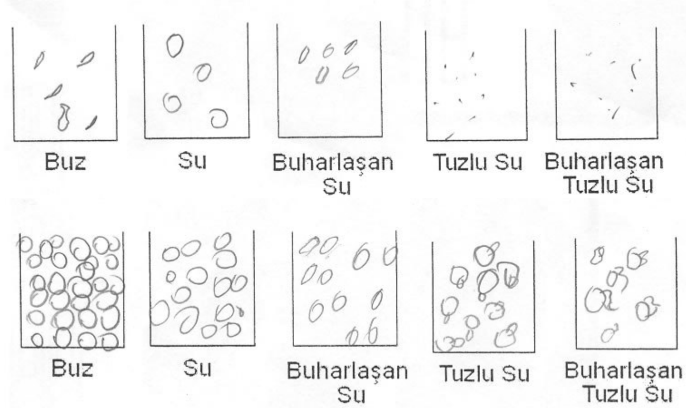
Additionally the dots, point and circle like drawings for gases were considered as particulate form representations, but use of circle like shapes instead of dots and points for gases were accepted to be more refined forms of particulate representation.

The Table 3.5 represents the pre and post test responses of each student for question 2 and observed changes in representations.

Table 3.5. The pre and post test responses of each student for question 2 and observed changes

	Pre/Post Measures for Question 2	Observed Changes in Representations
S1		A change toward more accurate and more refined particulate representations. Pre measure includes particulate representations with macroscopic interferences for gas. No macroscopic interference observed in post measure.
S2		A change from macroscopic to accurate particulate representations between pre and post measures. More refined representations in posttest. Pre measure includes some macroscopic interference in the cases of water and evaporating water.
S3		A change from macroscopic to more accurate particulate representations with macroscopic interferences in drawings of water vapor.

S4		A change from macroscopic to accurate and more refined particulate representation. No macroscopic interference observed in post measure.
S5		A change from macroscopic to more accurate particulate representation with macroscopic interference in the case of ice.
S6		A change from macroscopic to accurate and more refined forms of particulate representation. No macroscopic interference observed in post measure.
S7		Change from particulate representations with dominant macroscopic interferences in all cases to accurate particulate representations with no macroscopic interference.

S8		A change toward more accurate and more refined forms of particulate representations.

The results of students' responses to Question 2 showed that for all of the students, there was a positive change in particulate representations between pre and post measures. Five students (S2, S3, S4, S5 and S6) used definite macroscopic forms of representations in pre test, but they provided more accurate particulate representations (with some macroscopic interference in the drawings of S2, S3 and S4) in post measure.

For three students more refined forms of particle representations were observed in their posttests. These three students (S1, S7 and S8) started with particulate drawings with some macroscopic interference, but ended up using accurate and refined molecular representations at post test. The following figure (Figure 3.37) shows students' drawings categorically.

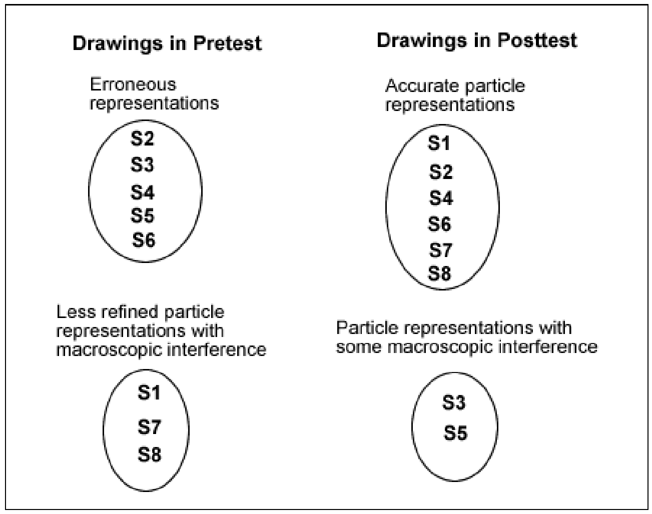


Figure 3.37. Students' response schema for question 2

3.6.4.2. Semi-Structured Interviews: The semi-structured interview was carried out when elaborating the 3rd question of the posttest which was used to determine whether students had developed argumentation skills. It aimed to identify whether students presented any evidence to support a claim and warrant to explain the relationship between claim and evidences (the main frame of argumentation building process which is explained in literature section), and if they do so, then whether they could also provided any warrant or explanation statements to clarify the relationship between claim and evidences. Two claim questions were presented to students and they were asked to give a yes/ no answer first. Students are firstly asked that "Do you think the claim that all matters are made up of invisibly small particles with some empty space between them is true or false?", and then the researcher asked further questions and made prompts such as "how do you know that this claim is true/false? How could you persuade a person or a friend to accept your claim as correct?" These questions were asked to get detailed responses and students are expected to provide evidences and warrant for their claims and build up argument statements.

The second claim question, "Do you think that the earth is spinning around?", was asked students to be evaluated as true or false and similarly, after first response, additional questions (similar to those stated in the previous question) were used by the researcher to get evidence and warrant statements.

During interviews, students' responses and researcher's prompts were audio-recorded. In order to analyze qualitative data, the audio records of each student were transcribed and three main data categories are created for each claim question which are:

- Claim accepted/rejected: It describes whether student accept the claim as true or reject.
- Evidence (if any): It describes if student accepts the claim as true, whether she/he provide any evidence statement(s).
- Warrant (if any): It describes if student accept the claim as true and provide evidence(s) for the claim, whether she/he provide any warrant statement(s) to explain how the evidences are related with the claim.

The following table (Table 3.6) presents data for question 3 in post test. The claims about the particulate nature of matter, and earth's spinning are named as claim 1 and claim 2 respectively.

Table 3.6. Students' data for question 3 in posttest

S1	Claim	Evidence(s)	Warrant(s)
Claim 1	accepted	1. look into matter using a special microscope (Visual evidence)	One
Claim 2	accepted	1. Photographs and video records taken from satellites (Visual evidence) 2. Formation of days and nights	One (after promt)
S2	Claim	Evidence(s)	Warrant(s)
Claim 1	accepted	1. "I explore WebFen, I give the address to my friend to persuade him" 2. Use of magic lens(Visual evidence)	No
Claim 2	accepted	1. Formation of days and nights 2. Photographs from satellites(Visual evidence)	No
S3	Claim	Evidence(s)	Warrant(s)
Claim 1	accepted	1. analyzed solid, liquid and gas matters using magic lens(*) 2. Carrying out experiments (Visual evidence)	No
Claim 2	accepted	1. day and night are formed as earth is spinning around	No
S4	Claim	Evidence(s)	Warrant(s)
Claim 1	accepted	1. "I investigated much" 2. use of magic lens to analyze the structure of oxygen gas (Visual evidence)	No
Claim 2	accepted	1. "A lot of people are saying this" 2. Formation of day and night. (She also uses the term evidence to explain claim 2)	No
S5	Claim	Evidence(s)	Warrant(s)
Claim 1	accepted	No	No
Claim 2	accepted	No	No
S6	Claim	Evidence(s)	Warrant(s)
Claim 1	accepted	1. Made observations 2. Use magic lens (*) (Visual evidence)	No
Claim 2	accepted	1. Video records and photographs from space (Visual evidence) 2. Formation of day and night	One (*)
S7	Claim	Evidence(s)	Warrant(s)
Claim 1	accepted	1. Carrying out experiments 2. observing evaporating water using magic lens (Visual evidence) (She also uses the term evidence to explain claim 2)	One (**)
Claim 2	accepted	1. Investigations are evidences 2. Photographs taken from space evidences for this. (Visual evidence) (She is the only students who clearly state that those information are the evidences) 3. Formation of day and night, seasons	No
S8	Claim	Evidence(s)	Warrant(s)
Claim 1	accepted	1. Authority 2. We saw in game room and in compression experiment	One(**)
Claim 2	accepted	1. No (An evidence is provided on a different claim which is about the shape of the earth)	No

* Response is get after more than one prompt.
** A weak warrant on compressibility of gases

Students' responses were analyzed to find out if the system was effective to help students building up argument statements and gaining argumentation skills. The aim of data analysis was to find out whether they used any evidence statements to support the presented claims and whether they explained the relationship between evidences and claims with warrant statements.

The results showed that all of the students had evaluated claim 1 and claim 2 as correct and all of the students except one (S5) had provided some evidences for these claims but most of these evidences are stated after prompts.

Six of the students who provided evidences had used visual evidences such as magic lens, photographs, video records; the connection between visual evidences and related claims are more obvious. For instance S1 said: "In order to persuade my friend about this claim, I show a flask filled with air. He cannot see anything inside the flask, it is like empty. But if he looks into the flask using a special microscope, he can see observe the air (particles), therefore he can be persuaded".

Two students (S4 and S8) mentioned about authorities or commonly accepted promises as evidences. For instance S4 stated evidence for claim 2 as "A lot of people are saying this". Additionally, except from S7, none of the students mentioned carrying out experiments as evidence without any prompts, but she also added virtual evidences as sample experiment after some prompts.

Only two students (S4 and S7) used the term "evidence" (in Turkish "kanıt") while mentioning on the evidences for claims. S7 said that "Photographs (taken from the space) are the evidences for that (for the claim that the earth is spinning around)" and similarly S4 said formation of day and night was the evidence for the same claim.

In general, it can be said that students could not explain the connection between evidences and claims (which are warrant statements) clearly. Only S1 explained how magic lens can be an evidence to support claim 1. He said that with the observation of matter which is invisible (gases) using special microscopes, then the particulate structure can be seen. He could create a connection with claim and visual evidence.

Finally the results showed that students were not much aware of the necessity that a scientific claim needs to be supported with evidences and warrant needs to be used to clarify the connection how the evidences support claims; because most of the claim and warrant statements are generated by students after prompts.

3.6.4.3. WebFen Usability Questionnaires: WebFen usability test which consists of 9 likert-type and one open-ended item was administered to all participating students in order to measure students' perceptions of WebFen's usability. Likert-type items have 5 degrees.

Students' responses were converted to numerical values and 5 represents "the tool and subparts were very easy" (for items 1 to 7) or user wants very much (for items 8, 9) and 1 represents "the tool and subparts were very difficult" (for items 1 to 7) or user does not want very much (for items 8, 9). The answers to the first nine items on usability test are given in Table 3.7.

Table 3.7. Students' responses to usability questionnaire

	Item 1	**Item 2**	**Item 3**	**Item 4**	**Item 5**	**Item 6**	**Item 7**	**Item 8**	**Item 9**	**Total**
S1	5	5	5	5	3	4	5	4	5	**41**
S2	5	5	5	5	2	5	5	3	5	**40**
S3	4	5	5	5	2	3	5	5	5	**39**
S4	4	5	5	5	5	5	4	5	5	**43**
S5	5	5	5	5	5	4	5	4	4	**42**
S6	5	5	5	5	2	5	5	5	5	**42**
S7	4	5	5	5	3	4	5	4	4	**39**
S8	3	4	4	5	3	3	5	4	5	**32**

According to responses to each separate item of the usability test, the students were observed to find the text based instructions as either easy or very easy (item 1) to understand except one student, who responded as not decided. The program was considered to be easy (or very easy) to use (item 2). The objects such as syringes, beaker, salt plate in investigation room were found to be very easy (except one students who responded as easy) to drag (item 3). Running the video clips was very easy (item 4). The activities in rooms were found to be very easy, easy or not decided (item 6). For the item 6 which asks whether the activities in rooms are easy; six students responded as very easy or easy, and 3 students responded as neutral. Texts used in the tool were considered to be very easy (except one students who responded as easy) to read (item 7). The students preferred to use the system again very much or much except one students responded as not decided (item 8). The students preferred to study different units using similar tools (item 9).

The most variance between students' responses was observed in the item 5 which was about completing the report in decision room. Two students responded that it was very easy to complete the report; two students responded as easy, three students responded as not decided and one student responded as difficult.

Answers to the last open-ended question can be categorized into no change, suggestions about game room, comment and suggestion about text size and voice option for agents.

Table 3.8. Students' responses to the last question of usability questionnaire

	Response to open-ended question
S1	There may be more game after activities. By this way the things we have learned get stronger.
S2	I would change the decision room.
S3	I would change nothing, because it was a very good program.
S4	The texts of Selim and Selin were a little bit small. And it would be better if they talk.
S5	I would change nothing.
S6	I would change nothing, because it was a very good program.
S7	I would add more games in game room and add more experiments.
S8	I would change nothing.

Five students responded that if they were the programmer, they would not change anything about the program, and two of them added that is because they found the program very good. Two students made suggestions about the game room. They expressed that if they were the programmer, they could add more games (One of those students who responded about game room is also suggest to add more experiments in investigation room). Lastly, one student responded that the text size in the speech bubble of Selim and Selin was a little bit small, so it can be larger and it would be better if a voice option added for the agents.

In general, students' responses on usability of the system were positive except from one neutral point in the decision room (item 5). Some of the students have responded that they found it difficult (or not decided) to fill the report in decision room. That result is discussed in details at "Results and Discussion" section.

4. RESULTS AND DISCUSSION

The main aim of the present study is the design and development of a web-based science learning tool that uses the implications of constructivist views of learning and argumentation method as guidelines in the design framework. The study also includes a preliminary study with in-service science teachers on the effectiveness of the system and a pilot study with 6th grade students. The pilot study aims to get preliminary data about the possible effects of the tool, WebFen, on students' conceptual understanding on the particulate nature of matter and the development of argument building skills. The following paragraphs examine the results of the preliminary study and the pilot study with references to the literature and discuss importance and implications of findings.

The results of preliminary study with teachers are also used as a resource for system revisions. Results mainly indicated that teachers found the system useful and they thought that it could be used before or during instruction. One of the main findings in the results is the teachers' emphasis on the need and importance of computer-supported multimedia tools to improve students' conceptual understanding. Participating teachers supported the idea that the multimedia tool provided visually rich particle demonstrations and could be helpful for students to understand molecular representations of matter.

The results of the pilot study provide us some insight as to how the WebFen tool might contribute to the development of conceptual understanding on particulate nature of matter and argumentation skills. Although the number of participants are quite low (n= 8) the consistency of results allow us to make some predictions on possible effects of the tool. Therefore, the following paragraphs outline an insight regarding possible outcomes of WebFen rather than significant effects of the tool. Results obtained from the pilot sample mainly indicates a positive effect of WebFen tool on the development of conceptual understanding of particulate nature of matter, but a little improvement on argument building skills. Although sample students provided some evidences to their claims, most of them failed to justify how the evidences support their claims.

These results are observed to be consistent when considered in relation to past research. The literature includes a significant number of researches (e.g. Ardaç & Akaygün, 2004; Sanger, 2000; Williamson & Abraham, 1995; Geban, Askar & Ozkan, 1992) that found out that use of computer supported environments that provide animated and three dimensional demonstrations of chemical phenomena is important to help students develop conceptual particle understanding and connect macroscopic level of representations with molecular representations. When the results of pilot study were examined to detect any conceptual change, it was seen that the findings confirmed the previous studies in the literature. According to results of pre and post-tests that measure particulate understanding of matter, after studying with WebFen, students presented a positive change from perception of matter with macroscopic character or having a particulate understanding with macroscopic interferences toward having an accurate or more refined forms of particulate understanding. It can be said that they differentiated two forms of representations which are macroscopic and particle level representations. One of the authors that mentioned the importance of the students' ability to transfer and connect between three representation levels was Johnson (1998). He claims that students' learning difficulties and having misconceptions about the particulate nature of matter is a result of the way of instruction rather than students' capabilities. This study was an attempt to provide materials such as animated, video based or three dimensional demonstrations of matter including macroscopic and particulate representations; therefore WebFen can be used to support instruction by providing opportunities for teachers to make transitions between representations.

It is possible to infer possible contributions of the WebFen tool on the development of argumentation skills by considering students' responses to interview questions that elaborate the third post test question. When the interview questions that asked whether students with agreed the claims (on particulate nature of matter and the earth's spinning) were analyzed it was found that most of the students could provide some evidences to support the claim with some or no prompts. Most of the evidences used by the students were visual evidences such as the particle animations presented inside the magic lens, video records or photographs to support the claims especially for first claim which is about particulate nature of matters. This result implies the important role of visualization in helping students understand, make sense and remember scientific phenomena. The use of visual evidence was particularly predominant when giving evidence for the claim on particulate nature of matter, which underlines possible contribution of molecular visualization and molecular (particle) level representations when teaching chemistry.

Although most of the students provided some evidences to the claims, most of the students' evidence statements were received after prompts and students were not observed to indicate a need to provide evidence to support a claim. They also failed to give clear warrant statements; they could not provide explanations on the relationship between evidences and claims. There may be a number of reasons for that result. First of all, students are not familiar with the argumentation, because today's science education often ignores argumentation and scientific inquiry practices (Osborne, Erduran & Simon, 2004b, Erduran, Ardac & Yakmacı-Guzel, 2006) and the terms such as finding evidences, supporting claims, building up arguments are new for them. Additionally the researchers who carry out argumentation studies with middle level students emphasize that in order to develop students' argument building and scientific process skills, students should be taught on what an argument is, how one can differentiate a strong or a weak argument, what are claims, data, evidences, and warrants. Further, they need to carry out warm up classroom activities for one-two weeks including student-student interaction. However the comprehensive evaluation study is not in the scope of the present study, the main aim of the study is design and development of the tool that can be used by teachers and students during instruction. During the implementation of pilot study, students are provided information on the structure of an argument only for 3-5 minutes when they were working on filling decision report activity in decision room and they did not get any supplementary instruction on argument building procedure before using WebFen. Sample students also worked with the system alone, so there was no student-student interaction which is stated as one of the main issue of argumentation.

Moreover, students' inadequate argument statements can be a result of the short period of the pilot study. Pilot study is carried out in one single session without a classroom setting. However all of the argumentation studies described in literature review section implemented their instructional models for a period between 4-36 months.

In order to measure WebFen's usability, students were administered a questionnaire. The results of total usability scores indicate that students found the system and its component easy to use. One noticeable difference between item responses was observed for the item that asks students whether filling the decision report was easy. Although students found the system and sub-parts (except decision room) easy to use, most of the students either felt that filling the decision report was difficult or they were unsure. In decision room, students were expected to write their arguments for the main problem including claim, evidence and warrant statements. Therefore it is very likely that the difficulty was about students' lack of understanding of argumentation rather than the functionality of the decision room which can be seen as a sub-section of WebFen. This result may have different explanations. One explanation is that students might be experiencing difficulties in connecting parts of a whole. Although they understand the evidences, they could not create a connection between evidences which can be seen as parts of a complete argument and they could not notice the necessity of using those evidences to support their claim. They might process the activities as isolated learning experiences. For instance they provided correct answers to the assessment questions in competition room, and they could also easily explain the experimental activities in investigation and video rooms when asked but they could not clarify how those evidences relate to the main claim. A possible reason for this result can be that students are unfamiliar with such practices as discussed in previous paragraphs. Probably, they have not been asked to create such a connection between a claim and evidences throughout their school lives and it is difficult for them. They also have a cognitive load while studying with the system and because of the difficulty of conceptual learning process; they did not perceive finding and relating evidence as a part of the whole learning process. In other words, they did not pay enough attention on what they are doing in activities of investigation and video room is actually an evidence development or finding process which is necessary to support the claim. So, further studies are needed to be organized to analyze possible reasons of these results.

In order to overcome students' difficulties in relating evidences to the claim, and to reduce cognitive load, more emphasis need to be provided after the creation of each evidence and at each small step, students can be informed or asked whether or how the obtained evidence supports their initial claim. They can be asked to evaluate the claim.

Some additional support such as providing or allowing students to draw an argument map that schematically present the relation between claims, evidences and warrants with boxes, arrows and keywords can be provided by the system especially in decision room to highlight the relation of the evidence with the claim. In the present study, text-based list of evidences collected from investigation and video room is presented at the decision room where students are expected to build up their argument statements.

The present study is an attempt to making use of advantages of ICT and Web to support content and argumentation skills and it provides a template that can be used to create similar multimedia-based instructional materials that support argumentation practices. More learning materials on different science units can be added to the system and can be used in classroom settings.

5. CONCLUSION

One of the aims of the research was to design a web-based science learning tool, WebFen, with a sample unit on particulate nature of matter for 6th graders. The main design framework of the WebFen is guided by the implications of current instructional models of constructivist views and implications of argumentation studies. Usability principles of web-based learning environments are also used as reference in design and development phase to create a usable system. The other aim is to develop the tool using Adobe Flash and ASP.net software environments. A relational database is created using Sql server in order to keep records of users and responses of students.

WebFen includes a set of activity rooms that incorporate interactive learning activities on the selected unit, particulate nature of matter. Each room has different goals. Activities are designed around a starting question that requires students to identify the accurate particulate representation of evaporating chalky water. Students' responses to this main question are accepted as their claims about the nature of matter. Students are then expected to visit a number of rooms in order to collect evidence to support their claim and reflect on or share their views. Briefly, investigation and video rooms include experiment-based or video based activities that focus on the macroscopic and particulate representations of matter. As students carry out tasks in those two rooms, they collect evidences that can be used to support their initial claim. Discussion room includes a form-like online discussion board and is designed to provide opportunities for collaboration or carry out online small group discussions. Decision room is the place where students observe their views based on the collected evidences and build up arguments by creating a decision report. Competition room includes multiple choice questions on the selected unit and game room includes a matching substance with particulate demonstrations game. Lastly expert room includes additional textual and pictorial materials about the unit.

WebFen allows teachers to monitor students' responses to all of the tasks and questions in the system and also get information about how many correct and incorrect responses are given to each task or question. Teachers also have responsibility to initialize the discussion feature by assigning a discussion topic.

The research also includes a preliminary study with in-service teachers which aims to get qualitative data through semi-structured interviews. Teachers provided data about scientific accuracy, usefulness in instruction, usability, weaknesses and strength of the tool. According to the results of the preliminary study, system revisions were carried out.

In order to gain initial information about the effectiveness of the tool in development of conceptual understanding and argumentation skills, a pilot study was carried out with eight 11 years old students who have completed 5^{th} grade. Data is collected through pre-post test, usability scale and students' voice records and interviews about development of arguments. The results showed that the WebFen is effective in development of conceptual understanding. A noticeable difference is observed in particulate understanding between pre and post measures. Students also have found the system and the sub-tools easy to use and manipulate except the decision room section. However students presented weak performance in building up arguments. They provided inadequate argument statements. A more detailed analysis concerning weak performance in building up arguments and possible reasons are discussed in the discussion section. A rather straightforward and commonly acknowledged educational implication seems to be a need to increase familiarity with argumentation skills.

The results of the preliminary and pilot study show that the WebFen can be used in science classrooms with teachers' guidance. Although limited in number, teacher suggestions are favorable and encouraging. Teachers seemed to particularly favor the visual facilities and proximity to the existing curriculum standards. Although to a lesser extend, teachers also favored the emphasis on argumentation skills and the structured path that enables the development of scientific discourse. A sample instructional plan for teachers about how to integrate WebFen in regular classrooms is also developed and presented in Appendix A.

5.1. Limitations of the Study and Recommendation for Further Studies

Since the main aim of the present study is the design and development of the WebFen, and the study does not primarily focus on comprehensive evaluation of the tool, it just includes a formative evaluation (pilot study) phase. Therefore there are some limitations that need to be overcome in further validation (comprehensive evaluation) studies. These limitations and suggestions for further works are briefly mentioned in the following paragraphs.

One of the limitations in pilot study is about time constraints and absence of supplementary instruction on argumentation. Students spent nearly one and a half hour or two hours studying with the tool and completing necessary instruments such as tests, usability questionnaire and in the scope of pilot study they could not provided with a detailed information or instruction on argumentation and components of a strong scientific arguments. Therefore it is recommended that students should be explicitly taught about argumentation. For instance they should know what an argument and the components of an argument are or what the examples of strong and weak scientific arguments are before they start to work with the WebFen.

The present study includes one section from the science curriculum of 6th graders. Therefore different units can be designed and developed within the present framework and created template for further works. Further studies should also be carried out with a large sample group of students having various backgrounds within a school setting to provide opportunities for student-student, student-teacher interaction and to provide group discussions using discussion board feature of the tool. Students' responses during discussions can be qualitatively analyzed in order to obtain more extensive results about their argument building skills and to generalize the results.

Audio options should be provided by the tool for disabled students and for the students who prefer listening to reading the instructions. This feature is also one of the students' suggestions obtained from usability questionnaire. One student suggested that it would be better if the agents namely, Selin and Selim who give the instructions and feedbacks could speak. Adding more games and learning tasks are some other suggestions of sample students in the pilot study.

APPENDIX A: A SAMPLE INSTRUCTIONAL PLAN

Aşağıda verilen ders planı, araştırmacı tarafından geliştirilen, web destekli fen öğretim aracı olan WebFen'in sınıf ortamında etkin bir şekilde kullanılabilmesi için öğretmenlere yol göstermek amacıyla hazırlanan örnek bir ders planıdır. Planın hazırlanmasında yapılandırıcı yaklaşımı destekleyen güncel öğretim modelleri, fen eğitiminde argümantasyon metodunu kullanan araştırmaların bulguları ve bu çalışmanın fen öğretmenleri ile yapılan ön değerlendirme sürecinde, katılımcı öğretmenlerin önerileri temel oluşturmuştur. Sunulan ders planı bir örnek olup, öğretmenler sınıf olanakları ve öğrenci özelliklerine göre yeni planlar oluşturabilir ve WebFen sistemini kendi sınıflarına farklı şekillerde de dahil edebilirler.

Ders / Seviye : Fen ve Teknoloji / 6.sınıf

Ünite / Konu: Maddenin Tanecikli Yapısı / Maddelerin Yapı Taşları, Atomlar

Kazanımlar:

- Sıvıların ve gazların sıkışma-genleşme özelliklerini karşılaştırır.
- Gazların sıkışma-genleşme özelliğindenden gaz tanecikleri arasında boşluklar olduğu çıkarımını yapar.
- Maddelerin görünmez küçük parçalara bölünebildiğini deneyler yoluyla fark eder.
- Tüm maddelerin gözle görülemeyen küçük ve hareketli taneciklerden oluştuğunu belirtir.
- Gaz haldeki maddeleri oluşturan tanecikler arasındaki boşluk miktarının sıvı ve katılardakilere gore daha fazla olduğunu farkeder.
- Maddeleri oluşturan taneciklerin yerleşim düzenlerinin katı haldeki maddelerden sıvı haldeki maddelere doğru gidildikçe bozulduğunu farkeder.
- Maddelerin nereye kadar ardaşık bölünebileceğini sorgular.
- Maddeleri oluşturan yapı taşlarını belirtmenk için "atom" terimini kullanır.

Araç ve Gereçler: Öğrenci sayısı kadar İnternet bağlantısı olan bilgisayar.

Süre: 1 ders saati (40-50 dakika)

Ders Öncesi Süreç:

Öğrenciler dersi WebFen programını kullanmaya başlamadan önce, argümantasyon konusunda iki veya üç haftalık bir ön eğitim almalıdırlar. Bu eğitimde öğrencilere güçlü bir argümanın ne olduğu, nasıl desteklenmesi gerektiği, iddia-delil-gerekçe(destek) cümlelerinin birbirleri ile nasıl ilişkilendirilmesi gerektiği sınıf ortamında, öğretmen rehberliğinde anlatılmalı ve çeşitli fen konularından argüman örnekleri incelenerek sınıf içi diyaloglarla öğrencilerin argümantasyon sürecini öğrenmeleri sağlanmalıdır. Böylece öğrenciler WebFen ile maddenin tanecikli yapısı konusunu çalışmaya başlamadan önce argümantasyon süreci ile ilgili önbilgiye sahip olurlar ve programı daha etkin bir şekilde kullanabilirler.

Ders Süreci:

(3-4 dakika)-Dersin başında öğretmen konu ile ilgili kısa bir bilgi vererek (konunun adı, alan adı ve neden önemli bir konu olduğu gibi) ve "Sizce tüm maddeler temelde aynı olabilir mi?", "Maddeleri çok yakından inceleme şansımız olsaydı onları nasıl görürdük sizce?" gibi giriş sorular sorarak öğrencilerin ön bilgilerini ortaya çıkarmaya ve onları derse hazır hale getirmeye çalışır. Daha sonra öğrenciler WebFen programına kullanıcı adları ve şifreleriyle giriş yaparlar.

(1-2 dakika)-Giriş bölümünü inceledikten sonra öğrencilerden maddeleri inceleme yolculuğuna başlamak için maddelerin yapısına ilişkin ortaya atılan tanecik boyutunda 4 farklı buharlaşan tebeşirli su gösteriminden kendilerince doğru olanı işaretlemeri istenir. Öğretmen buradaki seçimlerinin tüm etkinlikler boyunca dikkate alacakları iddiaları olacağını vurgular. Öğrenciler seçimlerini yaptıktan sonra odalar sayfasından gözlem ya da video odasındaki etkinliklerle çalışmaya başlar.

Öğretmen gözlem odasındaki “Hangisi Sıkışır?” ve “Tuzlu Su” etkinliklerininin tahmin-gözlem-açıklama tipinde etkinlikler olduğunu belirtir. Gözlem ve Video odasındaki etkinlikler arasında kesin bir sıralama yoktur. Etkinlikleri istenilen sırayla çalıştırılabilir.

(10-15 dakika)-Öğretmen öğrencilerden gözlem odasındaki üç etkinliği yapmalarını ister. Etkinlikler tamamlandıktan sonra 2-3 dakika öğrencilerin verdikleri açıklama cümleleri incelenir. Öğretmen bu aşamada sistemden öğrenci cevaplarını kontrol edip aynı açıklama cevaplarını seçen (aynı kanıtları bulan) öğrencilerden 3-4’er kişilik gruplar oluşturarak tartışma başlatabilir (3-5 dakika). Öğretmen uzman odasına gelmeden önce maddelerin yapı taşlarından bahsederken “atom” yerine “tanecik” terimini kullanmalıdır.

(8-10 dakika)-Video odasındaki etkinlikler de istenilen sıra ile tamamlanır ve öğrenci cevapları öğretmen rehberliğinde karşılaştırılır. Sınıf içi uygulamalarda grup tartışmaları sözel olarak sınıf içinde yapılabileceği için toplantı odasında bulunan çevrimiçi tartışma panosu, ders süresinin yetersiz olması durumunda, öğretmen ve öğrenciler tarafından, ders dışı etkinlik olarak, ders tamamlandıktan sonra öğrencilerin karar raporlarında yazdıkları argümanlarını paylaşabilecekleri bir ortam olarak kullanılabilir.

(10-15 dakika)-Karar odasında öğrencilerin gözlem ve video odasındaki etkinliklerde seçtikleri tahmin, gözlem ve açıklamalar incelenir. Öğrenciler not defteri resmi üzerine listelenen kanıtların her birini kontrol ederek iddialarını destekleyip desteklemediğine karar verir. Buharlaşan tebeşirli suyun tanecik gösterimi (ana problem) ile ilgili iddialarını değiştirmek isteyen öğrenciler yeni iddialarını seçerler. Yeni iddia seçildikten sonra karar raporu bölümüne gelinerek, öğretmen her öğrenciden katı, sıvı ve gaz haldeki maddelerle ilgili argümanlarını oluşturmalarını ister. Bu aşamada öğretmen daha önceki derslerde (ders öncesi süreçte) belirtilen güçlü bir bilimsel argümanın özelliklerini 1-2 dakika kısaca tekrar eder. Öğretmen öğrencilerin kullandıkları kanıtlar ve destek cümlelerini kontrol ederek zorlandıkları noktada destek verebilir.

Ders süresinin yeterli olması durumunda yarışma odasındaki değerlendirme etkinliği, oyun odasındaki eşleştirme oyunu ve uzman odasındaki konular sınıf içinde çalışılabilir. Öğretmen ders sonrası etkinlik olarak öğrencilerden uzman odasını incelemelerini isteyebilir. Daha sonra toplantı odasında uzman odasındaki konularla ilgili tartışma başlığı açarak öğrencilerden sınıf dışında İnternet üzerinden çevirimiçi tartışmaya katılmalarını isteyebilir.

APPENDIX B: WEBFEN USABILITY QUESTIONNAIRE FOR STUDENT

Bu anket, kullanmış olduğun WEBFEN öğrenme ortamının ve içerdigi etkinliklerin kullanılabilirlik açısından değerlendirilebilmesi için hazırlanmıştır. Soruları dikkatlice okuyup, uygun bulduğun seçeneği işaretleyebilirsin. Bu ankete vereceğin cevaplar kullandığın sistemin geliştirilmesinde yardımcı olacaktır.

İsim, Soyisim: Fen Bilgisi Karne Notun:
Okulunun Adı:

Selin ve Selim'in dediklerini anlamak kolay mıydı?

Çok kolaydı Kolaydı Kararsızım Zordu Çok Zordu

Programi kullanmak kolay mıydı?

Çok kolaydı Kolaydı Kararsızım Zordu Çok Zordu

Gözlem odasında şiringa, beher, tuzluk gibi malzemeleri taşımak kolay mıydı?

Çok kolaydı Kolaydı Kararsızım Zordu Çok Zordu

Video odasındaki videoları çalıştırmak kolay mıydı?

Çok kolaydı Kolaydı Kararsızım Zordu Çok Zordu

Karar odasında raporu doldurmak kolay mıydı?

Çok kolaydı Kolaydı Kararsızım Zordu Çok Zordu

Odalardaki etkinlikler kolay mıydı?

Çok kolaydı Kolaydı Kararsızım Zordu Çok Zordu

Programdaki yazıları kolayca okuyabildin mi?

Evet, çok kolay okudum Evet, kolay okudum Kararsızım Hayır, okumak zordu Hayır, okumak çok zordu

Sistemi tekrar kullanmak ister misiniz?

Çok isterim İsterim Kararsızım Istemem Hiç istemem

Diğer üniteleri de bu şekilde çalışmak ister misiniz?

Çok isterim İsterim Kararsızım İstemem Hiç istemem

Eğer sen programcı olsaydın programın neresini değiştirirdin? Neden?

……………………………………………………………………………………………

……………………………………………………………………………………………

NO:

Original Usability Questionnaire for students - Bal (2004):

Soruları anlamak kolay mıydı?

Çok kolaydı Kolaydı Kararsızım Zordu Çok Zordu

Sistemi kullanmak kolay mıydı?

Çok kolaydı Kolaydı Kararsızım Zordu Çok Zordu

İşçileri taşımak kolay mıydı?

Çok kolaydı Kolaydı Kararsızım Zordu Çok Zordu

Kırmızı üçgeni taşımak kolay mıydı?

Çok kolaydı Kolaydı Kararsızım Zordu Çok Zordu

Yük taşımak kolay mıydı?

Çok kolaydı Kolaydı Kararsızım Zordu Çok Zordu

Program ekranı kolay anlaşılıyor muydu?

Çok kolaydı Kolaydı Kararsızım Zordu Çok Zordu

Sizce programdaki yazı miktarı fazla mıydı?

Çok fazlaydı Fazlaydı Normaldi Azdı Çok Azdı

Sistemi tekrar kullanmak ister misiniz?

Çok isterim İsterim Kararsızım İstemem Hiç istemem

Diğer üniteleri de bu şekilde çalışmak ister misiniz?

Çok isterim İsterim Kararsızım İstemem Hiç istemem

Eğer siz programcı olsaydınız programın neresini değiştirirdiniz?

……………………………………………………………………………………..

……………………………………………………………………………………

APPENDIX C: PRE AND POSTTEST FOR STUDENTS

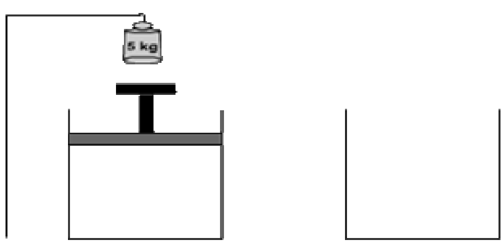
Post-test that is administered to sample students is presented below. The only difference in pre and posttest was one additional (3rd) question in posttest. The pretest consist of first two question of posttest.

İsim, Soyisim:

Uygulama Sonrası

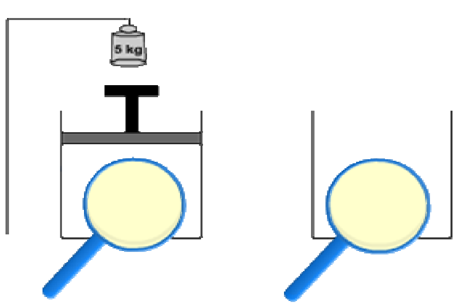
Aşağıdaki açık uçlu sorular, Maddenin Tanecikli Yapısı konusunda öğrencilerin bilgi düzeylerini ölçmek amacıyla hazırlanmıştır. Her soruya olabildiğince açık cevap verilmesi, çizim ve yazıların kolayca anlaşılır olması gerekmektedir. Çalışmaya verdiğiniz destekten dolayı teşekkür ederiz.

1 a) Aşağıda içi oksijen dolu bir kap var, bu kabın içindeki piston hareket edebilir. Bu pistonun üzerine 5 kiloluk bir ağırlık bırakırsak pistonun ve kabın sonraki durumunun nasıl olacağını çizerek göster.

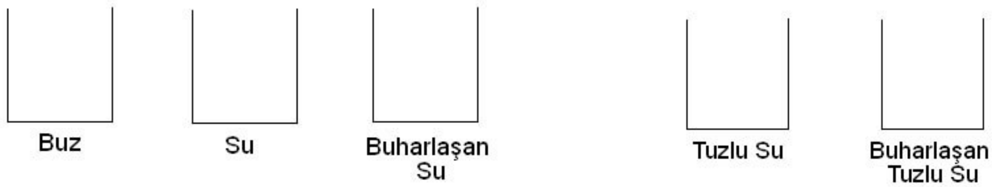


Ağırlık bırakılmadan önce   Ağırlık bırakıldıktan sonra

b) Eğer elinde sihirli bir büyüteç olsaydı ve maddeleri en küçük boyutlarına kadar gözlemleyebilseydin, kaptaki oksijen gazını mikroskopik boyutta ağırlık bırakılmadan önce ve ağırlık bırakıldıktan sonra nasıl çizerdin.



2) Elinde yine sihirli bir büyüteç olsaydı ve maddeleri en küçük boyutlarına kadar gözlemleyebilseydin, kaplardaki maddeleri mikroskopik boyutta nasıl çizerdin.



3) “Tüm maddeler aralarında belli miktarlarda boşluk olan ve gözle görülmeyen taneciklerden oluşmuştur" iddiası sence doğru mudur, yanlış mıdır? Neden ?

Doğrudur / Yanlıştır
Çünkü……………………………………………………………………………………
……………………………………………………………………………………………

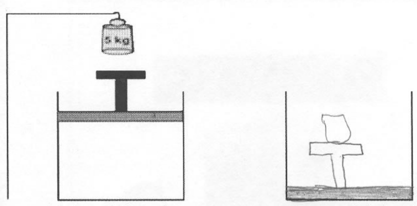
APPENDIX D: SAMPLES OF SUBJECTS' ANSWERS TO PRE AND POST-TESTS

Isim, Soyisim

Uygulama Öncesi

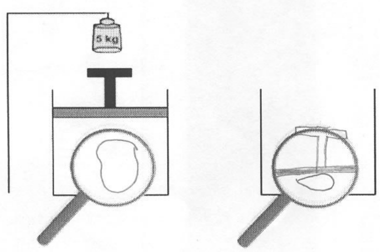
Aşağıdaki açık uçlu sorular, Maddenin Tanecikli Yapısı konusunda öğrencilerin bilgi düzeylerini ölçmek amacıyla hazırlanmıştır. Her soruya olabildiğince açık cevap verilmesi, çizim ve yazıların kolayca anlaşılır olması gerekmektedir. Çalışmaya verdiğiniz destekten dolayı teşekkür ederiz.

1 a) Ağaşıda içi oksijen dolu bir kap var, bu kabın içindeki piston hareket edebilir. Bu pistonun üzerine 5 kiloluk bir ağırlık bırakırsak pistonun ve kabın sonraki durumunun nasıl olacağını çizerek göster.



Ağırlık bırakılmadan once Ağırlık bırakıldıktan sonra

b) Eğer elinde sihirli bir büyüteç olsaydı ve maddeleri en küçük boyutlarına kadar gözlemleyebilseydin, kaptaki oksijen gazını mikroskopik boyutta ağırlık bırakılmadan once ve ağırlık bırakıldıktan sonra nasıl çizerdin.



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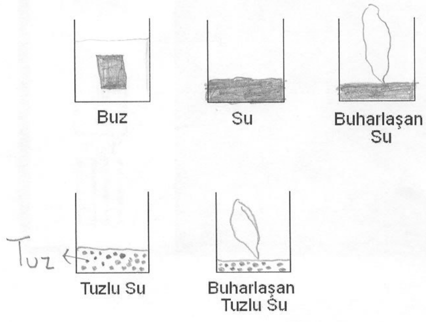

İsim, Soyisim:

Uygulama Sonrası

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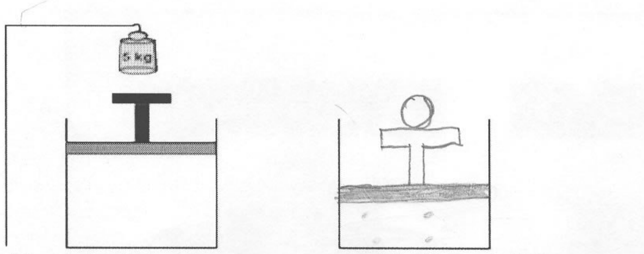

Ağırlık bırakılmadan once   Ağırlık bırakıldıktan sonra

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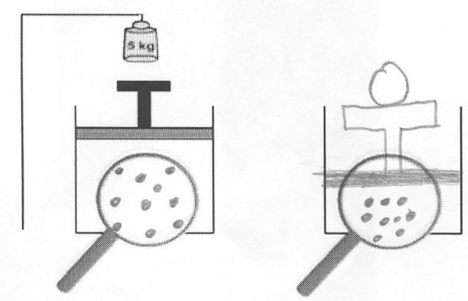

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Doğrudur / Yanlıştır

Çünkü………………………………………………………………………………………

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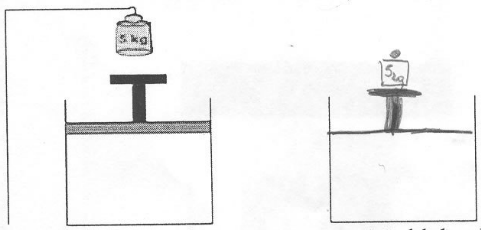

Ağırlık bırakılmadan once		Ağırlık bırakıldıktan sonra

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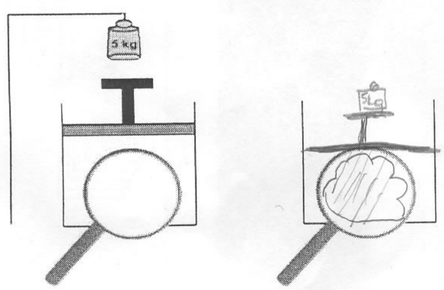

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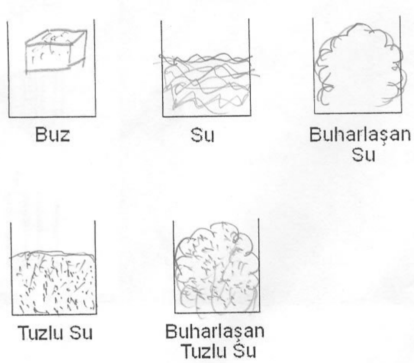

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Uygulama Sonrası

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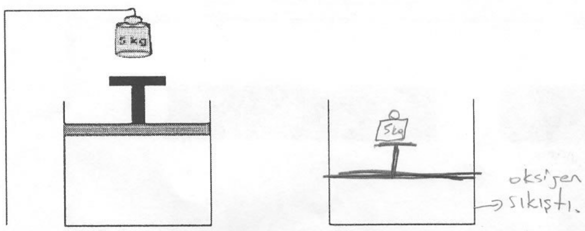

Ağırlık bırakılmadan once   Ağırlık bırakıldıktan sonra

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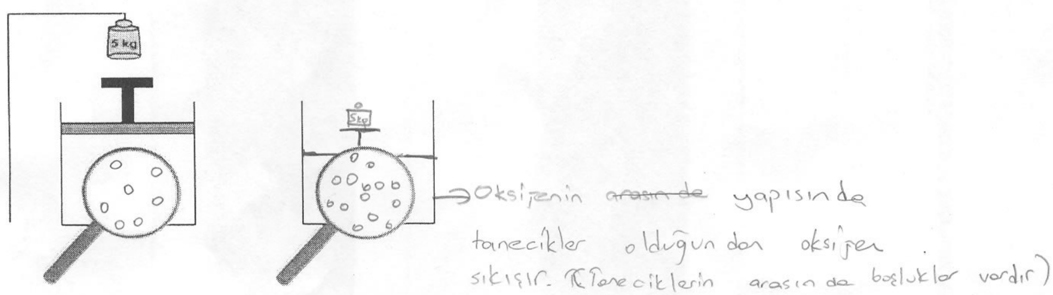

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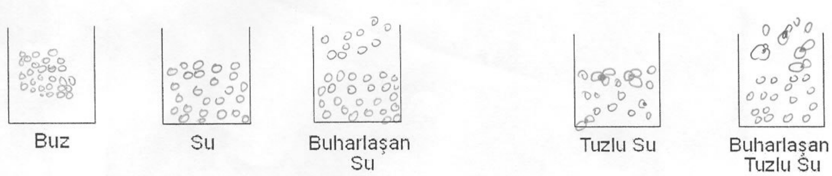

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Doğrudur / Yanlıştır

Çünkü...

....

APPENDIX E: WEBSERVICE CREATED FOR WEBFEN

```
namespace UI.Konular.MTY
{
    using System;
    using System.ComponentModel;
    using System.Web;
    using System.Web.Services;
    using Castle.ActiveRecord;
    using Castle.ActiveRecord.Framework;
    using Kernel;
    using NHibernate.Expression;

    /// <summary>
    /// Summary description for MTYService
    /// </summary>
    [WebService(Namespace = "http://cet.boun.edu.tr/webfen/")]
    [WebServiceBinding(ConformsTo = WsiProfiles.BasicProfile1_1)]
    [ToolboxItem(false)]
    public class MTYService : WebService
    {
        [WebMethod]
        public string GetCurrentUser()
        {
            return HttpContext.Current.User.Identity.Name;
        }

        [WebMethod]
        public bool UserEnteredActivity(string activityName)
        {
            try
            {
                ActivityLog activityLog = new ActivityLog();
                activityLog.Activity =
            ActiveRecordBase<Activity>.FindOne(Expression.Eq("Name", activityName));
                activityLog.DateEnter = DateTime.Now;
                activityLog.UserName = HttpContext.Current.User.Identity.Name;

                activityLog.SaveAndFlush();
                return true;
            }
            catch (ActiveRecordException)
            {
                return false;
            }
```

```
        }

        [WebMethod]
        public bool UserExitActivity(string activityName)
        {
            try
            {
                ActivityLog[] userLogs =
                    ActiveRecordBase<ActivityLog>.FindAll(Expression.Eq("UserName",
                                                         HttpContext.Current.User.Identity.Name));

                // find last entered activity
                ActivityLog lastLog = null;
                foreach (ActivityLog log in userLogs)
                {
                    if (log.Activity.Name != activityName)
                        continue;
                    if ((lastLog == null) ||
                        (log.DateEnter > lastLog.DateEnter && !log.DateExit.HasValue))
                    {
                        lastLog = log;
                    }
                }

                if (lastLog == null)
                    return false;
                lastLog.DateExit = DateTime.Now;
                lastLog.SaveAndFlush();
                return true;
            }
            catch (ActiveRecordException)
            {
                return false;
            }
            catch (Exception)
            {
                return false;
            }
        }

        [WebMethod]
        public bool NewKararRecord(string unitName, string rapor)
        {
            try
            {
                KararRoom karar = new KararRoom();
                karar.RaporText = rapor;
                karar.Unit      =      ActiveRecordBase<Unit>.FindOne(Expression.Eq("Name",
unitName));
```

```
            karar.UserName = HttpContext.Current.User.Identity.Name;
            karar.SaveAndFlush();
            return true;
        }
        catch (ActiveRecordException)
        {
            return false;
        }
    }

    [WebMethod]
    public bool StudentResponseToQuestion(int questionID, byte choiceNumber)
    {
        return StudentAnsweredQuestion(questionID, choiceNumber, null);
    }

    [WebMethod]
    public bool StudentResponseToQuestionWithScore(int questionID, byte
choiceNumber, int score)
    {
        return StudentAnsweredQuestion(questionID, choiceNumber, score);
    }

    public bool StudentAnsweredQuestion(int questionID, byte choiceNumber, int?
score)
    {
        try
        {
            StudentAnswer answer = new StudentAnswer();
            answer.Question = ActiveRecordBase<Question>.Find(questionID);
            answer.Score = score;
            answer.UserName = HttpContext.Current.User.Identity.Name;
            answer.ChoiceNumber = choiceNumber;

            answer.SaveAndFlush();
            return true;
        }
        catch (ActiveRecordException)
        {
            return false;
        }
    }
}
```

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