# THE EFFECTS OF COGNITIVE LOAD IN LEARNING FROM GOAL BASED SCENARIO DESIGNED MULTIMEDIA LEARNING ENVIRONMENT FOR LEARNERS HAVING DIFFERENT WORKING MEMORY CAPACITIES

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**I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.**

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# ABSTRACT

## THE EFFECTS OF COGNITIVE LOAD IN LEARNING FROM GOAL BASED SCENARIO DESIGNED MULTIMEDIA LEARNING ENVIRONMENT FOR LEARNERS HAVING DIFFERENT WORKING MEMORY CAPACITIES

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The purpose of this study is to investigate the effects of principles aiming to reduce extraneous cognitive load in learning from goal based scenario designed multimedia learning environment for learners having different working memory capacities. In addition, the effects of goal based scenario and the principles of cognitive load theory on students' perception, motivation and satisfaction has been explored. Two versions of the multimedia were developed for this study. In the first version (+CLT), the principles such as split attention, multimedia, modality, redundancy, coherence and signaling was applied. In the second version (-CLT), these principles were violated. Mixed method was used and two studies were conducted for this study. The first study was conducted with 82 ninth grade students from one of the Anatolian High School in Ankara. However, the participants' working memory capacities were found very close to each other.

Therefore, the second study was conducted with 54 $11^{th}$ grade students having different working memory capacity from the same school. The result of the first study showed that the cognitive load principles aim at reducing extraneous cognitive load increased learning gains, decreased invested mental effort and affected students’ motivation and satisfaction in positive ways. On the other hand, when cognitive load principles were not considered, this decreased learning gains, increased invested mental effort and affected students’ motivation and satisfaction in negative ways.

The result of the second study showed that the only difference between high and low WMC students found on the number of errors made in sequencing meiosis sub phases in favor of the first version (+CLT). This might be explained by the task characteristics in that the difference between high and low WMC individuals can be observed when task demanded attention. It can be concluded that students benefited from the cognitive load principles reducing extraneous cognitive based on the findings of both studies.

Keywords: Cognitive Load Theory. Working Memory Capacity, Multimedia, Goal Based Scenario

# ÖZ

**AMAÇ TABANLI KURGU YAKLAŞIMI TEMEL ALINARAK HAZIRLANMIŞ ÇOKLU ORTAM YAZILIMLARINDAKI BILIŞSEL YÜKÜN, FARKLI ÇALIŞAN BELLEK KAPASITESINE SAHIP ÖĞRENCILERIN ÖĞRENMELERI ÜZERINDEKI ETKILERI**

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Bu çalışmanın amacı amaç tabanlı kurgu yaklaşımı temel alınarak hazırlanmış çoklu ortam yazılımlarındaki bilişsel yükün farklı çalışan bellek kapasitesine sahip öğrencilerin öğrenmeleri üzerindeki etkilerini araştırmaktadır. Buna ek olarak, amaç tabanlı kurgu yaklaşımı ve bilişsel yük teorisinin önerdiği ilkelerin öğrencilerin algıları, motivasyonları ve doyumları üzerindeki etkileri de araştırılmıştır.

Bu araştırma kapsamında amaç tabanlı kurgu yaklaşımı temel alınarak hazırlanan çoklu ortam iki sürüm halinde geliştirilmiştir. Birinci sürümün tasarımında, bilişsel yük ilkelerinden dikkat bölünmesi, çoklu ortam, biçem, gereksizlik, tutarlıklık ve işaretleme ilkeleri uygulanmıştır. İkinci sürümün tasarımında ise bu ilkeler ihlal edilmiş veya uygulanmamıştır.

Bu çalışmada karma araştırma yöntemi kullanılmış ve iki çalışma yapılmıştır. İlk çalışma Ankara da bulunan bir Anadolu lisesinden 82 dokuzuncu sınıf öğrencisiyle gerçekleştirilmiştir. Ancak, bu öğrencilerin çalışan bellek kapasiteleri birbirlerine çok yakın bulunmuştur. Bu nedenle, ikinci çalışma aynı okuldan farklı çalışan bellek kapasitelerine sahip 54 11. sınıf öğrencisiyle gerçekleştirilmiştir. Birinci çalışmanın bulguları, konu dışı bilişsel yükü azaltan ilkelerin öğrenme kazanımlarını arttırdığını, harcanan zihinsel çabayı azalttığını ve öğrencilerin motivasyonlarını ve doyumlarını pozitif yönde etkilediğini göstermiştir. Öte yandan, bilişsel yük ilkeleri göz ardı edildiğinde, bunun öğrenme kazanımlarını düşürdüğünü, harcanan zihinsel çabayı arttırdığını ve öğrencilerin motivasyonlarını ve doyumlarını negatif yönde etkilediği görülmüştür.

İkinci çalışmanın sonucunda ise yüksek ve düşük çalışan bellek kapasitesine sahip öğrenciler arasındaki fark yalnızca öğrencilerin mayozun alt fazlarını sıralarken yaptıkları hata sayısında çoklu ortamın birinci sürümünün lehine elde edilmiştir. Bu bulgu, verilen görevin özellikleri ile açıklanabilir. Şöyle ki, düşük ve yüksek çalışan belek kapasitesine sahip bireyler arasındaki farklar ancak verilen görev dikkat gerektirdiğinde gözlemlenebilir. Sonuç olarak, her iki çalışmadan elde edilen bulgular doğrultusunda konu dışı bilişsel yükü azaltan bu ilkelerden öğrencilerin yararlandığı söylenebilir.

Anahtar kelimeler: Bilişsel Yük Teorisi, Çalışan Bellek Kapasitesi, Çoklu Ortam, Amaç Tabanlı Kurgu

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## INTRODUCTION

Constructivist philosophy brings different point of view about how learning occurs and how to design such learning environments (Duffy & Cunningham, 1996). Constructivist paradigm which is based on the interpretivist view assumes that learners can construct their knowledge as they make sense of it (Driscoll, 2000). The constructivist paradigm has offers many instructional methods for designing learning environments. These are: micro worlds, problem based learning, collaborative learning, bubble dialogue, hypermedia, open-ended learning environment and goal based scenario (GBS) (Driscoll, 2000). Specifically, this study aims to discuss the *goal based scenario* since this approach is one of the most promising methods for creating computer based learning environment. Developing effective GBS by using computer increase the opportunities to benefit from the advantages of the method because computer capability facilitates meeting the needs of prerequisite condition, which is very hard to achieve in the classroom; hence, developing effective GBS by using computer is mandatory for the appropriate use of *goal based scenario*. The g*oal based scenario* emphasizes developing a learning model in which learning goal allow the student to learn “how to” rather than “know that.” By knowing how, students eventually learn content knowledge in the service of accomplishing their task. Then, they know not only why they need to know something but also how to use the knowledge (Schank, Fano, Bell & Jona, 1994). *Goal based scenario* is a type of pedagogical approach in generative learning environment used to optimize e-learning (Naidu, 2003). Many studies show that GBS is an effective way of teaching by providing opportunities for the learners to know why and how they use knowledge. (Bell, Bareiss & Beckwith, 1994; Schoenfeld-Tacher, Persichitte & Jones 2001a; Zumbach & Reimann, 2002).

*Goal based scenario* offers realistic environments for complex learning tasks and has the potential to motivate learners; however, the severe risk of this approach is that the task complexity is high and if the learners cannot handle the task complexity, because of overload on working memory capacity, it might hamper learning (Van Merriënboer, Kirschner, & Kester, 2003). To eliminate this overload, the limitation of working memory should be taken into account. Cognitive load theory provides valuable guidelines on how to deal with this overload (Van Merriënboer, Kirschner, & Kester, 2003). In addition to CLT, the cognitive theory of multimedia learning (CTML) (Mayer, 2001) also provides guidelines aiming at reduction ineffective cognitive load or extraneous cognitive load, which is ineffective for learning.

Cognitive load theory "is concerned with the development of instructional methods that efficiently use people's limited cognitive processing capacity to stimulate their ability to apply acquired knowledge and skills to new situations" (CLT; Paas, Tuovinen, Tabbers &:Van Gerven, 2003, p. 63). The major assumption behind the CLT is that the individuals' working memory has limited capacity (Kirschner, 2002). Within the framework of CLT, it is already known that the amount of learning takes place and complexity of the learning content is affected by the amount of working memory resources used to conduct a task (Paas, Tuovinen, Tabbers &:Van Gerven, 2003). Therefore, instructional formats should not overload the working memory capacity and allow the learners to use their capacity for actual learning (Bannert, 2002) In addition, cognitive load is a prominent factor that determines the success of an instructional intervention and should not be considered as a by-product of the learning process (Paas, Tuovinen, Tabbers &:Van Gerven, 2003). Therefore, many studies are conducted to find out ways to reduce extraneous cognitive load for meaningful learning from multimedia environments. (Clark &Mayer, 2003; Kalyuga, Chandler & Sweller, 2004; Mayer & Moreno., 2003; Seufert & Brünken, 2006; Tabbers, Martens & Van Merriënboer, 2004; Van Bruggen, Kirschner & Jochems., 2002; Van Gerven, Paas, Van Merriënboer & Schmidt, 2002).

## 1.1 Background of the Study

"The best way to improve instruction is to begin with a research based understanding of how people learn." (Mayer & Moreno, 2003, p. 51). Not only *cognitive theory of multimedia learning (CTML)* and *cognitive load theory (CLT)* but also *goal based scenario (GBS)* are based on sound theory of memory and learning. Cognitive theory of the multimedia learning and cognitive load theory base their assumptions on limited working memory capacity and try to provide guidelines to design instructional materials (the multimedia) aiming at efficient use of the learner's cognitive resources. The goal based scenario is considered as an effective instructional approach to teaching and the underlying principles of GBS are also founded on a sound theory of memory and learning which is called case based reasoning. The main purpose of this approach is not only to increase the learning of factual knowledge in a context by showing how it will be used but also to promote skill developments (Schank, Fano, Bell & Jona, 1994).

Every Instructional designer or teacher should be careful in using the goal based scenario as an instructional method in designing learning environments because of its high complexity (Van Merriënboer, Kirschner, & Kester, 2003). If the learners cannot handle the high complexity, learners' limited working memory will be overloaded. This can impede or diminish the benefits of the GBS in the learning processes. In order to increase the effects of GBS on the learning process, the limitation of learners' working memory should be taken into account. Valuable guidelines aiming at reduction the overload were proposed in the cognitive load theory (Van Merriënboer, Kirschner, & Kester, 2003) and the cognitive theory of multimedia learning (Mayer, 2001). Therefore, it is very important to take into account the principles developed by CTML and CTL while using GBS as an instructional approach for computer based learning environments. The combination of these might be expected to increase both effectiveness and efficiency of the instructions.

Most of the guidelines or principles provided by CTML and CTL are research based; however, the main shortcoming of these principles is that most of them are gained from controlled laboratory experiments and it would be difficult to say that they will also produce similar effects in actual classroom settings. Indeed, some contradictory findings were also found when the modality principle was implemented in actual classroom settings (Tabbers, Martens & Van Merriënboer, 2004). How these principles affect learning process in actual classroom setting has not been investigated widely among researchers.

Goal based scenario has the potential to motivate learners both extrinsically (Schaller et al., 2001) and intrinsically (Zumbach & Reimann, 2002). It is assumed that the principles that applied in GBS framework do not only affect the learning outcome but also the motivation and satisfaction of the learners. In a recent article, the relationship between motivation, performance and cognitive load is investigated by task involvement equating proposed by Paas, Tuovinen, Van Merriënboer & Darabi (2005). Task involvement is used to calculate the learner involvement in instructional conditions. The assumption behind this equation is that motivation, mental effort, and performance are positively related. In this case, learner involvement is higher with the more mental effort which is likely to be invested in instructional conditions and with the higher performance.

Even though the CTL and CTML design principles are developed based on individual's limited working memory, there is not enough research that investigates how learners having different working memory capacity (WMC) affected from these principles in actual classroom settings.

## 1.2 Purpose of the Study

For this study, two versions of goal based scenario centered multimedia learning environments were developed. In design of the first version (+CLT), the principles such as split attention, multimedia, modality, redundancy, coherence and signaling was applied. In design of the second version (-CLT), the principles were violated. The purpose of this study is **two fold**. Firstly, this study aims to investigate the effects of principles aiming to reduce ineffective or extraneous cognitive load applied in GBS centered multimedia learning environments for learners having different working memory capacity. Secondly, the effects of goal based scenario and the principles of cognitive load theory on students' perception, motivation and satisfaction has been investigated. Therefore the study deals with both learning process and learning outcome in the multimedia learning environment.

## 1.3 Research Questions

In order to reveal the effects of extraneous or ineffective cognitive load in learning from the multimedia for learners having different working memory capacity and the opinions of the learners toward the the multimedia, the following questions guided this study.

**1.** To what extent cognitive load could explain the possible difference on learning outcome from goal based scenario designed multimedia for the learners with different working memory capacity.

 **1.1** Is there a significant difference between GBSc3DM+CLT and GBSc3DM-CLT on learning outcome?

**1.2** Is there a significant difference between high WMC, medium WMC and low WMC learners on learning outcomes from GBSc3DM-CLT?

**1.3** Is there a significant difference between high WMC, medium WMC and low WMC learners on learning outcomes from GBSc3DM+CLT?

**1.4** Is there an interaction effect between learners' working memory capacity and two version of GBSc3DM on learning outcome?

**2.** What are the students' opinions about the cognitive load principles in GBS?

**2.1** How does the cognitive load in GBSc3DM affect student motivation?

**2.2** How does the cognitive load in GBSc3DM affect student satisfaction?

**3.** What are the students' perceptions towards goal based scenario designed multimedia?

## 1.4 Significance of the Study

This study will attempt to provide answers to the questions about the effects of extraneous cognitive load in the goal based scenario designed multimedia for learners having different working memory capacity. Many research studies point out that the goal based scenario is an effective instructional method (Bell, Bareiss & Beckwith, 1994; Schoenfeld-Tacher, Persichitte & Jones 2001; Zumbach & Reimann, 2002); however; there is not enough research studies conducted to investigate the effects of extraneous cognitive load and working memory capacity in multimedia learning environments. This study provides opportunities to examine the difference between learning outcome from goal based scenario designed multimedia which is developed with CLT principle and without the CLT principle. This study also attempts to understand the learners' satisfaction, motivation and perception toward GBSc3DM+CLT and GBSc3DM-CLT. In addition, it aims to reveal the relation between cognitive load and motivation.

This will be a study that tries to divide participants based on their working memory capacity in CLT framework and implement the principles of cognitive load theory in natural environment rather than laboratory settings. In previous research, the effect of working memory capacity has been studied in CLT framework for elderly and young people. In addition, the visual and verbal span of the participants has been studied more frequently for relatively the same age groups in the literature. However, two slave systems of working memory capacity are responsible for storage of information and central executive is responsible for coordinating and maintaining upcoming information. Since the goal based scenario multimedia program includes both visual and verbal information and requires learners to perform complex cognitive task, rather than visual and verbal span, working memory span taken into account for this study. To state it another way, working memory capacity is the measurement of central executive (Unsworth, Heitz, Schrock & Engle, 2005) and it is known that the function of central executive is coordinating two slave systems and maintaining information, hence, to investigate working memory capacity for same age group in terms of individual difference for such a complex learning environment assumes to be much more appropriate for the present study.

Curriculum of schools is changed recently based on the constructivist approach in Turkey. Nevertheless, there is limited number of educational software that supports this curriculum. Therefore, this study will provide valuable insight for developing and evaluating educational software that meets the needs of this curriculum. Also, it will make contribution to understand the learning process. This study attempts to provide opportunities to examine the learners' motivation and satisfaction on towards the goal based scenario designed multimedia which is developed with CLT principle and without the CLT principles. In addition, this study provides valuable information for developing and evaluating educational software on the constructivist paradigm and the CLT framework.

## 1.5 Definition of Terms

**Goal Based Scenario:** GBS "is a type of learn-by-doing task with very specific constraints on the selection of material to be taught, the goals the student will pursue, the environment in which the student will work, the tasks the student will perform, and the resources that are made available to the student" (Schank et al., 1994, p. 305).

**Case Based Reasoning:** "It is our theory of how we remember and how we use our memories in order to solve new problems. It is a descriptive theory, not a design theory" (Schank, Berman, Machpherson, 1999, p. 166).

**Cognitive Load Theory:** "It is concerned with the development of instructional methods that efficiently use people's limited cognitive processing capacity to stimulate their ability to apply acquired knowledge and skills to new situations (CLT; Paas, Tuovinen, Tabbers &:Van Gerven, 2003, p. 63)."

**Cognitive Theory of Multimedia Learning:** Cognitive theory of multimedia learning based their assumption on dual coding theory (Paivio, 1986), limited working memory capacity (Baddeley, 1986) and active processing. Five cognitive activities should take place in order to meaningful learning occurs. These are: 1) selecting relevant words for processing in verbal working memory 2) selecting relevant images for processing in visual working memory 3) organizing selected words into a verbal mental model 4) organizing selected images into a visual mental model 5) Integrating verbal and visual models and connecting them to prior knowledge (Mayer, 2005).

**Working Memory Capacity:** WMC is the controlled-attention component of the working memory system. WMC is a domain independent, limited capacity processing resource that we use to keep relevant information active and available, while at the same time filtering out distraction (Rosen &Engle, 1997).

**Multimedia Principle:** Multimedia presentation refers to any presentation that contains both words and pictures. By words, it is meant both printed and spoken text. By graphics, it is meant not only static illustration such as graphs, photos but also dynamic illustration such as video or animation (Clark & Mayer, 2003; Mayer &Moreno, 2002).

**Modality Principle:** Modality refers to placing material into spoken forms of words rather than printed word whenever the graphic and or animation is the focus of the words and both are given simultaneously (Clark & Mayer, 2003; Mayer & Moreno, 2002; Sweller, Van Merrienboer & Paas, 1998).

**Redundancy Principle:** Redundancy refers to presenting words in both text and audio narration which found that hamper learning. To eliminate redundancy, either text or narration should be used whenever it is approporiate for context. Redundancy is a major effect that should be considered because its negative consequences on instructional design (Sweller et al., 1998).

**Split Attention Principle:** Split attention refers to presenting words and pictures separately. Learners must use their limited cognitive resource to use mentally organize and integrate the materials when they are separated from each other on the screen. On the contrary, to eliminate split attention, they should be integrated so that learners can combine them in their working memory and make meaningful connection between them (Clark & Mayer, 2003; Mayer &Moreno: 2002; 2003; Sweller et al., 1998).

**Coherence Principle:** Coherence refers to presenting irrelevant sound, picture and graphics which can hurt learning. In line with the coherence principle, extraneous picture and word should be eliminated in learning environment (Clark & Mayer, 2003; Mayer and Moreno, 2002).

**Signaling Principle:** Signaling refers to adding non content information, visually or auditory, to the content in order to focus attention to those aspects which is important while watching dynamic display (Sweller et al., 1998).

**GBSc3DM+CLT:** A multimedia goal based scenario developed with the principles of the cognitive load theory.

**GBSc3DM-CLT:** A multimedia goal based scenario developed without the principles of the cognitive load theory.

# CHAPTER 2

## REVIEW OF LITERATURE

### 2.1 Goal Based Scenario

Goal Based Scenario is one of the constructivist methods developed based on sound theory of memory and learning. In the GBS, the students try to find out solution to the problems in the domain of student's interest that show sustainable goals and learning occurs while students achieving those goals in a context (Schank, Fano, Bell & Jona, 1994; Schank, Berman & Macpherson, 1999). Rather than representing topic to the student, GBSs are developed based on the skills that a student can learn. The value of the GBS is becoming obvious at this point because GBS emphasizes creating a learning model that "learning goals aim for learner to learn **how to** rather than **know that**" (Schank, Berman & Macpherson, 1999, p. 165). Defining skills as "knowing how to do something" are the essence of the GBS. Therefore, the objectives that instructional designers want the student to master in GBS should be described in terms of skills. The skills are closely related to goals and the skills can be acquired by learners when the skills are allowed to do something they want or need to do. The learners are involved in a process which provides opportunities them with practicing skills when they try to accomplish the goals. The detailed information on goals, skills and their relationship are stated below:

*The goals* are considered important aspect of the learning and discussed widely among many educators. In the GBS, learning goals are based on the proper context and motivation for a set of target skills learning. The goals are closely related to the skills and so defining learning goals properly and practice these goals into the context contribute to attain the skills (Schank, Fano, Bell & Jona, 1994). Only selecting suitable goals does not guarantee the necessary motivation or the context to maintain the acquisition of the target skills (Schank, Fano, Bell & Jona, 1994). Nevertheless, *skill* acquisition by practice in the context is the central notion in the GBS framework. Practicing skills help build representation of that skill at the initial phase. The declarative knowledge of the learner can be easily converted into procedural knowledge through practicing. It also leads to more efficient and effortless skill performance by doing automatically,

*The skills* are closely related to the goals. Developing appropriate skills have crucial importance in order to achieve the learning goals. There is contrasting perspective about relationship between the context and skill. While developing skills, learners are exposed to a variety of cases and so they have adequate opportunity to shape their mental model of that skill. The learners get the right clues from context when they practice them into authentic environment (Brown, Collins & Duquid, 1989, Collins, 1994). On the other hand, it has been claimed that if a skill divided into independent sub skills, learner has opportunities to learn each sub skill independently and this has some advantageous (Gagne, 1973). As pointed out by Collins (1994), both situated and unsituated education is problematic in that learning things in a specific context is lack of generalization and transfer, on the other hand, learning them without context is lack of motivation to learn and it is the retention of abstract concepts. However, the skills and the context are considered fundamental concepts in designing the goal based scenario (Schank et al, 1994). In addition, it is asserted that the problems of situated learning can be passed over by adding some principles in designing goal based scenario (Collins, 1994).

### 2.1.1 The Roots of Goal Based Scenario

Goal Based Scenario is an effective approach to teaching and learning because “the underlying principles of goal based scenario are founded on a sound theory of memory and learning” (Schank et al, 1994, p. 340). According to the this approach, it has been claimed that the best way to teach learners is to give them opportunities to be involved in situations and to do some skills in acquiring the knowledge that the teachers want them to learn.

The theory underlying goal based scenario is case based reasoning (CBR). It is a theory of memory and learning which aims to explain how people remember and use their memories in order to solve new problems (Schank, Berman & Macpherson, 1999). In this theory, it is assumed that while the learners want to do something, they begin with a goal. After identifying a goal, the learners become involved in a process; if they can reach desired solution they indexed the cases in the memory. As a result, learners can create case libraries with their experiences. In addition, the learners organize their experiences which is called *indexing* in order to benefit from them when or where needed. However, if the learners cannot reach desired solution they turn back to the process. This is called *expectation failure*. These expectation failures also indexed as a case into the memory. Then, the learners try to bring explanation to their expectation failures. This is only the case, if the learners can connect explanation to their expectation failures when indexing in the case library. While learning new things, the learners can use their case libraries and transfer their past experiences to the new situation. Although it can be assumed that each case is context specific so it is too hard to transfer that knowledge, it is feasible to draw general conclusion that applied between different contexts where the similarities of the memories is based on themes. For example, “if at first you do not succeed, try try again” can be used across context (Schank, Berman & Macpherson, 1999, p. 167).

CBS is not the only way the learners’ reason. Sometimes, the learners can face with a new situation and they cannot bear in mind any similar prior experiences from which to make similar experiences. “In such a situation, you will have to begin reasoning process from the first principle” (Schank, Berman & Macpherson, 1999, p. 167). If it is not the case, the learners only guess to find solution to new problems, which is not reasoning at all. However, most of the time human beings can transfer their past experiences into the new one and so they can use CBR efficiently.

To sum up, it is assumed that if the learners situate in a meaningful and motivating role and the goal in learning process, they can appropriately labelled their experiences and expectation failures and then indexing them in memory so that they can use whenever they needed.

#### 2.1.1.1 Story Telling

It is emphasized that only knowing facts do not permit indexing the situation with regard to its relevance to the facts (Schank, Berman & Macpherson, 1999). In other words, only explaining the facts to the learners is not allowed them to transfer this knowledge into a new situation. As a result, the knowledge in the learner mind is inert. To make it more explicit, learning some facts without context can not let indexing the characteristics of the situation in which the concept or facts are relevant (Schank, Fano, Bell & Jona, 1994). This is where the traditional teaching fails because teaching are based on isolated facts and learner do not know the relevance of the skill they are learning (Schank, Berman & Macpherson, 1999).

“Our memories, to a large extent, consist of stories of our expectation failures.” (Schank, Fano, Bell & Jona, 1994, p. 315). When learners encounter with failures in the service of achieving the goal in their life, they stored them in the form of stories. Therefore, it is reasonable to teach people in the form of stories and so storytelling programs will be promising with regard to this issue (Schank, Fano, Bell & Jona, 1994). Schank (2002) also says that curriculum should be designed based on stories. To justify his argument, he claims that stories are the center of human conciseness because people live stories, tell stories and so these stories shape them also. Therefore, the curriculum should be developed based on stories and these stories mainly should be goal based and activity based. Schank (1994) in his "A Radical Look at Education" article also says that the whole school program should be changed based on storytelling. To give an example, he claims that rather than given math to biology student independent of biological concept, it does not help them much. Rather, it will be more beneficial to teach required math to student into biology context and make learning math more meaningful for the biology student by using storytelling in GBS. At this point, the ability of storyteller to model student expectation is the key issue for the effectiveness of storytelling in teaching.

#### 2.1.1.2 Motivation

Motivation is defined as a construct "which is primarily concerned with activation and persistence of behavior, is also partly rooted in cognitive activities" (Bandura, 1977 p. 193). Motivation can influence how, when and what we learn (Schunk, 1991). In addition, it is agreed upon that behavioral indexes which are *choice of task, effort and persistence* indicate the presence of the motivation (Wang, Johnson, Mayer, Rizzo, Shaw & Collins, 2008). There are two types of motivation which are intrinsic and extrinsic. Intrinsic motivation is related to the activities which are done because of its interesting features; on the other hand, extrinsic motivation is related to the activities done because it might result in different outcome. The difference between intrinsic and extrinsic motivation is that extrinsic motivation refers to doing an activity for its interesting and enjoyable characteristics rather than its instrumental value (Ryan & Deci, 2000).

The effective leaning environment which students pursing goal creates conditions that produce strong intrinsic motivation to learn (Schank, Fano, Bell & Jona, 1994). The GBS itself comprises a rich amount of content and provide interesting and complex activities. It is also motivating the students because of these features. The GBS states a goal and so the learners know that new knowledge helps that to achieve a goal both relevant and meaningful. As a result, it increases their intrinsic motivation (Schank, Berman & Macpherson, 1999).

### 2.1.2 The Components of Goal Based Scenario

GBS mainly consists of two main parts (Schank et al., 1994). These are the ***mission context*** which consists of mission and cover story and the ***mission structure*** consisting of scenario operation and the mission focus.

**Mission Context:** Mission context includes concept which is the related aspects of the goal based scenario. It mainly consists of mission and the cover story. The detailed information about the main component of the mission context and their design criteria has been summarized in Table 1.1.

**Mission Structure:** Mission structure includes all plans, activities and operations that a learner needs to do to achieve the given mission. It mainly consists of mission focus and scenario operations. The detailed information about the main component of the mission structure and their design criteria has been summarized in Table 1.1.

**Table 1.1** GBS main components *given from in Schank *et al* (1994) pp. 343-345

| GBS Components | Designing Criteria |
|---|---|
| ***Mission Context*** | |
| ***Mission:*** *The mission is the overall goal of the GBS* | **Goal distinction:** The goal should be clear, plausible and consistent with the cover. Progress towards the goal as well as its accomplishment.<br>**Goal motivation:** Much of the motivation to work through the GBS will come from the desire to complete the mission. The mission should be a goal that the students already have or that there is reason to believe the student will enthusiastically adopt.<br>**Target skill dependence:** Completion of the mission should require mastery of the target skills dependence and knowledge.<br>**Empowerment:** Completing the mission should demonstrate to the student that he or she is now capable of achieving a wide class of goals.<br>**Flexible achievement:** A mission should be selected that can be achieved many different achievement ways, yet for which no single solution is guaranteed to work every time. |
| **Cover Story:** It is the background story line for achieving goal | **Role coherence:** The cover story should provide a desirable role for the student within a plausible exciting and accessible story.<br>**Target skill density:** The cover story should be designed to lead to situations that maximize the need to apply the target skills and minimize the need for others.<br>**Frequent practice opportunities**: Advancing the cover story should require minimal time and effort relative to that spent on acquiring target skills and knowledge. The cover story should provide situations that allow the target skills to be practiced in a wide variety of contexts.<br>**Integrated support:** Additional assistance required by students should be provided using materials consistent with the cover story when possible. |
| ***Mission Structure*** | |
| ***Mission Focus:*** The overall organization of the student's activities within a GBS | **Task consistency**: The overall focus of the student's activities should be suggested by the mission and cover story. Possible mission focuses include explanation, control, discovery and design. |

**Table 1.1 (Continued)**

| | |
|---|---|
| | **Student investment**:: The mission focus should promote a student's sense of personal investment in the mission<br>**Process emphasis**: Pedagogical goals should depend principally on the process of trying to complete the mission.<br>**Artifact dependence**: The "artifact" of the mission focus, be it a design, an explanation, or otherwise, should reflect the student's understanding of the domain and embody a solution to the problem at hand. The properties of the artifact and its performance within the cover story should reflect the strengths and weaknesses of the solution. |
| ***Scenario Operation:*** The activities the student performs in GBS | **Responsiveness:** Students should be able to observe the causal effects of their operations.<br>**Expressivity:** Students should be provided with a sufficient number of operations to allow them to pursue the mission as they see fit. The operations available should include those that can lead to a failure in achieving the mission<br>**Causal consistency:** Operations and their outcomes should be consistent with the cover story and mission.<br>**Facilitation of strategies**: The student should be relieved of operations that are not central to the pedagogical goals of the GBS |

In addition to the main parts of the GBS, in their theoretical paper, Schank, Berman and Macpherson (1999) state that GBS mainly consists of seven components. These are *learning goals, mission, role, cover story, scenario operation, resources and feedback.*

***Learning Goals:*** Defining clear learning goals about what designers want learners to learn is the first step in designing process. There are two different categories under the learning goals: process knowledge and content knowledge. Process knowledge is defined as the knowledge of how learners should practice skills in service of achieving the goal. Content knowledge is all the information that the learners need to know in order to achieve the goal.

***Mission:*** A mission should be motivational or realistic for students in GBS. It should be stated in a form of a goal that a real person would need to do. Also, the mission should provide enough opportunities to learn the skills and the knowledge that teachers want to teach.

***Role:*** The role defines the character that students are supposed to be in storyline. The role should provide enough opportunity to practice the skills and also it should be motivational.

***Cover Story:*** The cover story is the essential part of the mission because it provides a story line for it. The cover story should provide many activities for learners to practice the skills by searching the knowledge that teachers want the students to learn.

***Scenario Operation:*** The scenario operations include all activities that are involved in GBS designed environments. While designing activities, it should be considered that scenario operation should be closely related to both the mission and the learning goals. In addition, activities in scenario operations should be constructed that each activity has consequences and they are becoming appear at many points throughout the scenario. To make it more clearly, there should be some decision points that the students do for activities occasion. Decision can be successful or failure. If the decision is successful, the learners should be given positive consequences. On the other hand, if the decision is failure, the learners should be given negative consequences.

***Resources:*** The resources should be designed to provide enough information that the students need. There should be enough and well-organized information in resources for the learners to complete the mission successfully. The information should provide student with the stories. It is assumed that the best way to convey information is not to teach de-contextualized facts, instead, to represent context in stories so that learners can understand as an extension of the stories they already know. In GBS, scenario should be representing clearly in order to eliminate the need for speaking too much about the scenario. Rather, the learners should spend most of their time with the practicing the skills and learning the information that consist of learning goals. The key point for designing resources is that learners should not need to do more than is necessary for the learning goals to be achieved.

***Feedback***: In GBS, feedback should be situated in an appropriate context that provides just-in-time for the students to use. Feedback is given when learners are faced with the target domain context and skills. Feedback is given in three ways. These are consequences of actions, through coaches and through domain expert. The consequences of actions can be provided the learners into ways. If the learners perform a task in GBS environment and based on his success or failure the GBS simulate negative or positive consequences. The second type of feedback can be given such that as learners perform tasks within a GBS, an online coach following their progress can suggest advice when needed, providing just-in-time source to scaffold the student through the task. For the last type of feedback, through domain expert, the GBS can offers feedback through domain experts by telling stories about similar experiences.

### 2.1.3 Review of Research on Goal Based Scenario

GBS can be used as a teaching method for all levels ranging from formal to informal learning situations (Kolodner, 1994). However, it should be stated that it is really a challenging approach because it requires a radical restructuring of curriculum and school itself (Schank, 1994). Although it requires such a radical change, Kolodner (1994) claims that the prominent strength of the GBS is the readiness of the people for such a radical restructuring which does not affect to use GBS effectively.

Most researches in the GBS are mainly trying to explain the GBS designing process and the remaining evaluates its effectiveness in terms of different aspects. Firstly, the studies that focus on designing process presented and then empirical studies using GBS as a framework try to be summarized.

GBS provides the learners to be actively involved in the learning environments which represent the facts and skills in the context of real world use. Providing these features, Kass, Burke, Blevis and Williams (1994) developed a program for complex social skills and give detailed explanation about the designing process but they did not do any evaluation. Foster (1994) provides a rationale for using goal based scenario to teach financial statement analysis (FRA). He stated that the GBS architecture has the ability to eliminate the shortcomings of traditional case method and he concludes that FRA can be a promising alternative approach compared to the traditionally case based teaching method. In another study, Foster and Bariess (1995) try to figure out the traditional shortcomings of business case method for undergraduate and graduate education. They point out that the traditional case method has some shortcomings in terms of providing limited assistance, delayed feedback, providing little motivation to learners. Then, they figure out how FRA system can eliminate these shortcomings by providing learning by doing environment, giving students a realistic role in problem solving case and coaching while performing the task. FRA is developed as multimedia software system. On the other hand, Bolinger and Sullivan (2004) provide a framework for using goal based scenario in teaching accounting in classroom environment. In their paper, they give five steps to explain how GBS implemented in real accounting classroom. Rapatan (2004) also explains design procedure of a goal based scenario simulation (The Last Resort) for ecotourism. Although there is no information about evaluation process in the paper, the author concludes that the students and professionals have positive comments on interface design of program and integration of learning objectives.

A more recent research on designing goal based scenario particularly focus on how to integrate scaffolding in goal based scenario for interactive game on biodiversity for children (Strobel &Idan, 2006). The authors conclude that scaffolding might be supported by background story, checklist, index cards, information bites and glossary in GBS designed game environment for children. In another recent study, Nemoto and Suzuki (2005) develop a checklist for instructional designer to evaluate whether existing scenarios follow the GBS design principles.

It is pointed out by many researchers that GBS framework provides an Investigate and Decide architecture for educational software (Bell & Korcuska, 1994, Dobson, 1998, Qui & Reisbeck, 2002). Bell and Korcuska (1994) proposed a prototype authoring tools for special purpose task models which is called Goal Based Scenario Builder for interactive educational software. On the other hand, Qui and Riesbeck (2002) introduce a new concept for goal based scenario. The authors criticize traditional goal based scenario design for having pre-defined context and not allowing open ended activities. To overcome this problem, the authors create an architecture for hybrid GBS and implement it with an already developed software called INDIE (Dobson, 1998). A hybrid INDIE learning environment both includes traditional support in GBS and provides opportunities to include a human tutor to respond open-ended inputs from the students.

Some empirical researches that evaluate GBS have been summarized in this section. Bell, Bareiss and Beckwith (1994) provide detailed information in designing process of GBS and they also evaluate the GBS based program. The program is called "Sickle Cell Counselor (SSC)". In this program, the learners role is the genetic counselor and the learner mission is to give advice to puter-simulated couples about the likelihood of having a child with disease (Bell, 1994). The authors make three evaluations for the program. With regard to the patterns of usage, they found that users spend much time in using the program and they conclude that the program is interesting for the user because it is presented in a museum so visitors do not need to use it. In addition, the authors compare the program and pamphlet with no intervention or control group by using two types of assessment which are role-playing, interviews and paper and pencil test. Although there is significant difference between program and control group, there is no difference between pamphlet and control group. Users taking the SSC program make significant fewer irrelevant responses on the posttest than the others. Based on the results, it is concluded that GBS is an effective way of teaching for contextualized knowledge.

Specifically, some of the researchers try to highlight the use of goal based scenario in web environment. Naidu, Ip and Linser (2000) developed a dynamic goal based role play simulation on the web. They point out some differences between dynamic goal based role play simulations and goal based scenario. The latter provides students with task goal (mission) and role, on the other hand, the former give the role in the scenario and allow students to develop their own goal in the learning environment. Although they did not give detailed information about assessment, context and procedures, the summative evaluation results show that the students' responses on the achievement of learning outcomes are between very useful and useful and the perceived effectives are relatively strong. It is concluded that the overall experience of the students' is very positive in the environment. However, Mouza and Bell (2001) systematically try to asses the impact of web driven goal based scenario as a part of science classroom activity. They did not find significant difference between pre and post survey both for students and teachers but they infer that the program could have positive impact on classroom teaching from qualitative data. Lots of issues regarding to appropriate use of computers in classroom environment has been addressed. Schaller, Bunnell and Nagel (2001) points out the benefits of GBS for web based education. They claim that GBS provides extrinsic motivation for uninterested but the potentional learners especially when it's appealing increased by narratives, games, simulations and creative play activities.

Zumbach and Reimann (2002) try to compare different methods with using the same media. In their study, three different approaches, the GBS, Tutorial and

Strategy training, has been developed by using hypermedia environment. These approaches were selected based on their goal orientation. The result shows that GBS are more motivated intrinsically than others, students get better overviews and they are able to use their knowledge into argumentation task. While the GBS are better for structural knowledge, it does not show better results for factual knowledge than others.

Schoenfeld, Persichitte and Jones, (2001a) investigate the impact of different factor on multimedia GBS. In their study, it is found that GBS provide equal opportunities for the learners come from different gender and ethnicity. In addition, it is found that this type of instruction is more beneficial to the students possessing the formal reasoning ability necessary to investigate and develop hypotheses in scientific settings (Schoenfeld, Persichitte & Jones, 2001a, 2001b). In a more recent study, prospective computer teachers' perceptions of and experiences in goal-based scenario (GBS) centered 3D educational game development process has been investigated (Yildirim & Kilic, 2008). It is found that the pre-service teachers preferred GBS-centered educational games than traditional educational games and they considered the most important feature of educational games was their contribution to motivation, attention, and retention.

The research generally shows that GBS has positive effect not only on teaching and learning process but also on students' motivation. In addition, it is found that the GBS is appropriate for teaching complex learning skill. Although most of the studies are mainly based on designing process, it can be inferred from existing literature that goal based scenario is a promising method for classroom instruction and developing educational software.

### 2.1.4 Assessment of Learners' Perceptions of GBS

Most of the studies conducted on goal based scenario are mainly preliminary studies that focus on designing process. There is not enough research studies systematically intend to assess students' perception of GBS in detail. However, it is well known that learners' perceptions, intentions and activities are mediating factors between learning environments and learning outcomes (Elen & Lowyck, 2000). In other words, learners' perspectives and activities can influence their use of learning environment (Lowyck, Lehtinen & Elen, 2004).

Perceptions are defined as a construct 'result from actual interaction between instructional conceptions and a peculiar learning environment.' (Lowyck, Elen & Clarebout, 2005, p. 443). Considering learners perception of classroom environments as predictor variables, there has been well established consistent relationship between the nature of the classroom and learners cognitive and motivational outcome (Taylor, Fraser & Fisher, 1997). To ensure that integration of constructivist methods falls in line with the teacher and instructional designer expectation, investigating learners' perception of constructivist multimedia learning environment has become crucial issue. Assessing perceptions can give information about actual use of learning environment; hence, it should be assessed when students are exposed to instruction and then right after the instruction (Lowyck, Elen & Clarebout, 2004).

There are mainly three approaches used to investigate learners' perception of the learning environments (Dorman, 2002). The two approaches are classroom observation of explicit events and ethnographic data. Although they provide insightful data to understand learners' perception of the learning environments, the analysis procedure is time consuming. The other approach is using questionnaire surveys of actual and preferred forms for the learning environments (Dorman, 2002). They are reliable and easy to use to assess quality of the learning environments from students or teachers' perspectives. It also allows researchers or teachers to collect data from many students in a relatively short time. Therefore, many research studies have been conducted to develop instrument so as to assess the qualities of the classroom learning from students and teachers' perspectives in three decades (Fraser, 1999). Some of the questionnaires developed for science classroom are “Learning Environment Inventory (LEI), Classroom Environment Scale (CES), My Class Inventory (MCI), Science Laboratory Environment Inventory (SLEI), and Questionnaire on Teacher Interaction (QTI), What Is Happening in This Class? (WIHIC), and Constructivist Learning Environment Survey (CLES)” (Wu, Chang, Guo, 2009, p. 209). In addition, more effort is invested to developed instruments with the integration of modern technologies in education. Some examples are “Constructivist Internet-based learning environment survey improvement (CILESI)” (Lee & Tsai, 2005) and distance learning environments (Walker & Fraser, 2005).

Although many instruments were developed for this purpose, none of them were enough to describe students’ perception of their learning experiences in a constructivist-oriented learning environment by using multimedia programs. Therefore, constructivist multimedia learning environment survey (CMLES) is to provide a new, widely-applicable instrument for use in the constructivist multimedia learning environments (Maor, 2000). This questionnaire “assesses teachers’ and students’ perceptions of the learning environment when students use online multimedia programs while teachers use constructivism as a reference for their teaching.’(Moar & Fraser, 2005, p. 221). Constructivist approach is used as a reference for designing the questionnaires and it aims to get insight not only about the process of learning with the multimedia program but also the nature of the multimedia from students’ and teachers’ perspectives (Moar & Fraser, 2005).

CMLES consists of two main parts. The first part of the questionnaires consists of three subscales and aims to assess students’ perception of the process of learning with multimedia. The first subscale, negotiation, based on the Constructivist Learning Environment Survey (Taylor, Fraser & Fisher, 1997) and the other subscales, *inquiry learning and reflective thinking* based on the Computer Classroom Environment Inventory (Maor & Fraser, 1996). The other main part of the CMLES is developed to assess students’ perception on the multimedia program itself and contains three subscales which are *authenticity, complexity and challenge* (Maor &Fraser, 2005).

A careful exploration regarding to students' perceptions and preferences towards constructivist oriented the multimedia learning environments might be an important foundation to develop appropriate constructivist multimedia learning environment and then examine its effectiveness.

## 2.2. Cognitive Load Theory

Cognitive load theory (Sweller, 1988) "is concerned with the development of instructional methods that efficiently use people's limited cognitive processing capacity to stimulate their ability to apply acquired knowledge and skills to new situations (CLT; Paas, Tuovinen, Tabbers & Van Gerven, 2003, p. 63)." The major assumption behind the CLT is that individual's working memory has limited capacity (Kirschner, 2002: Paas, Tuovinen, Tabbers & Van Gerven, 2003) and the effectiveness of instructional design depends on that central constraint (Sweller, Merrienboer & Paas, 1998, Schnotz & Kürschner, 2007). Within the framework of CLT, It is already known that the amount learning takes place during instruction and the complexity of what is learned is affected by the available resources in working memory capacity (Paas, Tuovinen, Tabbers &:Van Gerven, 2003). The primary concern of cognitive load theory is to make easier the process of information in working memory (Sweller, Merrienboer & Paas, 1998). Therefore, the instructional format should not overload the working memory capacity and so allow the learners to use their limited capacity for actual learning (Bannert, 2002).

### 2.2.1 Types of Cognitive Load

Cognitive load "is generally considered a construct representing the load that performing a particular task imposes on the cognitive system. It can be conceptualized as a task-based dimension (i.e., mental load) and a learner based dimension (i.e., mental effort), both of which affect performance" (Sweller, Merrienboer & Paas, 1998, p. 266). Cognitive load is not considered as a by-product of the learning process, rather, as the prominent factor that determines the success of an instructional intervention (Paas, Tuovinen, Tabbers &Van Gerven, 2003).

Three types of cognitive load are defined in the CLT framework (Sweller, Merrienboer & Paas, 1998). These are *intrinsic cognitive load, extrinsic cognitive load and germane cognitive load*.

#### 2.2.1.1 Intrinsic Cognitive Load

*Intrinsic cognitive load* is attributed the inherit structure and complexity of the instructional materials. Formerly, it is assumed that the intrinsic cognitive load can not be directly manipulated by instructional designer (Sweller, Van Merrienboer & Paas, 1998). However, some research efforts are devoted to find out instructional manipulations that reduce intrinsic cognitive load (Gerjets, Scheiter & Catrambone, 2004: 2006; Van Merrienboer, Kirschner & Kester, 2003). For example, the isolated-interacting instructional method (Pollock, Chandler & Sweller, 2002) modular type of worked example compared to molar example (Gerjets, Scheiter & Catrambone, 2004) and simplified whole tasks (Van Merrienboer, Kirschner & Kester,2003) are the methods that can be used to reduce intrinsic load and so enhance learning. In addition to the number of the interacting elements, the intrinsic cognitive load depends learners' prior knowledge and increase in knowledge taking place during learning. The increasing expertise level can reduce this type of cognitive load (Bannert, 2002; Paas & Kester, 2006). A more recent argument is about the nature of intrinsic cognitive load. In one side, it is argued that the intrinsic cognitive load is fixed, on the other side, it is considered fixed just for "a specific learning task at a specific level of expertise"; however, it is not considered as a fixed in general (Schnotz & Kürschner, 2007, p. 479).

#### 2.2.1.2 Extraneous Cognitive Load

Extraneous cognitive load is the result of implementing "instructional techniques that require students to engage in activities that are not directed at schema acquisition" (Sweller 1994, p. 299). Extraneous cognitive load is an ineffective type of load for learning (Van Gog, Paas & Van Merrienboer, 2006; 2008) and it is the effort required by the learner to process poorly designed instruction (Kirschner, 2002; Sweller, Van Merrienboer & Paas, 1998). There are two main definitions for extraneous cognitive load in the cognitive load theory. The first one points out that the reason for this load is the instructional format which impose unnecessarily high amount of element interactivity on working memory. The other one is considered extraneous load as the result of cognitive activities which is not relevant to learning, that is, it impedes the schema acquisition and automation. Despite of difference between definitions, the latter definition has been accepted widely among researchers and it is agreed upon that extraneous cognitive load is an ineffective type of load that impede learning and it should be reduced as much as possible in instructional design process (Sweller, Van Merrienboer & Paas, 1998; Schnotz & Kürschner, 2007). Although traditional view of cognitive load theory defines extraneous cognitive load as it is ineffective load for learning, recent attempt in the theory tries to define different types of extraneous cognitive load in the instructional design process (Schnotz & Kürschner, 2007).

Early attempts in the cognitive load theory are toward finding instructional techniques to reduce the extraneous cognitive load which can be manipulated by the instructional designers. The first instructional technique is the goal free effect (Sweller, Van Merrienboer & Paas, 1998), worked example effect (Paas & Van Merrienboer, 1994; Paas, Van Gog, Van Merrienboer, 2006; Sweller, Van

Merrienboer & Paas, 1998), completion problem effect (Sweller, Van Merrienboer & Paas, 1998; Atkinson, Renkl & Merril, 2003). Besides instructional techniques developed for problem solving, cognitive load theorist also develops instructional techniques for knowledge acquisition from multiple sources of information. The most prominent are the split attention effect, modality effect (Bannert, 2002; Schnotz & Kürschner, 2007) and redundancy effect (Bannert, 2002).

#### 2.2.1.3 Germane Cognitive Load

Germane cognitive load reflects "the effort that contributes to the construction of schemas" (Sweller, Van Merrienboer & Paas, 1998, p. 259). The basic assumption behind the germane load is that the available working memory capacity resulting from low intrinsic cognitive load and low extraneous cognitive load reduced by instructional techniques, or combination of both, may be used to engage learners activities to improve the process of schema acquisition (Sweller, Van Merrienboer & Paas, 1998). Current trends in the cognitive load theory are towards finding out new ways to increase germane cognitive load through redirecting learner attention from irrelevant extraneous cognitive process to the germane process of schema construction (Bannert, 2002; Paas & Kester, 2006). One of the strategies that are known to increase the germane load induce by the animations is allow the learners to control it (Ayres & Paas, 2007). With regard to the worked example, the germane cognitive load inducing strategy is increasing variability (Paas & Van Merrienboer, 1994). As cited in Van Gog et al (2008), there are also some strategies to increase the germane load in learning processes. These are: assigning learners to self explain the rationale behind the solution step (Atkinson, Renkl, & Merrill, 2003), studying high variability of examples (Paas & Van Merrienboer, 1994) and considering prior knowledge of learners and changing knowledge level of the learners during instruction (Van Gog, Paas, & Van Merrienboer, 2006).

### 2.2.2 Measuring Cognitive Load

There are three main types of mental effort measurement techniques in the literature. These are subjective measurement, physiological measurement, and task & performance-based measurement (Sweller, Van Merrienboer & Paas, 1998). In this research, subjective measurement techniques is used as a mean of measuring mental effort because subjective rating scales has been considered as an appropriate approach to use in actual classroom settings. Therefore, the other two measurement category has been summarized briefly and subjective measurement and individual assessment techniques are under investigation in detail.

It is assumed that change in cognitive functioning can be observable through the psychological measure. (Sweller, Van Merrienboer & Paas, 1998). These measures are heart rate variability (Paas & Van Merrienboer, 1994), brain activity and eye activity. Task & performance based measurement have two subscales of measurement which are primary task measurement and secondary task. Mental effort invested on primary task was measured by the performance on secondary task. There are very limited studies (Brünken, Plass & Leutner, 2003), Chandler & Sweller, 1996) to investigate these techniques in CLT framework. The reason for that is the possible interference of secondary task on primary task. (Sweller, Van Merrienboer & Paas, 1998; Paas, Tuovinen, Tabbers & Van Gerven, 2003). To sum up, psychological measurement and task & performance measurement is used so rarely in CLT framework (for review, Paas, Tuovinen, Tabbers & Van Gerven, 2003). They are not considered as an appropriate measurement technique for this study because the current study is conducted as a part of regular classroom and the measurement techniques selected for the current study to measure the mental effort should be easily administrated in classroom settings.

Subjective techniques are based on the assumption that the learners can express their mental effort invested on a task. These techniques generally use rating scale to introspect the invested mental effort. Subjective rating scale measurement (Paas & Van Merriënboer, 1993) is the most frequently used measurement technique in the CLT literature (for review, Paas et al., 2003). It is considered as the "most promising technique for research in the context of cognitive load" (Sweller et al., 1998, p. 268). In addition, the subjective rating scales are "sensitive to relatively small differences in cognitive load and they are valid, reliable and unintrusive" (Paas et al, 2003, p. 66). Students can express their mental effort with 9-point mental effort rating scale ranging from 1 (very, very low mental effort) to 9 (very, very high mental effort). The validity and reliability of this scale was tested in Turkish context by Kilic and Karadeniz (2004).

#### 2.2.2.1 Current Approach in Measuring Cognitive Load

Current approaches in measuring cognitive load can be investigated in two different aspects. On one hand, researchers try to find out new techniques to measure cognitive load, on the other hand, more effort is invested to find out new ways to measure different types of cognitive load with subjective rating scales.

Subjective time estimation, neuroimaging techniques, and functional magnetic resonance techniques has been considered as new techniques for measuring cognitive load (Paas et al., 2003). More recently, new techniques like speech analysis (Yin & Chen, 2007) and cognitive load measurement model have been suggested to measure the cognitive load (Yousoof, Sapiyan & Kamaluddin, 2007). In the former approach, it is claimed that psychological measurement, subjective rating scale and performance based measurement are not appropriate techniques because of a wide range of reasons. However, the behavioral approach like linguistic index and speech based measurement has been considered as a possible solution to overcome shortcomings of the earlier measurement techniques. It is claimed that measuring speech is relatively easy and low cost and non-intrusive by offering an automatic speech based measuring system (Yin & Chen, 2007). On the other hand, the latter approach provides a framework to measure cognitive load into three phases in order to modify learning materials not to overload working memory capacity (Yousoof, Sapiyan & Kamaluddin, 2007). Although these techniques are too intrusive to be used in instructional research, they will provide valuable inside to improve measurement issues in the cognitive load theory.

Particularly, I want to focus on studies that try to measure different types of cognitive load with subjective rating scale. Although subjective rating scale has been used to measure mental effort as general effort, recently many researchers have used this technique to measure different type of cognitive load which are intrinsic, extrinsic and germane cognitive load. The primary attempt is toward measuring intrinsic cognitive load. In Ayres (2001) study, he emphasized that it is possible to measure the intrinsic cognitive load by dual task paradigm. In following studies, Ayres (2006a; 2006b) he found that keeping germane cognitive load and extraneous cognitive load constant, subjective rating scale is a suitable and highly reliable technique to measure intrinsic cognitive load in math domains. In example based learning environment, the subjective rating scale modified based on NASA-TLX developed by Hart and Staveland (1988) was used to measure intrinsic, extrinsic and germane cognitive load (Gerjets, Scheiter & Catrambone, 2004).

In a more recent study, the authors address specific questions indented to measure intrinsic, extrinsic and germane cognitive load are as follows: the question 'how hard the participant had to work to understand the contents of the learning environment' has been consider to measure germane cognitive load, 'how much mental and physical activity was required to accomplish the learning task, e.g., thinking, deciding, calculating, remembering, looking, searching etc.' has been asserted to measure intrinsic cognitive load and 'how much effort the participant had to invest to navigate the learning environment' has been accepted as a way of measuring extrinsic cognitive load in a wide variety of learning environment (Cierniak , Scheiter & Gerjets , 2009).

Although the reviewed studies used the same approach to measure different types of cognitive load so far, the different types of cognitive load were assessed with six items scale, that is, one item for intrinsic, three items for extraneous, one item for germane cognitive load and one item for overall load with 9 point likert scale (Opfermann, Gerjets & Scheiter, 2006). More recently, the five items scale, one for intrinsic, three for extraneous and one for germane cognitive load has been used in CLT framework (Gerjets, Scheiter, Opfermann, Hesse & Eysink, 2009)

Although recently much more effort is invested in measuring different types of cognitive load with subjective rating scale by claiming that developed instruments has enough capabilities to distinguish different types of cognitive load, some researchers pointed out that these researches have some doubts and should be taken into account carefully (Schnotz & Kürschner,2007; Van Gog & Paas, 2008). However, it can be said that the cognitive load theory suffers from measurement scale that distinguish different types of cognitive load and this effort invested by a group of German researcher to measure them separately are timely and necessary to advance the theory.

### 2.2.3 Instructional Efficiency

The efficiency of instructional condition computed with test performance and invested mental effort to attain this performance was introduced by Paas and Van Marrienboer (1993). The authors assume that rather than the comparing performance on a task or test, it is important to evaluate invested mental effort to attain this performance. By doing so, the researchers or instructional designers are able to compare the efficiency of instructional conditions. For example, two instructional conditions may result in same performance scores; however, the invested mental effort to attain the performance score for the first condition might be less than the other conditions. Therefore, it is assumed that measuring transfer performance gives information about the effectiveness of instructional condition;

however, combining performance with mental effort can provide information about the efficiency of instructional condition (Paas & Van Marrienboer, 1993).

Instructional efficiency measure is used to calculate the efficiency of instructional conditions (Paas & Van Marrienboer, 1993). The procedure starts with transforming learning outcome (performance) and invested mental effort to attain performance for each participant into z-score. Then, the mean z-score for every condition are presented in Cartesian coordinate system with mental effort z-scores on the horizontal axis and learning outcomes z-score on the vertical axis (Paas & Van Marrienboer, 1993). Although the original construct for instructional efficiency conceptualized as presented above, it is revealed that many researchers use an adapted version of this efficiency measure (Van Gog & Paas, 2008). Among 37 studies used instructional efficiency measure since 1993, it is found that 33 studies used the adapted version of instructional efficiency measure. The original instructional efficiency measure tries to find out the learning outcome as a combination of performance and invested mental effort to attain the performance, the adapted measure tries to represent the instructional efficiency in terms of the learning process in that the invested mental effort in instruction and test performance after instruction has been combined in equation for instructional efficiency. Adaptive instructional efficiency measure has been conducted in two ways. Mental effort invested in learning phase combined with performance in learning (Corbalan, Kester & Van Merriënboer, 2006; Salden, Paas, Broers, & Van Merriënboer, 2004; Salden, Paas, & Van Merriënboer, 2006) and the mental effort combined with test score to calculate the instructional efficiency (Tindall-Ford, Chandler & Sweller, 1997; Van Merriënboer, Schuurman, De Croock & Paas, 2002).

Van Gog and Paas (2008) point out that using adaptive measure of instructional efficiency might show interesting result if the aim of the study is to manage the extraneous cognitive load in instruction. However, it is assumed that using adaptive measure for studies aims to increase germane cognitive load is misleading. That is, germane cognitive load is an effective type of mental load so it is assumed that it should be higher during the instruction. This invested mental effort during instruction might help students to get higher test score by reducing invested mental effort during test to attain this performance. Therefore, the original equation for instructional efficiency should be used for studies intend to manage germane load. The Equation 2.1 has been used for measuring instructional efficiency:

$$\text{Efficiency} = \frac{zP_{\text{test}} - zE_{\text{learning}}}{\sqrt{2}}. \qquad (2.1)$$

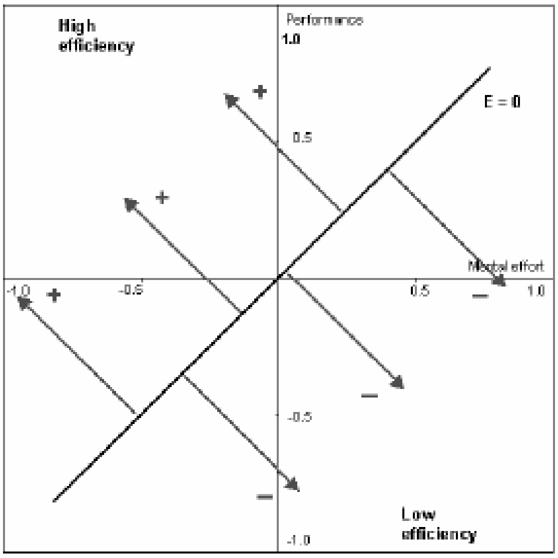



**Figure 2.1** Instructional Efficiency for learning process

## 2.3. Managing Extraneous Cognitive Load in Multimedia Learning Environment

This part includes review of many studies aiming at managing extraneous cognitive load in the multimedia learning environments. Review of each principles or effects has been given separately. Principles and effects are used interchangeably.

***Multimedia*** principle refers to any presentation that contains printed or spoken text and static or dynamic illustrations. It has been assumed that learners can learn better with words and pictures together than words alone (Clark & Mayer, 2003; Mayer &Moreno, 2002). ***Modality*** refers to placing material into spoken forms of words rather than printed word whenever the graphic and/or animation is the focus of the words and both are given simultaneously (Clark & Mayer, 2003; Mayer & Moreno, 2002; Sweller et al., 1998). ***Redundancy*** refers to presenting words in both text and audio narration which was found that affect learning negatively so it is a major effect that should be considered because of its negative consequences on instructional design (Sweller et al., 1998). ***Spilt attention*** refers to presenting words and pictures separately. Learners must use their limited cognitive resource to use mentally organize and integrate the materials when they are separated from each other on the screen. On the contrary, if they are integrated, learners can combine them in their working memory and make meaningful connection between them. (Clark & Mayer, 2003; Mayer &Moreno: 2002; Sweller et al., 1998). ***Coherence*** refers to presenting irrelevant sound, picture and graphics which can hurt learning. In line with the coherence principle, extraneous picture and word should be eliminated (Clark & Mayer, 2003; Mayer & Moreno, 2002). **S*ignaling*** refers to adding non content information, visually or auditory, to the content in order to focus attention to those aspects which is important while watching dynamic display (Sweller et al., 1998).

### 2.3.1 Research Studies on CLT

According to the cognitive theory of multimedia learning, incorporating relevant graphics to words is a powerful way to help learners engage in active learning. Many research studies have been conducted to find out the effects of the ***multimedia principle*** by using printed or spoken text and static or dynamic illustrations together compared to printed or spoken text only condition (Moreno & Valdez, 2005;Mayer & Anderson, 1991; Mayer & Anderson, 1992). Moreno and

Valdez (2005) found that students learn best when words and pictures presented together and higher performance was achieved with relatively lower cognitive load. For dynamic illustration, it is also found that learning took place deeply when animation and narration was presented than narration only condition (Mayer & Anderson, 1991, Experiment 2a; Mayer & Anderson, 1992, Experiments 1 and 2).

Cognitive theory assumed that giving concurrent graphics and onscreen text requires learners to process all information in visual channels. Therefore, this can result in overload in visual channel. In order to decrease the overload in visual channel, the information should be separated into two formats and then text should be narrated so that it can be processed by verbal channel (Clark & Mayer, 2003; Mayer & Moreno, 2002; Sweller et al, 1998). Many research studies has showed that applying the ***modality*** principle in multimedia learning environment result in better learning outcome (Jeung, Chandler & Sweller, 1997; Mayer & Moreno, 1998; Moreno & Mayer, 1999; Mousavi, Low & Sweller, 1995; Tindall-Ford, Kalyuga, Chandler & Sweller, 1997). The similarities between those studies are that the subject studied was technical such as mechanics, geometry, electric circuits and the learning materials were system paced. Contrary to these findings, when the ***modality*** effect was implemented in classroom environment, the superiority of the ***modality*** effect could not be found (Tabbers, Martens & Van Marrienboer, 2004). The authors explained this unexpected result with regard to difference between subjects matter and pace of the instruction compared to previous research in that the learning materials was developed based on instructional design and it was self paced. Consistent with the Tabbers et al (2004), Burkes (2007) found that the ***modality*** even have negative effect in online learning environment as a result of lengthy audio narrative track that students need to hold in working memory.

The findings of meta-analysis about the ***modality*** effect on achievement conducted by Ginns (2005) indicated moderate to large average effect for more complex, system-paced instructional materials, but smaller average effects for self-paced or less complex instructional materials. Recently, the research conducted by

Harskamp, Mayer and Shru (2007) tries to find out the contradicting findings on the ***modality*** effect in multimedia learning environments for regular classroom settings. Contrary to Tabbers et al (2004) studies, they found significant difference in favor of the ***modality*** effect in self paced multimedia for transfer test but not for retention test. However, the authors pointed out that learning time was an important factor that should be taken into account and they found that fast learners benefit significantly more from animation and narration condition than animation and text condition for transfer test. In a recent study, the possible impact of the ***modality*** principles has been studied for lifelong learning (Van Gerven, Paas, Van Marrienboer & Schmidt, 2006). The participants of this study consist of old and young people. It is found that both young and old participants invest less mental effort in bimodal condition. Moreover, Kablan & Erden (2008) found that using the ***modality*** principle has also yield significantly low mental effort, high performance and instructional efficiency in science context.

With regard to the ***redundancy***, using only animation and narration couldn't overload the visual channel in that animation will be processed through visual channel and narration will be processed with verbal channel. However, using both animation, narration and on-screen text can overload visual channel of working memory. It is assumed that learners will learn more deeply from presentation in which redundant on-screen text is excluded rather than included. On the other hand, using dual modes of presentation can be helpful when the spoken material may be hard to process, or if seeing and hearing the words contribute learning (Clark & Mayer, 2003).

This ***redundancy*** effect has been demonstrated in a number of previous studies using diagram-and-text instructional presentations (Kalyuga, Chandler & Sweller, 1999; Sweller & Chandler, 1994). The effects of the ***redundancy*** have been studied in animation condition also (Moreno & Mayer, 2002.; Kalyuga, Chandler & Sweller, 1999). Kalyuga, Chandler and Sweller (1999) found that auditory presentation of text found to be superior compared to visual only condition but not when text presented both auditory and visual forms (Experiment1). It is concluded that the redundant use of visual form imposes high cognitive load and hampers learning. In another study, Kalyuga, Chandler and Sweller (2004) tried to find out different methods to benefit from redundant information in technical instruction. It is assumed that presenting information twice might be beneficial under some certain condition. They compare concurrent and nonconcurrent occurrence of the same information into different forms. The result were somewhat mixed, however, when the instructional time keep constant (Experiment 2), it is found that nonconcurrent presentation of information yield significantly better learning outcome and lower mental effort than concurrent presentation. In Moreno and Mayer (2002) study, the same result for the ***redundancy*** was found for simultaneous and successive presentation of the same information. Therefore, it can be concluded that redundant information can be used for some condition in non concurrent or successive way.

In a more recent study investigating the ***redundancy***, the effect of presentation of redundant information (sequential or static) in multimedia instruction has been investigated (Jamet & Bohec, 2006). The result of this recent study shows that regardless of type of presentation, duplication of information in written form result in impairment in transfer and retention test. This contribute the fact that visual channel is overloaded when redundant written text presented especially when students don’t have control over the presentation

With regard to the ***split attention***, it is assumed that integrated information can decrease extraneous cognitive load that material impose on students (Ayres & Sweller, 2005). The ***split attention*** principle differs from ***modality*** in such a way that text should be integrated in terms of proximity for ***split attention***, on the other hand, ***modality*** principle proposed to give text in audio format.

The ***split attention*** effect has been found in a number of previous studies using integrated material (Tarmizi & Sweller, 1998; Sweller, Chandler, Tiermey & Cooper, 1990; Chandler & Sweller, 1991; Moreno & Mayer, 1999, Kester, Kirschner & Van Marrienboer, 2005). In those studies, it is found that integrated instruction can reduce extraneous cognitive load by minimizing effort to search relevant part and allow the students to invest their mental effort in actual learning. As a result, the participants getting integrated information outperformed than the participants in separated condition. Kalyuga, Chandler and Sweller (1999) and Mayer and Moreno (1998) proposed to use different modality or color coding (Kalyuga et al., 1999) to decrease extraneous load results from the ***split attention***. The result of meta analysis on the ***split attention*** (temporal and spatial) shows that integrated version of learning material can decrease extraneous cognitive load and result in better learning outcome (Ginns, 2006).

In a recent study, Pociask and Morssion (2008) try to find out the effect of the ***redundancy*** and the ***split attention*** in ecologically valid learning environment. They found that the revised material based on the ***split attention*** and the ***redundancy*** yield better learning outcome and less mental effort. Therefore, the ***split attention*** and the ***redundancy*** effect can be seen as effective design approach in natural learning environments.

According to the arousal theory, entertaining and interesting embedded effects cause learners to become more emotionally aroused and therefore they work harder to learn the material. Arousal theory predicts that the students will learn more from multimedia presentation that contain interesting sounds and music than from multimedia presentation without interesting sound and music. On the contrary, the cognitive theory is against using irrelevant music in multimedia because of limited capacity of working memory. Arousal theory also predicts that adding interesting but extraneous picture will promote better learning. On the other hand, cognitive theory assumed that because of limited capacity of working memory learner can have difficulty in making sense of the material (Clark & Mayer, 2003: Mayer & Moreno, 2002)

Moreno and Mayer (2000) conducted two experiments to find out the effects of the ***coherence*** principle in multimedia learning environment. In two studies, it is found that students received sound and music in addition to animation and concurrent narration performed worse than animation and narration group. Group receiving sound performed worse in second experiment. The authors concluded that adding irrelevant sound can overload the learner’s auditory working memory.

Up to know, the effect of the ***coherence*** principle has been studied in multimedia learning environment which is 2D learning environment. On the other hand, the use of these principles in 3D game learning environment has became popular among researchers. Nelson and Erlandson (2008) present some scenarios on how to apply most well known principle in learning environments. The big concerns for 3D game based learning environment about the ***coherence*** principle is that situated learning environment and the nature of multi user of virtual learning environment includes many objects that aims to take students attention and provide them a realistic environments. Therefore, using the ***coherence*** principle contradicts the underlying principles of 3D game environment. This area of research needs to further investigation.

The ***signaling*** effect has been widely studied among researchers and it is accepted as an effective approach to reduce visual search in multimedia learning environment (Mayer, Dyck & Cook, 1984; Mautone & Mayer, 2001; Kalyuga, Chandler & Sweller, 1999; Tabbers, Martens & Van Marrienboer, 2004; De Koning, Tabbers, Remy, Rikers & Paas, 2007).

Mayer et al (1984) found out that ***signaling*** causal elements in a scientific passage enhanced mental model building. With the advancement of instructional technology, Mautone and Mayer (2001) try to find out the effects of the ***signaling*** in animation but they did not found a significant effect in favor of the ***signaling***. On the other hand, De Koning et al (2007) found that cueing did not only increase retention and transfer for cued information but also uncued information. Kalyuga et al (1999) showed that color coding decrease the amount of cognitive load by reducing visual search. However, the same result could not be found for mental effort in other studies (De Koning, et al, 2007; Tabbers et al, 2004).

To sum up, the purpose of all principles explained above aims to enhance learning by minimizing extraneous cognitive load in multimedia learning environment. Although the research findings are mixed, the use of these well established research findings should be tested in ecological valid settings. It can also be concluded from reviewed studies that information and learners characteristics (Paas & Kester, 2006) should be well investigated. In addition, rather than only measuring learning outcome, the researcher should be able to have a closer look at learning process that students involve in different learning conditions. The main purpose of this study is to combine these principles in the multimedia learning environments and to investigate them in ecological valid learning environments by taking into account learners' characteristics.

### 2.4. Individual Difference and Cognitive Load

Cognitive load theory and cognitive multimedia learning theory base their assumption on learners' limited working memory capacity and unlimited long term memory (Sweller et al., 1998; Mayer, 2001). The cognitive theories propose some design guidelines to eliminate the ineffective load imposed on working memory so that learners can use their working memory capacity for actual learning. In CLT framework, it is pointed out that the learners and information characteristics are important factors that need to be taken into account in designing learning environments (Paas &Kester, 2006). There are plenty of research shows that the learner' prior knowledge is an important issue which benefits or undercut learning outcome from different types of instructional conditions (Kalyuga 2005; Kalyuga, 2006; Kalyuga, Ayres, Chandler & Sweller, 2003). The effects of prior knowledge in the cognitive load theory is explained as an expertise reversal effect (Kalyuga et al., 2003) which means that low and high prior knowledge students benefit differently from same instructional conditions due to domain knowledge. In other words, high prior knowledge students have a schema in their long term memory and when they face with the already known content they can retrieve it into working memory as a single unit and so they do not invest high mental effort to understand the content. On the other hand, the low prior knowledge students don't have already constructed schemas in their long term memory. When they learn new content, each concept of it is processed separately and so they invest high mental effort to learn the content. Since the cognitive load theory and cognitive theory of multimedia learning base their assumption on limited working memory capacity, it would be important to investigate the individual difference in terms of working memory capacity for different instructional conditions.

The cognitive load theory and the cognitive theory of multimedia theory base their assumption on working memory model proposed by Baddeley and Hitch (1974). According to this model, working memory "refers to a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive task as language comprehension, learning and reasoning" (Baddeley, 1992, p. 256). Working memory consist of three subcomponents which are *central executive, phonological loop and visuospatial sketchpad.* Phonological loop which maintain and rehearse speech based information and visuospatial sketch manipulates visual images are two slave system of working memory (Baddeley, 1992). On the other hand, central executive which is most crucial component of working memory is responsible for coordinating information from two-slave system and manipulation of information for higher order cognitive skills. Recently, a new sub component which is *episodic buffer* has been proposed for working memory. Episodic buffer is a multidimensional code from long term memory and phonological loop and visual spatial sketchpad and it is a temporary point between the long term memory and the two slave systems. It is also responsible for keeping information into coherent episodes (Baddeley, 2000).

Since the function of this system are related to the higher order cognitive skills like reading and comprehension while keeping information in a short period, the variation of individual on working memory should be consistent with the performance on cognitive tasks (Unsworth & Engle, 2007).

### 2.4.1 Resarch Studies on WMC

Many studies have been conducted to find out individual ***working memory capacity and its relation to cognitive tasks.*** Daneman and Carpenter (1980) created a reading span task and try to find out the effects of working memory capacity or span in text comprehension. They found that ***high working span*** were better for comprehension in misleading text and better to draw inferences from the text. In an another study, the researchers used operation word span task and divided participants into ***low and high working memory capacity***. They found that ***low span*** students made fewer judgments than ***high span*** participants in the counterfactual scenarios under a secondary cognitive load. The authors inferred that ***high working memory capacity*** students were able to suppress irrelevant thought when making decision (Goldinger, Kleider, Azuma & Beike, 2003).

Most research in the cognitive theories focus on dual task paradigm to investigate the effects of ***two slave systems of working memory and cognitive load*** in multimedia learning. The effects of ***visual span*** and ***cognitive load*** (Pujari, 2007) in multimedia learning have been studied on learning outcome (Mayer & Sims, 1994; Gyselinck, Cornaldi, Dubois, De Beni & Ehrlich, 2002; Pujari, 2007)

Mayer and Sims (1994) compared the effects of contiguity (split attention) principle for the ***low and high spatial ability*** students which determined by mental rotation and paper folding test in learning from animations. In experiment 1, they found that the ***high spatial*** students performed better in learning from concurrent (animation and narration) format than successive (animation followed by narration) and control condition (narration followed by animation). However, there was no significant difference between these conditions for the ***low ability*** students. The authors explained this result ability as enhancer assumption in that it is assumed that ***high spatial*** students can devote more resources to learn from concurrent condition than to devote other two conditions. However, the ***low ability*** students devote more effort to develop visual representation of concurrent condition so they have fewer cognitive resources for mental construction. In second experiment, it is also found that the ***high spatial ability*** students benefit more from concurrent format. As a conclusion, both the ***high and the low ability*** students benefit from the split attention principle.

Gyselinck et al (2002) conducted two experiments to find out the effects of both ***phonological loop and visuospatial memory*** in multimedia learning environments. The participants' ***verbal span*** was measured by digit span task and ***spatial span*** was measured by Corsi block test. In Experiment 1, they found that concurrent tapping task impaired comprehension in text plus illustration group but not text only format. However, no significant difference was found for the ***low spatial*** group in two conditions. In experiment 2, it is found that articulatory task impaired text only condition but not illustration only condition for ***high verbal span*** group, however, no significant difference was found for ***low verbal span*** students. Unfortunately, the two studies did not measure the learners' ***cognitive load*** during experiment so that inferences can be drawn from the relationship between different ***types of span*** and ***mental effort***.

In a more recent study, relationship between ***visual span, mental effort*** and different instructional format has been investigated (Pujari, 2007). The authors divide participants based on their ***visual span*** determined by Corsi block test and to investigate this individual difference in regard to leaning from animation plus text and static pictures plus text. It is found that the ***high span*** participants performed better into both condition compared to the ***low span*** participants and invest less ***mental effort.***

Although the central assumptions of cognitive theories are based on working memory, there is not enough research to look at the effects of ***working memory capacity and its relation to cognitive load*** in multimedia learning environments. The effects of working memory capacity might be much more important than before since the cognitive theories recently try to find out new instructional formats that impose germane cognitive load which is related to the construction of meaningful schemas.

The effect of ***working memory capacity*** has been investigated by cognitive load researchers especially for ***elderly people*** (Van Gerven, Paas, Van Marrienboer & Schmidt, 2000; Van Gerven, Paas, Van Marrienboer, Hendrick & Schmidt, 2003; Van Gerven, Paas, Van Marrienboer & Schmidt, 2006). Van Gerven et al (2000) propose some instructional formats that aim to help elderly people because of decline in their ***working memory capacity***, decrease in processing speed and reduced ability to distinguish between relevant and irrelevant information. For follow up studies, authors try to found out the effects of different instructional format for different age group in terms of ***working memory capacity*** measured by computation span task. It is found that both age groups benefit most from bimodal condition of instructional format and invested less ***mental effort***, particularly; ***elderly*** participants benefit more from bimodal condition (Van Gerven et al., 2003). On the contrary, in more recent study, there is no significant difference between modality and variability of worked example for ***elderly*** participants and they invested less mental effort in both conditions (Van Gerven et al., 2006).

As presented above, the effects of working memory capacity has been studied in CLT framework for elderly and young people. On the other hand, the visual and verbal span of the participants has been for relatively the same age groups. The question raised from review of literature is ***two folds***. At first, all studies conducted in laboratory settings and in relatively short experiments. Then, the two slave systems of working memory capacity are responsible for storage of information and they are studied widely among the researchers; however, central executive is responsible for coordinating and maintaining information. To address ***the first issue***, the present study conducted in an ecologically valid environment and relatively long duration of education. Instructional materials prepared for this study is a type of investigate and decide learning environment which is developed on goal based scenario.

To address ***the second issue***, the participants working memory capacity has been measured as an individual difference rather than visual and verbal span. In an earlier study, patients with Alzheimer, elderly and young people were compared for doing two tasks concurrently in that one for visual and one for verbal. It is found that normal elderly subjects were no impaired more than young people; however, the patients were impaired much in both memory and tracking task when they need to combine them. As expected, the patients' performance on combined task was defeated because of central executive deficit (Baddeley, 1992). The similar result was found in later study (Logie, Gocchini, Salla & Baddeley, 2004). Although it is extreme example because the patients have markedly impairment in central executive function, it still provides information about the function of central executive. Since the goal based scenario multimedia program provides both visual and verbal information and it requires students to perform complex cognitive task by combining and maintaining incoming verbal and visual information in a relatively long period of time, rather than visual and verbal span, working memory span taken into account for this study. That is, working memory capacity is the measurement of central executive (Unsworth, Heitz, Schrock & Engle, 2005) and it is known that the function of central executive is coordinating two slave systems and maintaining information; hence, to investigate working memory capacity for same age group in terms of individual difference for such a complex learning environment assumed to be much more appropriate for present study.

## 2.5. Summary of Literature Review

This chapter provides review of literature related to research problem of this study. Goal based scenario as an instructional method were presented in detail. Research studies conducting on GBS were reviewed under two subsections which are the studies conducted on designing process and presented empirical research findings. Then, research studies that include assessment of students' perception in constructivist multimedia learning environment were reviewed. Then, the cognitive load theory was reviewed in detail. Types of cognitive load, measurement issues in cognitive load and current approach in measuring cognitive load were reviewed. Afterwards, instructional efficiency which gives information about the relationship between performance, mental effort and efficiency was presented.

Several instructional formats used to manage extraneous cognitive load in multimedia learning environment were defined and related literature was reviewed. At last, the research studies that tried to reveal the relationship between individual difference as a working memory capacity and cognitive load were stated.

# CHAPTER 3

# METHOD

This chapter describes the methodology that was used to conduct the study. It is divided into following subsections: (3.1) research problem and research questions; (3.2) overall design of the study; (3.3) context and subject; (3.4) instrumentation; (3.5) data collection procedure; (3.6) data analysis; and (3.7) assumptions and limitations of the study.

## 3.1 Research Problem and Research Questions

This study was designed to investigate the effects of instructional formats that reduce extraneous cognitive load in learning from the goal based scenario designed multimedia learning environment for the learners having different working memory capacity. The purposes of this study were two folds. Firstly, this study aims to investigate the effects of principles applied in the GBS centered multimedia learning environments for the learners having different working memory capacity. Two versions of the multimedia were developed for this study. In design of the first version, the principles such as split attention, multimedia, modality, redundancy, coherence and signaling was applied. In the design of the second version, the principles were violated. Secondly, the effects of goal based scenario and the principles on students' perception, motivation and satisfaction has been investigated. Therefore the study deals with both learning process and learning outcome in the GBS multimedia learning environments. In accordance with the research purposes, the following research questions guided the current study:

**1.** To what extent cognitive load could explain the possible difference on learning outcome from goal based scenario designed multimedia for the learners with different working memory capacity.

   **1.1** Is there a significant difference between GBSc3DM+CLT and GBSc3DM-CLT on learning outcome?

   **1.2** Is there a significant difference between high WMC, medium WMC and low WMC learners on learning outcomes from GBSc3DM-CLT?

   **1.3** Is there a significant difference between high WMC, medium WMC and low WMC learners on learning outcomes from GBSc3DM+CLT?

   **1.4** Is there an interaction effect between learners' working memory capacity and two version of GBSc3DM on learning outcome?

**2.** What are the students' opinions about the cognitive load principles in GBS?

   **2.1** How does cognitive load in GBSc3DM affect student motivation?

   **2.2** How does cognitive load in GBSc3DM affect student satisfaction?

**3.** What are the students' perceptions towards goal based scenario designed multimedia?

## 3.2 Design of the Study

Mixed methods research was used to find out the answers of research questions for this study. Mixed methods allow researchers to address much more comprehensive research purposes than qualitative and quantitative research provides separately (Newman, Ridenour, Newman, & DeMarco, 2003). In addition, mixed method provides opportunities for researchers to grasp the best of quantitative and qualitative research methods. Since the purpose of this study was not only to investigate the effects of intervention on learning outcome but also to understand the leaning process in detail, the researcher decided to use mixed method as an appropriate research design for the current study.

Mixed method design has been used for five general purposes and every mixed methods design covers one or more of these five purposes. These are: (a) triangulation; (b) complementarily; (c) development; (d) initiation and (e) expansion (Greene, Caracelli & Graham, 1989). The purpose of the present study was complementarily in that quantitative method elaborated and enhanced with results from the qualitative method by considering complementary strengths and non overlapping weakness of these methods (Creswell & Plano-Clark, 2007; Johnson & Turner, 2003).

One of the important issues that need to be addressed for the value of mixed methods is the enhancement of interpretation of significance. Four types of significance, statistical significance, practical significance, clinical significance and economic significance are stated in quantitative research (Onwuegbuzie & Leech, 2004). On the other hand, a significant finding is “one that has meaning or representation” for qualitative research (Onwuegbuzie & Leech, 2004, p. 774). Schwandt (2001), in the Dictionary of Qualitative Inquiry, contends that “the significance of the action cannot be adequately explained in terms of a behaviorist stimulus-response model” (p. 153).

There are many problems identified for the interpretation of quantitative significance. For example, it is stated that researchers do not understand or misinterpret what information can be found through statistical significance testing. On the other hand, qualitative research finding is affected by researcher bias, observer effect and writing up (Onwuegbuzie & Leech, 2004).

A framework is proposed to enhance the interpretation of significant findings. It is assumed that collection, analysis and interpretation of quantitative data aids to interpretation of quantitative significance. In the same way, the quantitative data collection, analysis and interpretation is assumed to enhance the interpretation of meaning. Moreover, concurrent, sequential and parallel mixed analysis can also shed light on the interpretation of both quantitative and qualitative significance. For this research, parallel mixed analysis is used. Parallel mixed analysis should meet three criteria. These are “(a) both sets of data analyses (i.e., quantitative and qualitative data analyses) should occur separately, (b) neither type of analysis builds on the other during the data analysis stage, and (c) the results from each type of analysis are neither compared nor consolidated until *both* sets of data analyses have been completed” (Onwuegbuzie & Leech, 2004, p. 779).

For the present study, both qualitative data and quantitative data were collected separately in such a way that qualitative data were collected through reflective journals and interviews and quantitative data were collected through test, forms and log files separately. Secondly, the key informants were selected from interview based on reflective journal analysis and quantitative data were exposed to statistical analysis. Lastly, each data set analyzed separately and conclusion drawn from on both data set.

For the qualitative part of the study, multiple case embedded designs were used since the data collected from different participants in using different version of the multimedia program. There are five types of qualitative study: biography, phenomenology, grounded theory, ethnography, and case study (Denzin & Lincoln, 2005). Case study “seeks to engage in and report the complexity of social activity in order to represent the meanings that individual social actors bring to those settings and manufacture them” (Stark & Torrnce, 2005, p. 33). One of the important issues that need to be taken into consideration is the boundaries of case studies. The researcher should be careful not only the action under investigation but also social and historical context of the action (Stark & Torrnce, 2005). In this study, researcher tried to understand how principles effect the motivation and satisfaction and perception of toward GBS centered educational multimedia throughout the study. The actors were bounded with high school students, setting was computer laboratory and activities were bounded by their use of different verion of the multimedia program.

For the quantitative part of the study two design approaches were implemented. For the first study, quasi experimental design was used. Because of the study took place in natural setting, it was not convenient to randomly assign each student to condition, rather, the participants assigned to conditions as a group. The independent variable was the two versions of the multimedia and dependent variables were log files, achievement test as a pre-test and post-test and mental effort. Pre-test result was analyzed across independent variable and took into consideration as a covariance when there was significant difference.

In the first study, participants' working memory capacity was found very close to each other; in this case, it was not possible to assign the participants as having high, medium and low WMC to the two versions of multimedia. Therefore, the second study was conducted with a new group of participants having different working memory capacity. For the second study, 2 x 3 factorial design was used. Factorial design allows researcher to extend the number of relationship examined in n experimental study. In addition, it allows finding out interaction effect between an independent and moderator variable (Fraenkel & Wallen, 2000). The independent variables were two versions of multimedia (The first (+CLT) and the second version (+CLT) of GBSc3DM) X Working Memory Capacity (high WMC, medium WMC and low WMC). The dependent variables were log files, achievement test as a pre-test and post-test and mental effort. Pre-test result was analyzed across independent variables and took into consideration as a covariance when there was a significant difference. Each student from different WMC were assigned to each version of multimedia randomly.

## 3.3 Context and Participants

### 3.3.1 Goal Based Scenario Designed Multimedia Learning Environment

It is indicated in the literature that high school students have difficulty in learning and have misconceptions of mitosis and meiosis subjects in Biology (Atilboz, 2004; Bahar, Johnstone & Hansell, 1999; Tekkaya, Ozkan & Sungur, 2001). Informal interview with biology teachers for the current study also revealed that students have difficulty in learning cell division process. Therefore, mitosis and meiosis topics were selected as a content of GBSc3DM. While developing the GBSc3DM, participatory and user-centered design (Corry, Frick & Hansen, 1997) approaches were used. With regard to the participatory design, researcher conducted interviews with five high school students different from the participants of this study and explained them the scenarios developed for multimedia. In order to involve high school students' preferences in the multimedia design, drawings about learning environments and the related elements such as characters and viruses viruses were collected and used during the development of the multimedia by design/development team. In the design and development of the multimedia, series of formative evaluation were conducted with the students. Based on the feedback gathered from the formative evaluation process, some revisions were made in the design. For example, the animation for mitosis and meiosis was shown to the students. The researcher wanted them to explain the process during the animation. Students explained whole process took place in animation and want researcher to change the color of some items in animation so that they can be understood easily. Therefore, the colors of items in animation was changed based on students' preferences.

The design/development team consisted of one subject area teacher, two instructional designers, one graphic designer and one programmer. Subject area teacher having MS in Biology was from one of the high schools of Ankara. She has

10 years experience of teaching and she has been working in a school which implements the constructivist curriculum for one year. In addition, she has a three year experience in editing high school biology books in the Ministry of Education in Turkey. One of the instructional designers has a PhD degree at computer education and instructional technology department (CEIT) at METU. The instructional designer has lots of experiences in developing educational multimedia learning environments. In addition, she has been giving courses on developing educational software. The other instructional designer is a PhD student at CEIT and she has lots of experiences in developing multimedia. Graphic designer was involved in many educational software development projects for government and private company. Programmer has also lots of experiences in developing game based learning environments.

The instructional material, GBSc3DM, was developed as a game based learning environment. A motivational mission was given to the participants. The goal was to restart the mitosis and meiosis process which did not take place because of viruses' attacks to cells. Participant starts the game by selecting a character. After that, they can watch cover story. The cover story was designed as if it occurs in the year of 2090 for mitosis. It is stated that because of rapid industrialization and urbanization, industrial and household wastes, uncontrolled progress of technological developments and the effects of global warming, the world has come to an unbelievable state. At this point, living things can not complete their growth and development. In terms of height and weight, humans look like 5 year old children and their hair and nails do not grow, the wounded areas of their bodies do not heal and damaged tissues do not repair themselves. It can be observed that dead cells are not replaced with new ones. Due to plants not being able to complete their growth and development in the same manner, mankind is face to face with starvation. This unfavorable state in the development of plants threatens all living things and the world.

To solve the problem, it is stated that scientists from all nations came together to find out the reason. They found that the solution of the problem have commenced from the cell, which is the basic unit of living things and studies have been performed on cells in damaged and worn cells which do not renew themselves. As a result of these studies, it is found that mitosis which is necessary for growth and ensures the formation of new cells, substituting old cells found in all humans and constitutes the foundation of life no longer occurs. After identifying the problem, the reason why scientists need the participants to solve the problem was explained. For example, a task statement ‘Your duty is to join these scientists and solve the problem in the cells and ensure that the balance in the world is re-established and ensure that human, plants, animals and the world return to the way they used to be’ was given to students. Then, the participant is warned about difficulties resulting from viruses attack. At last, scientist beam the participant to a robot which progress at light speed and then send the participants to the body of the child with sores.

Although the mission was motivational, the events occurred in scenario were developed based on the scientific fact. By watching cover story, the participants know the importance of mitosis process for human beings and what will happen if it does not take place. Since all process takes place in *“cells’*, a small 3D game was designed to provide opportunities for students to be familiar with cell environments for the first week. Time and score gained from that part of the multimedia did not taken into account in the analysis.

The cover story developed for meiosis explains the importance of meiosis process for human beings. The cover story starts with statement about their progress on mitosis and then the problem for the meiosis was introduced. To give an example from cover story: “Congratulaitons! You have restored the order necessary for the growth and development of humans. However, humans living in this region have another important problem. Global warming is affecting humans rapidly and brunette people are losing their lives in an unexplainable manner. Scientists have determined that dark skinned persons are less affected from these conditions and can continue their lives. Scientists have begun to breed dark skinned babies in the test tube baby center they have established in the lab until they can find the solution to this danger in the World. However, for the purpose of conducting this activity, cells with dark skin genes need to be reproduced in the “Cell Production Center” and sent to the test tube baby center” Then, the participants task is given to students in that “Your task is, to get a ganetogonium from a woman’s ovaries and a ganetogonium from a man’s testicles and to form the cells necessary for dark skinned individuals and take these to the Test Tube Baby Center “

A main screen for mitosis and meiosis will appear after participants watching cover story for mitosis and meiosis. To achieve the goal, the students had to sequence the main phases of mitosis and meiosis in the correct order, and then should complete each of the sub phases. There are four main phases of mitosis need to be sequenced correct order and eight main phases for meiosis. After that, each main phase’s events needs to be sequenced correctly and the number of events vary across main phases. For example, there are four sub items for the first main phase of the mitosis and students get 10 points for each right answer and lost 10 point for wrong answers.

The GBSc3DM included library of resources about the subject to provide support for the students. GBSc3DM starts with selecting characters. After that, the students can watch the cover story and then they can start doing the task.


**Figure 3.1** The GBSc3DM starts with selecting characters

**Figure 3.2** Cover story given to students based on selected characters

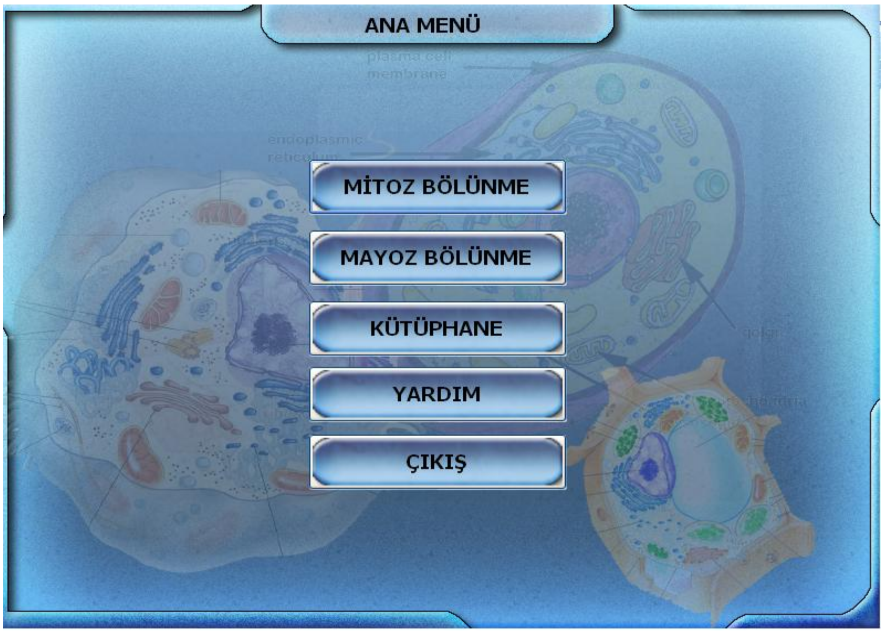
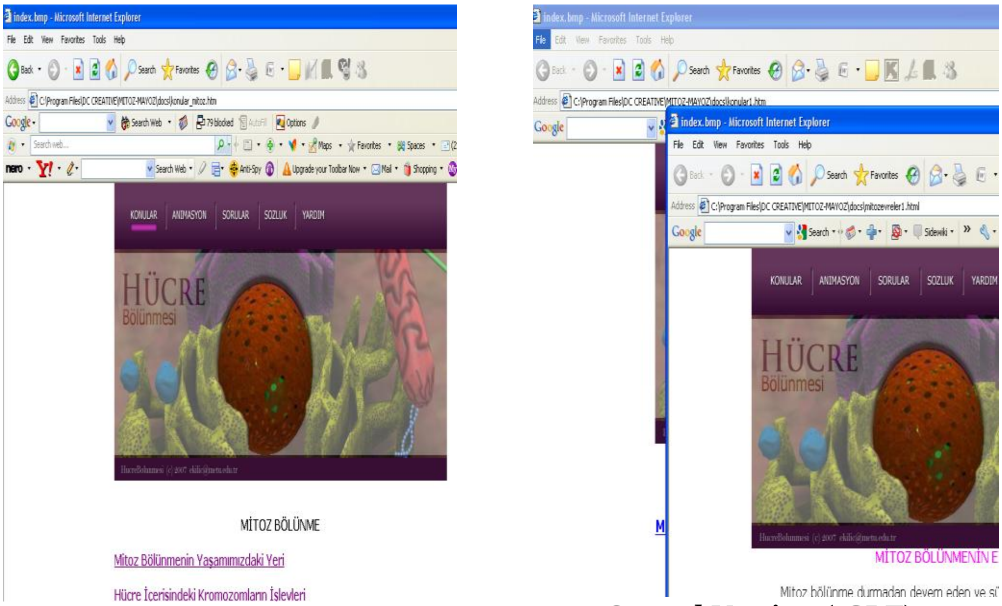



**Figure 3.3** Main menu of GBSc3DM

The GBSc3DM was developed into two versions. In the first version (+CLT), the multimedia was developed based on "split attention, multimedia, modality, coherence, signaling and redundancy" principles that reduce the extraneous cognitive load. In the second version (-CLT), the multimedia was developed without these principles. Other than the implementation or violation of principles, the remaining design and the content were the same in both versions.

***Split attention principle*** implemented/violated on main screen and on the library tool of the materials. The explanation for each button on the main screen was placed next to the related button on the first version of the multimedia (+CLT). However, in the second version (-CLT), the explanations were placed at the lower side of the screen. While each hyperlink was opened in the same window in the first version (+CLT), each hyperlink in the library was opened in different window in the second version (-CLT).



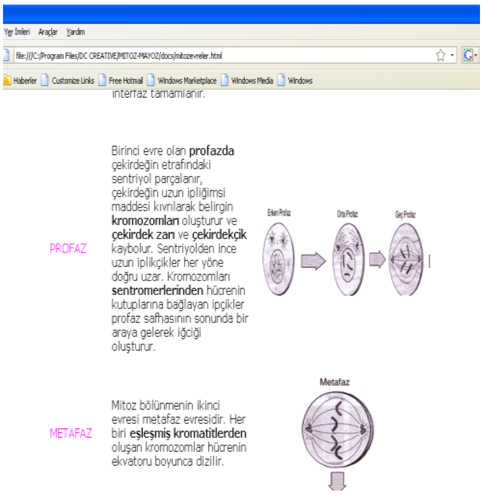

*First Version (+CLT)* *Second Version (-CLT)*

**Figure 3.4** Design of split attention principle between the first (+CLT) and the second version (-CLT) of GBSc3DM in library design.

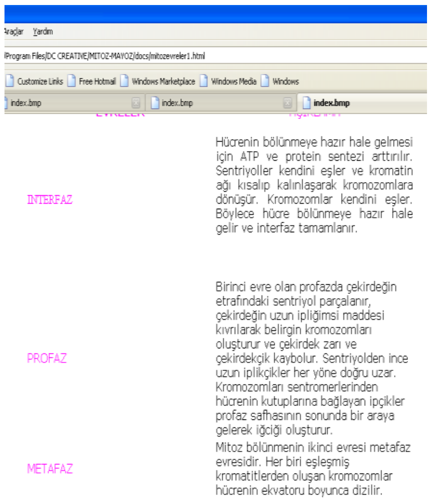

*First Version (+CLT)* *Second Version (-CLT)*

**Figure 3.5** Design of split attention principle between the first (+CLT) and the second version (-CLT) of GBSc3DM in main menu.

Although both materials were developed as the multimedia learning environments, in some part of the second version (-CLT) of the material that required students' active involvement to complete the given tasks, the ***multimedia principle*** was not considered. While both text and pictures were used in the design of above mentioned parts in the first version (+CLT) of the material, the pictures were excluded (text only condition was used) in the design of those parts in the second version (-CLT) of the material. The same principle applied in library design.




***First Version (+CLT)***




***Second Version (-CLT)***

**Figure 3.6** Design of multimedia principle between the first (+CLT) and the second version (-CLT) of GBSc3DM in library design.


***First Version (+CLT)*** ***Second Version (-CLT)***

**Figure 3.7** Design of multimedia principle between the first (+CLT) and the second version (-CLT) of GBSc3DM in sequencing main phase task.

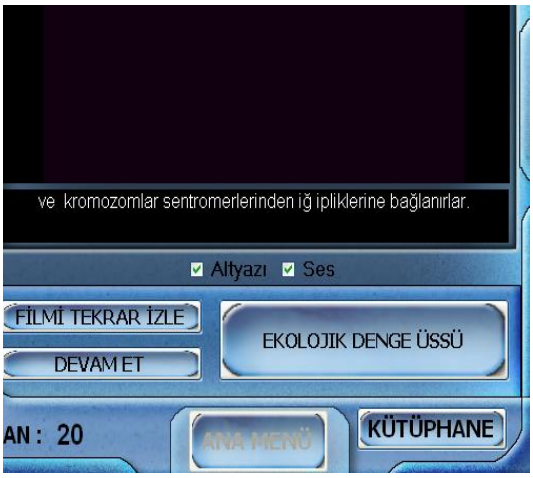
Both versions of the material were developed mainly based on 3D animation. The participants were exposed to the whole animation of mitosis or meiosis at first, and then had to complete sets of given tasks about the main and sub phases of mitosis or meiosis. After completion of the task about each phase, the participants were presented 3D animation about the completed phase. In the first version (+CLT) of the material, the whole animation of mitosis and meiosis, and the sub phases of each were presented through audio narration by implementing the ***modality principle***. In the second version (-CLT) of the material, however, text was used instead of audio narration.


***First Version (+CLT)*** ***Second Version (-CLT)***

**Figure 3.8** Design of modality principle between the first (+CLT) and the second version (-CLT) of GBSc3DM in sequencing sub phases task.

In the design of the first version (+CLT), the ***coherence principle*** was controlled by eliminating irrelevant sounds within the multimedia. On the other hand, irrelevant background music was incorporated into the second version (-CLT) of the multimedia.

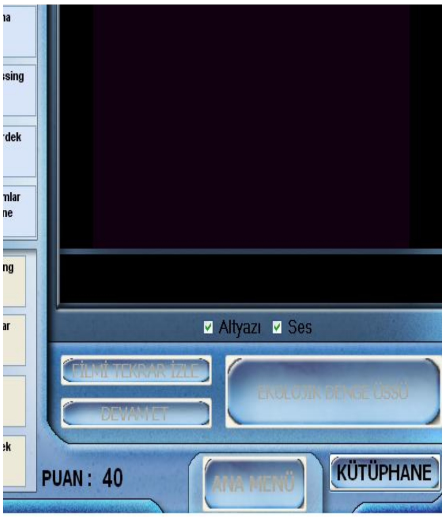
Presenting the same information in both text and audio modes, or providing additional information can hurt learning according to the ***redundancy principle.*** In the design of the first version (+CLT) of the material, students were provided with choice of switching off the text or the audio explanations of animations to eliminate redundancy. In the second version (-CLT), however, without the control of the students, the animations were presented with text, and additional information is provided through pop-up text boxes on the screen for about a-few seconds.




*First Version (+CLT)*


*Second Version (-CLT)*

**Figure 3.9** Design of redundancy principle between the first (+CLT) and the second version (-CLT) of GBSc3DM in3D animation.

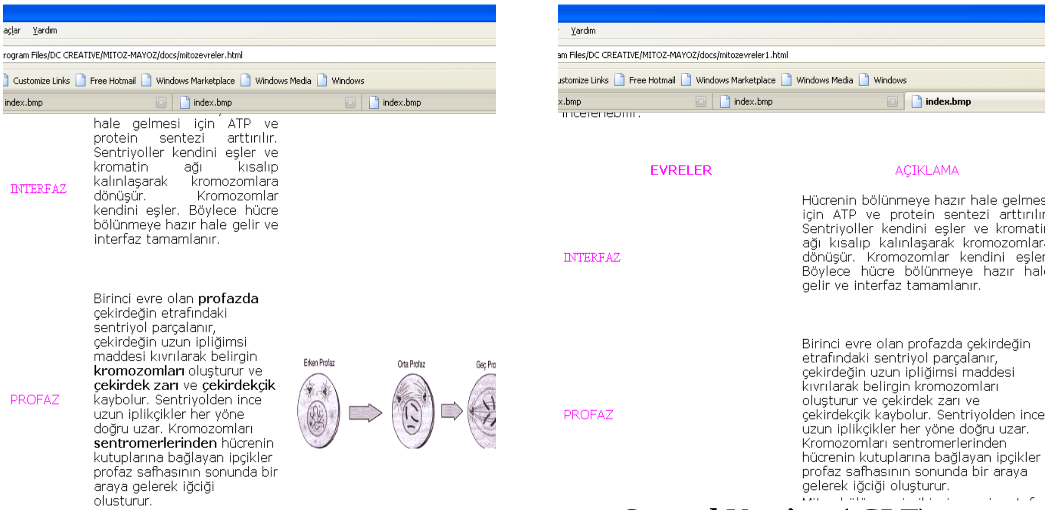



*First Version (+CLT)*


*Second Version (-CLT)*

**Figure 3.10** Design of redundancy principle between the first (+CLT) and the second version (-CLT) of GBSc3DM.

In the design of the first version (+CLT), the ***signaling*** was controlled by highlighting the key concepts in the design of the library. On the other hand, this was eliminated in the design of the library in the second version (-CLT) of the multimedia.




*First Version (+CLT)* *Second Version (-CLT)*

**Figure 3.11** Design of signaling principle between the first (+CLT) and the second version (-CLT) of GBSc3DM.

### 3.3.2 Participants of Study

82 ninth grade students (52 females and 30 males), from one of the Anatolian High Schools in Ankara, Turkey, participated in **the first** study. The reason for choosing this school was that biology teacher had experience in using the constructivist approach in her teaching, and participated in constructivist curriculum development process at Ministry of Education. Additionally, the school's computer laboratory infrastructure was appropriate to conduct this study.

Before the study, automated operation span task (AOSPAN) was administrated to find out participants' working memory capacity. However, it was found that most of the participants have similar working memory capacity. Therefore, the researcher decided to conduct a second study with a new group. The ninth grade students had to pass a nation wide exam to attend this school, and they were high achiever high school students at similar levels. However, it was not the case for 11$^{th}$ grade students in that they did not have to pass a nation wide exam to attend this school. In other words, the school was a general high school and 11$^{th}$ grade students were accepted this school without the exam. The school name was changed as an Anatolian high school and 9$^{th}$ grade students had to pass the exam to attend this school. So, it was assumed that it would be possible to find a heterogeneous group among these students. As it was assumed, a heterogeneous group was found among 11$^{th}$ grade students. For the second study, 54 11$^{th}$ grade students from the same school participated in this study.

For the first study, students were divided into four groups based on their classrooms because of the limited capacity of the computer laboratory. Two groups were assigned to first version (+CLT) and the other two groups were assigned to the second version (-CLT) of the material randomly. During the first week, two groups used the first version (+CLT), and the other two groups used the second version (-CLT) to learn mitosis in two class hours. During the second week, the two groups who used the first version (+CLT) for the first week, used the second version (-CLT), and the other two groups who used the second version (-CLT) for the first week, used the first version (+CLT) to learn meiosis in two class hours. Some of the data could not be recorded due to the technical problems encountered during the first week. Therefore, for the first week, students were asked to complete mitosis. At the end of the class, the data were gained from computer. Only 52 students' data were obtained because of the technical problems. These problems were eliminated for the following week. Table 3.1 represents the demographic information about students

**Table 3.1** Students' demographic information for mitosis for the first study

| | | Gender | | |
|---|---|---|---|---|
| | | Male | Female | Total |
| | First Version (+CLT) | 12 | 16 | 28 |
| | Group | 42.9% | 57.1% | 100.0% |
| | Gender | 63.2% | 48.5% | 53.8% |
| **Group** | Second Version (-CLT) | 7 | 17 | 24 |
| | Group | 29.2% | 70.8% | 100.0% |
| | Gender | 36.8% | 51.5% | 46.2% |
| | **Total** | 19 | 33 | 52 |
| | Group | 36.5% | 63.5% | 100.0% |
| | Gender | 100.0% | 100.0% | 100,0% |

Among 52 students, 28 of them (53. 8%) used first version (+CLT), the other 24 students (48. 2%) used second version (-CLT) while they were learning mitosis. Among 28 students, 12 male (42.9 %) and 16 female (57.1 %) students were used the first version (+CLT). On the other hand, among 24 students, 7 male (29.2%) and 17 (70.8%) female students used the second version (-CLT).

For the second week, students were asked to complete meiosis. At the end of the class, the data were gained from computer logs. Among 82 students, only seventy six (76) data were obtained because of unexpected technical problems. Table 3.2 represents the demographic information about students for meiosis.

**Table 3.2** Students' demographic information for meiosis for the first study

| | | Gender | | |
|---|---|---|---|---|
| | | Male | Female | Total |
| | First (+CLT) | 24 | 13 | 37 |
| | Group | 64.9% | 35.1% | 100.0% |
| | Gender | 51.1% | 44.0% | 48.7% |
| **Group** | Second (-CLT) | 23 | 16 | 39 |
| | Group | 59.0% | 41.0% | 100.0% |
| | Gender | 48.9% | 55.2% | 51.3% |

**Table 3.2 (Continued)**

| | | | |
|---|---|---|---|
| **Total** | 47 | 29 | 76 |
| Group | 61.8% | 38.2% | 100.0% |
| Gender | 100.0% | 100.0% | 100,0% |

Among 76 students, 37 of them (48. 7%) used first version (+CLT), the other 39 students (51. 0%) used the second version (-CLT) while they are learning meiosis. Among 37 students, 24 male (64.9 %) and 13 female (35.1 %) students were used the first version. On the other hand, among 39 students, 23 male (59.0%) and 16 (41.0%) female students used the second version.

For the **second study**, 54 11th grade students (31 females and 23 males) were selected based on their working memory capacity. They were divided into 2 groups and each group consisted of 27 participants. Each group includes 9 participants having high WMC, 9 of them having medium WMC and the last 9 participants having low WMC. The second study design differed from the first study in several aspects. Firstly, the second study last a week, and all data were collected during the study. Secondly, the groups were formed based on WMC and one group assigned to first version (+CLT) and the other group was assigned to the second version (-CLT) of the material randomly. Thirdly, the students learned the mitosis and meiosis together from the same version. Among 54 students, only 47 data were obtained because some students did not attending the school while the research took place. Table 3.3 represents the demographic information about students

**Table 3.3** Students' demographic for mitosis & meiosis for the second study

| | Gender | | |
|---|---|---|---|
| **First Version (+CLT)** | Male | Female | Total |

**Table 3.3 (Continued)**

| | | | | |
|---|---|---|---|---|
| | High WMC | 2 | 4 | 6 |
| | WMC | 33.3 % | 66.7 % | 100 % |
| | Gender | 16.7 % | 36.4% | 26.1 % |
| | Medium WMC | 3 | 5 | 8 |
| **WMC** | WMC | 37.5% | 62.5% | 100% |
| | Gender | 25% | 45.5% | 34.8% |
| | Low WMC | 7 | 2 | 9 |
| | WMC | 77.8% | 22.2% | 100% |
| | Gender | 85.3% | 18.2% | 39.1% |
| | **Total** | 12 | 11 | 23 |
| | WMC | 52.2% | 47.8% | 100 % |
| | Gender | 100% | 100% | 100% |
| **Second Version (-CLT)** | | | | |
| | High WMC | 3 | 6 | 9 |
| | WMC | 33.3 % | 66.7 % | 100% |
| | Gender | 27.7 % | 40.0% | 37.5 % |
| | Medium WMC | 5 | 3 | 8 |
| | WMC | 62.5% | 37.5% | 100% |
| | Gender | 50% | 21.4% | 33.3% |
| | Low WMC | 2 | 5 | 7 |
| | WMC | 28.6% | 71.4% | 100 % |
| | Gender | 40.9% | 28.0% | 29.2% |
| | **Total** | 10 | 14 | 24 |
| | WMC | 41.1% | 58.3% | 100% |
| | Gender | 100% | 100% | 100% |

Among 47 students, 23 students (48.9%) were used the first version (+CLT) and 24 studetns (51.1%) used the second version (-CLT) of the multimedia. 12 male (2 high WMC, 3 medium WMC and 7 low WMC) and 11 female (4 high WMC, 5 medium WMC and 2 low WMC) used the first version (+CLT) of the multimedia. 10 male (3 high WMC, 5 medium WMC and 2 low WMC) and 14 female (6 high WMC, 3 medium WMC and 5 low WMC ) were used the second version of the multimedia

## 3.4 Instrumentation

This section provides detailed information about the instruments used for data collection. In this study, data was gathered through a multiple choice cell achievement test. It was used as a pre-test and post-test. Pre-test result was used to find out participants' prior knowledge in order to control the possible effects of their prior knowledge on learning outcome after treatment. Post-test result was used to investigate the effects of treatment on the participants' performance. Subjective rating scale was used to measure cognitive load. Automated operation digit span task was used to measure the participants' working memory capacity.

In order to investigate the participants' perception, two forms of constructivist multimedia learning environment survey (CMLES) were used. CMLES actual form was administrated right after the participants exposed to instruction to reveal their actual use of the multimedia learning environments. CMLES preferred form was administrated after the study so as to investigate their preferences for the multimedia learning environments.

Two activity reports, one for mitosis and one for meiosis were administrated to the participants. Activity reports were developed as an additional activity which complements the multimedia learning environments. The scenarios developed for designing multimedia were extended and several questions were asked about content. Reflective journals were written by students after mitosis and meiosis about their experiences on using the multimedia Log files about the use of multimedia in terms of time, the number of errors they did during learning process were recorded. Focus group interviews with selected students were done to explore participants' motivation and satisfaction about cognitive load principles that used to reduce extraneous cognitive load in multimedia.

### 3.4.1 Cell Achievement Test

Cell Achievement Test developed by Atilboz (2004) was used for this study. The author developed the test through biology text book and the test covers cell division process. It consist of 20 multiple choice questions on mitosis and meioses. There were 5 questions for mitosis, 8 questions for meiosis and 7 questions for mitosis and meiosis with four options for each question. The students were required to complete the test in 20 minutes. The test was piloted with 95 9th grade students attending one of the high schools in Eryaman, Ankara. The content validity of this test was ensured with experts. The reliability of this test was 0.73 for Cronbach's alpha and 0.75 for Kuder Richardson-20.

### 3.4.2 Subjective Rating Scale

'Subjective rating scale' adapted from Paas and Van Merriënboer (1993) was used to measure participants' mental effort spent in GBSc3DM. Subjective rating scale measurement is considered as the "most promising technique for research in the context of cognitive load" (Sweller et al., 1998, p. 268). In addition, the subjective rating scales are "sensitive to relatively small differences in cognitive load and they are valid, reliable and unintrusive" (Paas et al, 2003, p. 66). Students can express their mental effort with 9-point mental effort rating scale ranging from 1 (very, very low mental effort) to 9 (very, very high mental effort). The validity and reliability of this scale was tested in Turkish context by Kilic and Karadeniz (2004). The reliability of this scale was found 0.78 (Cronbach's alpha).

### 3.4.3 Automated Operation Span Task

Automated operation span task was a mouse driven test and the participants need to only click on the mouse to complete the task and also they can complete the task independently of the researcher (Unsworth, Heitz, Schrock & Engle, 2005). It included three practice sessions. The first session was letter span, the second session was for math portion of the task and the last one was combination of letter span and math proportion of the task. During the practice of the first session, the time for responding each math operation was calculated, and this time (plus 2.5 SD) was then used as a time limit for the math portion of the experimental session for that individual. After the practice session, the participants were instructed to solve some mathematical problems and then try to recall the letters appeared among math operations in the correct order. They were instructed about both accuracy of math problem and the proportion of recall. The participants were required to keep the accuracy of the math problem above 85 %. Otherwise, it was assumed that the data were invalid. AOSPAN has both good internal consistency (alpha 0.78) and test–retest reliability (0.83) in original study. The scores gained from task range from 0 to 75.

The researcher was in contact with Nash Unsworth during the adaptation process. Although the participants' age was different from the age of the participants of the original study, the author recommends keeping the number of letter as 75 and the number of math operation (75) the same as in original study. He recommends that changing the letter in the test would be enough for adaptation. The letters were selected with an expert in cognitive psychology. In addition, the translation of this instrument conducted by two language teachers and two experts in the field. It was piloted with 10 individuals to ensure the clarity of statements before the study. They were informed about the study and the researcher wanted them to explain any misleading statement or any statement that needs to be changed. None of them expressed any changes so the instruments were used without any changes for the current study.

### 3.4.4 Constructivist Multimedia Learning Environment Survey (CMLES)

The scale consisted of 30 five-point likert type (from 1 to 5 recorded as Almost Never, Seldom, Sometimes, Often and Always ) items and two parts with six subscales. Each sub scale consisted of 5 questions. The first part of the CMLES measures the students' perception on learning with multimedia program and composed of three subscales namely negotiation, inquiry learning and reflective thinking. The second part of CMLES measures the multimedia program and consisted of three subscales which are authenticity, complexity and challenge (Moar &Fraser 2005). Two forms of CMLES were used to collects data for this study. The actual form of CMLES was used to assess students' perception for their actual experience in goal based scenario designed multimedia learning environments by rating their level of agreements with the statements in actual form. They rated their preferences of statements in the same manner for the preferred form of CMLES.

### 3.4.5 Activity Reports

Two activity reports were developed as the extension of scenario of multimedia learning environments. The activity report for mitosis consisted of four questions and the other activity report for meiosis included seven questions. The aim of this report was to provide additional activities for students in line with the scenario developed for the multimedia program. All students except for two completed these activities and got full score.

### 3.4.6 Reflective Journal

In addition to the self reported difficulty of materials, reflective journal was used to collect data. In depth investigation helps the researchers gain a better understanding of how students are actually affected with the cognitive load (Stark, Mandl, Gruber & Renkl, 2002). At the end of the each unit, students were required to write reflective journals about their experiences on using the multimedia. There were 5 questions in reflective journals, and they were developed based on the literature to reveal students' opinions about the design issues in the multimedia. The goals of the three questions were to reveal the participants' opinions with regard to their roles, missions, goals and learning with multimedia. The aim of the fourth question was to investigate the participants' opinions about learning through traditional classroom instruction and GBSc3DM. The last question was asked to learn the students' opinions about the design of GBSc3DM whether there were things that make it more difficult or easier to focus their attention while using the multimedia.

### 3.4.7 Log files

Log files were automatically created and updated as participants proceeded through the program. Seven variables have been recorded. Information recorded included the **scores, total time spent in the environment**, **time spent in sequencing main phases, the number of errors made in sequencing main and sub phases, the frequency use of library**. Students get 10 points for each right answer and lost 10 point for wrong answers. **Score** was computed by subtracting total points of wrong answers from total points of right answer. For the meiosis, the data recorded were the same as in mitosis except for the time for the first study. All log files were created and updated for the second study.

### 3.4.8 Interview

A semi-structured interview which consisted of 10 questions was conducted with 27 students in three groups, and each group included 9 students attending the first study. The reasons for preferring group interviews were that they allow the interviewees to reflect on what the others in the group articulate, and then may build upon those mutual opinions. This method provides a base for validation by quality control in data collection through multiple perspectives on the same issue. Lastly, group interviews can be used to identify strengths and weaknesses of a program (Patton, 1987). The interviews were conducted to investigate students' opinions mainly on the cognitive load principles that applied in the goal based scenario centered multimedia. The key informants were selected based on their responses to the question related to multimedia design in reflective journal. Except for two questions, eight interview questions were developed to explore participants' motivation and satisfaction about the split attention, redundancy, modality, coherence and multimedia principles used in the multimedia.

## 3.5 Data Collection Procedure

The data were collected 2007-2008 fall semesters. It took about 45 days for two studies to conduct. The researcher went to school two weeks before the study to be familiar with the students and school environments. The researcher briefly explained the research study that wants to be conducted. Quantitative and qualitative data were collected and analyzed concurrently.

For the first study, the whole data were collected in one month. One week before the study, the cell achievement test was administrated. During the study, students were required to write reflective journals on their experiences with multimedia learning environment. The reflective journals' data were analyzed immediately after implementing each unit to select the interview participants. Focus group interview was conducted with 3 groups consisting of 9 students. Each interview took approximately 20 minutes. To assess students' perception on their actual experience the CMLES actual form was administrated at the end of the first week. The preferred from of CMLES was used at the end of the study. Log files were automatically kept and updated as participants proceeded through the program. The students were also required to complete the activity report for mitosis and meioses. At the end of the study, cell achievement test were administrated as a posttest.

In the first study, participants' working memory capacity was found very close to each other so it was not possible to assign participants as having high, medium and low WMC to the two versions of multimedia. Therefore, the second study was conducted with a new group of participants having different working memory capacity. For the second study, the whole data were collected in two class hours. Firstly, cell achievement test was administrated to the selected participants. Then, students were required to use the multimedia program and log files were kept and mental effort was measured. At the end of the study, students were required to complete the cell achievement test as a posttest. Table 3.4 shows detailed information about the data collection process from beginning to the end of the study.

**Table 3.4** Information about the data collection process

| Study | Version | Group | Time | Instrument Name | Data Collection Method |
|---|---|---|---|---|---|
| Study 1 | | | Before the study | Cell Achievement Test | Quantitative |
| | | | | AOSPAN | Quantitative |
| | Version I | Group I | | Log files for mitosis | Quantitative |
| | | Group II | | Subjective Rating Scale for mitosis | Quantitative |
| | Version II | Group III | First Week | CMLES actual form | Quantitative |
| | | Group IV | | Activity report for mitosis | Qualitative |
| | | | | Reflective Journal for mitosis | Qualitative |
| | Version I | Group III | | Log files for meiosis | Quantitative |
| | | Group IV | | Subjective rating scale for meiosis | Quantitative |
| | Version II | Group I | Second Week | CMLES preferred form | Quantitative |
| | | Group II | | Activity report for meiosis | Qualitative |
| | | | | Reflective Journal for meiosis | Quantitative |
| | | | | Focus Group Interview | Qualitative |
| | | | | Cell Achievement Test | Quantitative |
| Study 2 | Version I | High WMC | | AOSPAN | Quantitative |
| | | Medium WMC | | Cell Achievement Test | Quantitative |
| | | Low WMC | | Log files for mitosis and meiosis | Quantitative |
| | | High WMC | | | |
| | Version II | Medium WMC | | Subjective Rating Scale for whole learning phase | Quantitative |
| | | Low WMC | | | |

## 3.6 Data Analysis

### 3.6.1 Quantitative Data Analysis

***Study 1:*** Quantitative data were collected through cell achievement test, two forms of constructivist multimedia learning environment survey (CMLES), log files and subjective rating scale. The two version of the multimedia was independent and categorical variables for this study. The dependent variables were: mental effort, cell achievement test score, log files which were the scores, total time spent in the environment, time spent in sequencing main phases, the number of errors made in sequencing main and sub phases, the frequency use of library. They were continuous variable. Regardless of the multimedia versions, the CMLES actual and preferred forms were administrated to assess students' perception on the goal based scenario designed constructivist multimedia learning environments. The collected data from CMLES forms were continuous.

The following analyses were conducted to investigate the effects of instructional format that reduce extraneous cognitive load in the goal based scenario centered constructivist multimedia learning environments.

- Independent sample t-test was conducted to find out the difference between the first version (+CLT) and the second version (-CLT) of the multimedia on log files, mental effort, cell achievement test as a posttest. Prior knowledge difference has been considered as a covariance when significant difference has found between groups.
- Cronbach's alpha was calculated the reliability of the two forms of CMLES. T-test for matched pairs was conducted to investigate differences in students' actual perception and preferences for the multimedia learning enviroenmnts.

***Study 2:***

- Two way Analysis of Covariance, two way Analysis of Variance and Kruskal Wallis as non parametric statistical test were used to investigate the main and interaction effect of two independent variables (WMC and multimedia versions) on log files, mental effort, and cell achievement test as a posttest. Prior knowledge difference between participants has been considered as a covariance when significant difference has been found.

### 3.6.2 Validity and Reliability of Quantitative Data Analysis

Two essential features of good measure are reliability and validity. Reliability is related to the consistency, stability and predictability, on the other hand, validity refers to trustworthiness, accuracy, authenticity and soundness (Hubley & Zumbo, 1996).

There are two types of validity, *internal and external validity*. Internal validity refers to "inferences about whether co variation between A and B reflects a causal relationship from A and B in the form in which the variables re manipulated or measured" (Shadish, Cook & Campbell, 2002, p. 53). As cited in Shadish et al (2002), internal validity deals with causal inferences, rather than reproducibility, inferences from target population, measurement validity and whether researchers measure what they think about measure. There are mainly ten extraneous variable threats to internal validity. These are (a) subject characteristics, (b) mortality, (c) location, (d) instrumentation, (e) testing, (f) history, (g) maturation, (h) subject attitude, (i) regression (j) implementation and novelty effect (Fraenkel & Wallen, 2000). Since the study was conducted in naturalistic environment, mortality, maturation, novelty and testing effect was considered threats to internal validity. Mortality can not be controlled because the study took place in natural learning environment, to eliminate novelty and maturation effect the data were collected many times during study. In other words, it was the first time for students learning with constructivist multimedia so it was assumed that rather than treatment, the novelty of the multimedia program may result in this outcome. Data were collected two weeks so that researcher could observe possible differences when they first exposed to treatment and the second time. Cell achievement test was used before and after study and it was assumed that because of long duration of study the priming effect of testing did not affect the outcome. On the other hand, external validity refers to “inferences about the extent to which a causal relationship holds over variation in persons, settings, treatments and outcomes” (Shadish, Cook & Cmpbell, 2002, p. 83). For study1, the order of students attending the first version (+CLT) and the second version (-CLT) was changed. During the first week, two groups used the first version (+CLT), and the other two groups used the second version (-CLT) to learn mitosis in two class hours. During the second week, the two groups who used the first version (+CLT) for the first week, used the second version (-CLT), and the other two groups who used the second version (-CLT) for the first week, used the first version (+CLT) to learn meiosis in two class hours. This can threat to external validity in terms of multiple case interference. Based on multiple treatment interference which is a threat to external validity, it can be expected that the effects of the initial treatment can be measured; however, the possible effects of the initial treatment on subsequent treatment might be problematic (Bracht & Glass, 1963). The participants were exposed to different versions of multimedia in learrning mitosis and meiosis during the study. The reason for this is that the researcher wanted the students to expose both versions of the multimedia during the study so that the students were able to compare and contrast design principles into two versions of multimedia and allow the researcher collect rich qualitative data.

As stated above, reliability is related to the consistency, stability and predictability. There are mainly four approaches used to ensure the reliability of an instrument. These are test-retest, parallel forms, internal consistency and inter-rater techniques. A measure can be reliable without being valid, but it can not be valid without being reliable. So, reliable is essential, but not sufficient for validity (Hubley & Zumbo, 1996). There were five instruments for this study. Some of the instrument, CMLES and operation digit span task was used in Turkish context for the first time.

Construct validity in Turkish context with factorial analysis could not be done because of inadequate sample size. Rather, Cronbach's alpha value was computed for two forms of CMLES to ensure the reliability. The content validity of operation span task test was tested by two experts in cognitive psychology. To test the clarity of statement, the test was tested with 10 students. The detailed information can be found in the instrumentation part. Subjective rating scale was tested in Turkish context and it showed good internal consistency. The last instrument was cell achievement test which was tested before in another study and found reliable.

### 3.6.3 Qualitative Data Analysis

Qualitative data were collected through reflective journals and focus group interviews in the first study. The transcripts of the interviews and reflective journals were analyzed according to the qualitative analysis procedures. Marshall and Rossman (1999) recommended six steps while analyzing the data. These starts with 1 organizing the data; 2 generating categories, and themes; 3 coding the data; 4 testing the emergent understandings as considering students' individual differences; 5 searching for alternative explanations; and 6 writing the report. The transcripts of all reflective journals and focus group interviews were also analyzed according to this process given below:

- *Coding*: Individual comments were coded by focusing on research questions.
- *Ordering and displaying*: Information was collected, patterns and themes were determined. Data were displayed.
- *Conclusion drawing*: Conclusions were drawn based on data.

After coding process was completed, all interviews and reflective journals transcripts were scanned line by line again. To draw themes, the research questions were focused and deductive coding was used. Through the analysis, main themes were withdrawn and then the data were interpreted under these themes. The data were summarized in three main categories. It pointed out by Yildirim and Simsek (2004) quantifying qualitative data increase the reliability, decreasing subjectivity, getting opportunity of comparing codes or themes. Therefore, the data gained from group interviews and reflective journals were quantified.

### 3.6.4 Validity and Reliability of Qualitative Data Analysis

Validity and reliability are two important issues that any qualitative researcher should take into account while designing qualitative research (Patton, 2001, Yıldırım & Simsek, 2004). While reliability and validity issues are well documented in quantitative research separately, it is not separated in qualitative research as did in quantitative research (Golafshani, 2003).

To maintain internal validity, Merriam (1998) recommended six strategies for enhancing validity in qualitative research: i) Triangulation, ii) Checks, iii) Long-term observation, iv) Peer examination, v) Collaborative models of research, vi) Researcher’s biases. The researcher tried to follow these six stages during the study. To illustrate, different data collection method was used for this study to ensure the triangulation of the data. The reflective journals’ questions and interviews’ questions were prepared with an expert having a great deal of experience in research field. The clarity of the questions was subject to peer review. All interviews were recorded with the consent of the interviewees. Further, all interviews were transcribed by the researcher carefully and irrelevant answers during interviews were ignored from the transcripts. The data analysis process was reviewed by an expert and a peer (having PhD degree) at the Department of Elementary Science Education, especially during data coding and generating categories. In addition, the raw data were coded more than once by the researcher at different times to compare the codes in terms of their consistency. However, researcher’s bias could never fully be removed; but an awareness of personal biases was acknowledged during the study.

Reliability is concerned with the replicability of scientific findings. (Le Compte & Goetz, 1982). In other words, “in qualitative studies, researchers are concerned with the accuracy and comprehensiveness of their data. Qualitative researchers tend to view “reliability as a fit between what they record as data and what actually occurs in the setting under study” (Bogdan & Biklen, 1998, p. 36). Data were recorded mechanically because this approach can impede to ignore or forget important points. Then, the data obtained by interviews and reflective journals were presented in a descriptive way with the record of who did, what, under which circumstances. Data were reviewed twice by different researchers. The qualitative data were quantified to increase the reliability, decreasing subjectivity, getting opportunity of comparing codes or themes (Yıldırım & Şimşek , 2004).

As Merriam (1998) stated, generalization in qualitative study takes a different meaning. External validity is weaker part of the qualitative research design. To ensure the external validity, the researcher explained her social role within the research site. This information might guide the others wanting to conduct a similar study. Types of informants, physical and social context, assumptions, theories, definitions, methods of data collection and analysis delineated to enhance the external validity of the research

## 3.7. Assumptions and Limitations of the Study

For this study, the following assumptions are stated:

- The participants responded accurately to all the instruments used in this study.
- Reliability and validity of all the questionnaires, reflective journals and interview schedules used in this study were accurate enough to permit accurate assumptions.
- The data were recorded and analyzed accurately.

The following limitations apply to the present study:

- Validity of this study was limited to the reliability of the instruments used in this study.
- The study was limited with participants in this study.
- Validity and reliability was limited to the honesty of the participant's responses to the questionnaires, reflective journals and interviews.
- Although some instruments have been translated from foreign language, the factor analysis could not be done because of small sample size. The instruments validity was limited by expert review.
- Sample size for the second study was small which decrease the power of the inferences.
- Lack of control group

# CHAPTER 4

# RESULTS

In this chapter, the results of the study in regard to the research questions were presented.

## 4.1. The Effects of the Cognitive Load Principles on Learning Process and Learning Outcome (Research Question 1.1, Study I)

To give an answer for the first research question, the following analysis was conducted. The result of the statistical analysis for the first study was presented for mitosis and meiosis separately.

### 4.1.1 Assumptions of Independent Sample t-test

Independent sample t-test has three assumptions: Normality, equality of variances and independency of scores on the dependent variable.

For normality assumption, skewness and kurtosis values for students attending the first version (+CLT) and the second version (-CLT) were calculated. The skewness and kurtosis values were not in acceptable range in mitosis for two dependent variable, *score and main phase error,* in the first version (+CLT) and for three dependent variable, *score, main phase error and main phase time,* in second version (-CLT). Therefore, the outliers for each dependent variable were determined by histograms and plots across two different conditions and removed. Skewness and kurtosis value between +1 and -1 has been acceptable range (Pallant, 2007). However, the range between +2 and -2 has been considered acceptable values for those two values in educational research. Skewness and kurtosis values were presented descriptively in Table 4.1 for the first version (+CLT).

**Table 4.1** Descriptive statistics for dependent variables for **mitosis** in the first version (+CLT)

| | First Version (+CLT) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Variables** | N | Mean | SD | Range | Min | Max | Skewness | Kurtosis |
| Score | 27 | 304.81 | 74.28 | 290 | 150 | 240 | -287 | -462 |
| Mental effort | 28 | 3.85 | 1.67 | 6.00 | 1.00 | 7.00 | 0.89 | -1.297 |
| Main phase time | 28 | 31.60 | 30.33 | 110 | 114.0 | 31.60 | 1.427 | 1.271 |
| Main phase error | 24 | 0.458 | .832 | 2.00 | .00 | 2.00 | 1.374 | -.019 |
| Each phase error | 28 | 12.64 | 10.29 | 39.00 | 0 | 39 | .954 | .534 |
| Library use | 24 | 3.67 | 4.08 | 9.00 | 1.00 | 10 | .744 | -348 |
| Post-test-Mitosis | 28 | 3.21 | 1.03 | 3.00 | 2.00 | 5.00 | .410 | .-895 |

For the second version (-CLT), the information about each dependent variables after excluding outliers were presented in Table 4.2.

**Table 4.2** Descriptive statistics for dependent variables for **mitosis** in the second version (-CLT)

| | Second Version (-CLT) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Variables** | N | Mean | SD | Range | Min | Max | Skewness | Kurtosis |
| Score | 23 | 243.47 | 104.82 | 370 | 0 | 370.0 | -1.164 | .935 |
| Mental effort | 24 | 5.20 | 1.55 | 6.0 | 3.0 | 9 | 1.047 | 1.454 |
| Main phase time | 18 | 10.22 | 4.42 | 14.0 | 5.0 | 19.0 | 1.019 | -.129 |
| Main phase error | 23 | 2.04 | 3.89 | 12.0 | 0 | 12.0 | 1.709 | 1.501 |
| Each phase error | 24 | 23.00 | 15.80 | 63.00 | 0 | 63.00 | .952 | .590 |
| Library use | 24 | 4.12 | 2.72 | 9.0 | 1.0 | 10 | .744 | .472 |
| Post-test-Mitosis | 24 | 3.41 | 1.24 | 4.00 | 1.0 | 5.0 | -745 | .918 |

Normality assumption was tested for meiosis also. Both skewness and kurtosis values were computed. The skewness and kurtosis values were not in acceptable range in meiosis for four dependent variable, *score and main phase error, main phase time and each phase error* both in the first version (+CLT) and the second version (-CLT). Skewness and kurtosis values were presented descriptively in Table 4.3 for first version (+CLT).

**Table 4.3** Descriptive statistics for dependent variables for **meiosis** in the first version (+CLT)

| | First Version (+CLT) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Variables** | N | Mean | SD | Range | Min | Max | Skew. | Kurtosis |
| Score | 29 | 347.24 | 43.58 | 190.0 | 230.0 | 420.0 | .-559 | .476 |
| Mental effort | 37 | 3.64 | 1.76 | 6 | 1.0 | 7.0 | .187 | -1.051 |
| Main phase time | 34 | 42.5 | 32.4 | 118 | 11.0 | 129.0 | 1.328 | .848 |
| Main phase error | 32 | 3.09 | 4.25 | 15.0 | 0 | 15.0 | 1.300 | .787 |
| Each phase error | 33 | 9.90 | 7.49 | 31.0 | 0 | 31.0 | 1.286 | 1.576 |
| Library use | 37 | 2.64 | 3.19 | 12.0 | 0 | 12.0 | 1.522 | 1.573 |

**Table 4.3 (Continued)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Learning Time | 37 | 1157.0 | 350.1 | 1556.3 | 443.0 | 2001.3 | .258 | -.223 |
| Post-test-Meiosis | 37 | 3.75 | 1.60 | 7.0 | 0 | 7.0 | .090 | .415 |

For the second version (-CLT), the information about each dependent variables after excluding outliers were presented it Table 4.4.

**Table 4.4** Descriptive statistics for dependent variables for **meiosis** in the second version (-CLT)

| | | | | **Second Version (-CLT)** | | | | |
|---|---|---|---|---|---|---|---|---|
| **Variables** | N | Mean | SD | Range | Min | Max | Skew. | Kurtosis |
| Score | 28 | 343.57 | 38.51 | 140.0 | 260.0 | 400.0 | -.608 | -430 |
| Mental effort | 39 | 4.35 | 1.63 | 6.0 | 1.0 | 7.0 | -.388 | -.554 |
| Main phase time | 37 | 37.29 | 29.79 | 112.0 | 9.0 | 121.0 | 1.285 | .754 |
| Main phase error | 34 | 1.32 | 2.02 | 7.0 | 0 | 7.0 | 1.574 | 1.592 |
| Each phase error | 38 | 9.97 | 6.49 | 28 | 2.0 | 30.0 | 1.288 | 1.570 |
| Library use | 39 | 3.43 | 3.43 | 12.0 | 0 | 12 | 1.191 | .632 |
| Learning Time | 39 | 1109.5 | 295.66 | 1337.4 | 534.16 | 1871.5 | .325 | .124 |
| Post-test-Meiosis | 39 | 3.38 | 1.31 | 6.0 | 0 | 6.0 | -.105 | .150 |

For the equality of variance assumption, for each dependent variable Levene's Test of Equality was used. If there is no equality of variance, the t value for unequal variance was reported (Green & Salkind, 2008).

For the last assumption, independency of scores was examined. It was assumed that all students did their tests by themselves. The researcher and teacher observed all students participating in the study.

### 4.1.2 Data Analysis for Mitosis

#### 4.1.2.1 Prior Knowledge for Mitosis

A cell achievement test was administrated to find out students' prior knowledge at the beginning of the study. An independent sample t-test was conducted to compare the prior knowledge scores of students between the first version (+CLT) and the second version (-CLT) of the multimedia program. All assumptions were justified for this test. The result of independent sample t-test assuming equal variance (p=.20 larger than .05) showed that there was no significant difference in prior knowledge of the students between the first version (+CLT) (M=6.67, SD=3.11) and the second version (-CLT) of multimedia (M= 6.50, SD=2.55), $t(50)=.224$, $p > .05$. In particular, the questions directly related to the mitosis questions were indentified in cell achievement test and based on those five questions students' prior knowledge were compared among groups. An independent sample t-test was conducted to compare the prior knowledge of students who were exposed to the first version (+CLT) and the second version (-CLT) of the multimedia program. The result of independent sample t-test assuming equal variance (p=.14 larger than .05) showed that there was no significant difference in prior knowledge of students between the first version (+CLT) (M=2.50, SD=1.40), and the second version (-CLT) of multimedia (M= 2.33, SD=1.12), $t(50)= .467$, $p >.05$. Since there was no significant difference between students' prior knowledge across conditions, the prior knowledge did not take into account as a co variance.

#### 4.1.2.3 Mitosis Findings

All subsequent analyses are performed using independent sample t-test. For all statistical tests a significance level of .05 was maintained.

**Score:** An independent sample t-test was conducted to compare students' score gained from multimedia between the first (+CLT) and the second version (-CLT) of multimedia program. The result of independent sample t-test assuming equal variance (p=.22 larger than .05) showed that there was significant difference in students' scores between the first (+CLT) and the second version (-CLT) of multimedia program. Students' score in the first version (+CLT) was higher (M=304.81, SD= 74.28) than that was in the second version (-CLT) of multimedia program (M=243.47, SD= 104.82), $t(48)= 2.413$, $p <.05$.

**Mental effort:** The result of independent sample t-test assuming equal variance (p=.16 larger than .05) showed that there was significant difference in students' mental effort between the first (+CLT) and the second version (-CLT) of multimedia program. Students' mental effort in the first version was lower (+CLT) (M=3.64, SD= 1.64) than that was in the second version (-CLT) of multimedia program (M=5.21, SD= 1.59), $t(48)= -3.124$, $p <.05$.

**Main phase time:** The result of independent sample t-test assuming not equal variance showed that there was significant difference in time spent for sequencing the main phases of mitosis between the first (+CLT) and the second version (-CLT) of multimedia program. Time spent for sequencing the main phases in the first version (+CLT) was higher (M=31.60, SD= 30.33) than that was in the second version (-CLT) of multimedia program (M=10.22, SD= 4.42), $t(28.76)= -3.670$, $p <.05$.

**Main phase error:** Even though the main phase error in the first version was lower (+CLT) (M=.45, SD= .83) than that was in the second version (-CLT) of multimedia program (M=2.04, SD= 3.89), $t(23.93)= -1.913$, $p >.05$, the result of independent sample t-test assuming not equal variance showed that there was no significant difference in the main phase error between the first version (+CLT) and the second version (-CLT) of multimedia program.

**Each phase error:** The result of independent sample t-test assuming equal variance (p=.056 larger than .05) showed that there was significant difference in the number of each phase error between the first version (+CLT) and the second version (-CLT) of multimedia program. The number of each phase error in the first version (+CLT) was lower (M=12.64, SD= 10.29) than that was in the second version (-CLT) of multimedia program (M=23.00, SD= 15.80), $t(50)= -2.838$, $p < .05$.

**Library use:** Even though the frequency of library use in the first version (+CLT) was lower (M=3.67, SD= 4.08) than that was in the second version (-CLT) of multimedia program (M=4.12, SD= 2.72), $t(47.33)= -.469$, $p > .05$, the result of independent sample t-test assuming not equal variance showed that there was no significant difference in the frequency of library use between the first version (+CLT) and the second version (-CLT) of multimedia program.

**Post-test Mitosis:** The result of independent sample t-test assuming equal variance (p=.34 larger than .05) showed that there was no significant difference in students' post-test scores for mitosis question between the first version (+CLT) and the second version (-CLT) of multimedia program. Students' post-test score for mitosis questions in the first version (+CLT) was lower (M=3.21, SD= 1.03) than that was in the second version (-CLT) of multimedia program (M=3.41, SD= 1.24), $t(50)= -.640$, $p > .05$. All analysis result for mitosis was presented in Table 4.5.

**Table 4.5** Independent sample t-test result for **mitosis** findings

| Variable | Versions | N | M | SD | t | p | Effect Size |
|---|---|---|---|---|---|---|---|
| Score | Version I | 27 | 304.81 | 74.28 | 2.413 | p<.05 | .69 |
| | Version II | 23 | 243.47 | 104.8 | | | |
| Mental effort | Version I | 28 | 3.64 | 1.64 | -3.124 | p<.05 | .90 |
| | Version II | 24 | 5.21 | 1.59 | | | |
| Main phase time | Version I | 28 | 31.60 | 30.33 | -3.670 | P<.05 | 1.10 |
| | Version II | 18 | 10.22 | 4.42 | | | |
| Main phase error | Version I | 24 | .45 | .83 | -1.913 | p>.05 | .78 |
| | Version II | 23 | 2.04 | 3.89 | | | |
| Each phase error | Version I | 28 | 12.64 | 10.29 | -2.838 | p<05 | .63 |
| | Version II | 24 | 23.00 | 15.80 | | | |
| Library use | Version I | 24 | 3.67 | 4.08 | -.469 | p>.05 | .13 |
| | Version II | 24 | 4.12 | 2.72 | | | |
| Post test | Version I | 28 | 3.21 | 1.03 | -, 640 | p>.05 | .18 |
| | Version II | 24 | 3.41 | 1.24 | | | |

*Effect size is Cohen d*

#### 4.1.2.4 Instructional Efficiency for Mitosis

Instructional efficiency measure was conducted into two ways. Independent sample t-test was conducted to find out the instructional efficiency between conditions. All assumptions were justified for this test. For the first one, the score gained from multimedia and the mental effort during learning phase was used to calculate the efficiency and for the second one the score on the cell achievement test and the mental effort during learning phase was used to calculate efficiency measure and both presented in Table 4.6.

**Instructional efficiency- Learning phase:** An independent sample t-test was conducted to compare the instructional efficiency between the first version (+CLT) and the second version (-CLT) of multimedia program. The result of independent sample t-test assuming equal variance (p=.45 larger than .05) showed that there was significant difference in instructional efficiency between the first version (+CLT) (M=0.39, SD=0.78), and the second version (-CLT) (M= -0.45, SD= 1.09) ,t(50)= 3.28, $p < .05$ in favor of the first version (+CLT) of multimedia.

**Instructional efficiency- Test phase (5 questions):** An independent sample t-test was conducted to compare the instructional efficiency between the first version (+CLT) and the second version (-CLT) of multimedia. The result of independent sample t-test assuming equal variance (p=.82 larger than .05) showed that there was no significant difference in instructional efficiency between the first version (+CLT) (M=0.19, SD=0.96) and in the second version (-CLT) of multimedia (M= -0.22, SD= 0.91), t(50)= 1.60, $p > .05$.

**Table 4.6** Efficiency measure of learning and test phase for **mitosis**

| Efficiency | Versions | N | M | SD | t | p | Effect Size |
|---|---|---|---|---|---|---|---|
| Instructional efficiency learning phase | Version I | 28 | 0.39 | 0.78 | 3.28 | P<0.5 | .92 |
| | Version II | 24 | -0.45 | 1.09 | | | |
| Instructional efficiency test phase | Version I | 28 | 0.19 | 0.96 | 1.60 | p>0.5 | .45 |
| | Version II | 24 | -0.22 | 0.91 | | | |

### 4.1.3 Data analysis for Meiosis

#### 4.1.3.1 Prior Knowledge for Meiosis

A cell achievement test was administrated to find out students' prior knowledge at the beginning of the study. An independent sample t-test was conducted to compare the prior knowledge of the students between the first version (+CLT) and the second version (-CLT) of multimedia program. All assumptions were justified for this test. The result of independent sample t-test assuming equal variance (p=.39 larger than .05) showed that there was no significant difference in prior knowledge of students between the first version (+CLT) (M= 6.0, SD=3.01), and the second version (-CLT) of multimedia (M=7.0, SD=2.79), t(74)=-1.501, $p > .05$. In particular, the questions directly related to the meiosis questions were identified in cell achievement test and based on those eight questions students' prior knowledge were compared among groups. An independent sample t-test was conducted to compare the prior knowledge of students who exposed to the first version (+CLT) and the second version (-CLT) of multimedia program. The result of independent sample t-test assuming equal variance (p=.35 larger than .05) showed that there was no significant difference in prior knowledge of students between the first version (+CLT) (M=2.05, SD=1.59), and the second version (-CLT) of multimedia (M= 1.82, SD=1.35), t(74)= .689, $p > .05$. Since there was no significant difference between students across conditions, it did not take into account as a co variance.

#### 4.1.3.2 Meiosis Findings

All subsequent analyses are performed using independent sample t-test. For all statistical tests a significance level of .05 was maintained.

**Score:** An independent sample t-test was conducted to compare students' score gained from multimedia between the first version (+CLT) and the second version (-

CLT) of multimedia program. Even though the students' score in the first version (+CLT) was higher (M=347.24, SD= 43.58) than that was in the second version (-CLT) of multimedia program (M=343.57, SD= 38.51), t(55)= .336, $p$ >.05, the result of independent sample t-test assuming equal variance (p=.62 larger than .05) showed that there was no significant difference in students' scores between the first version (+CLT) and the second version (-CLT) of multimedia program.

**Mental effort:** Even though the students' mental effort in the first version (+CLT) was lower (M=3.64, SD= 1.76) than that was in the second version (-CLT) of multimedia program (M=4.35, SD= 1.63), t(74)= -1.823, $p$ > .05, the result of independent sample t-test assuming equal variance (p=.31 larger than .05) showed that there was no significant difference in the students' mental effort between the first version (+CLT) and the second version (-CLT) of multimedia program.

**Main phase time:** Even though the time spent for sequencing main phases in the first version (+CLT) was higher (M=42.52, SD= 32.47) than that was in the second version (-CLT) of multimedia program (M=37.29, SD= 29.79), t(69)= .708, $p$ > .05, the result of independent sample t-test assuming equal variance (p=.16 larger than .05) showed that there was no significant difference in the time spent for sequencing main phases of meiosis between the first version (+CLT) and the second version (-CLT) of multimedia program.

**Main phase error:** The result of independent sample t-test assuming not equal variance showed that there was significant difference in the main phase error between the first version (+CLT) and the second version (-CLT) of multimedia program. The main phase error in the first version (+CLT) was higher (M=3.09, SD= 4.25) than that was in the second version (-CLT) of multimedia program (M=1.32, SD= 2.02), t(43.77)= 2.137, $p$ < .05.

**Each phase error:** Even though the number of each phase error in the first version (+CLT) was lower (M=9.90, SD= 7.49) than that was in the second version (-CLT) of multimedia program (M=9.97, SD= 6.49), t(69)= -.039, $p$ > .05, the result of independent sample t-test assuming equal variance (p=.75 larger than .05) showed that there was no significant difference in the number of each phase error between the first version (+CLT) and in the second version (-CLT) of multimedia program.

**Library use:** Even though the number of library use in the first version (+CLT) was lower (+CLT) (M=2.64, SD= 3.19) than that was in the second version (-CLT) of multimedia program (M=3.43, SD= 3.43), t(74)= -1.033, $p > .05$, the result of independent sample t-test assuming equal variance (p=.26 larger than .05) showed that there was no significant difference in the number of library use between the first version (+CLT) and the second version (-CLT) of multimedia program.

**Learning Time:** Even though the learning time spent in the first version (+CLT) was higher (+CLT) (M=1157.02, SD= 350.17) than that was in the second version (-CLT) of multimedia program (M=1109.54, SD= 295.66), t(74)= .640, $p > .05$, the result of independent sample t-test assuming equal variance (p=.58 larger than .05) showed that there was no significant difference in the learning time spent between the first version (+CLT) and the second version (-CLT) of multimedia program.

**Post-test Meiosis:** Even though the students' post-test score for meiosis questions in the first version (+CLT) was higher (M=3.75, SD= 1.60) than that was in the second version (-CLT) of multimedia program (M=3.38, SD= 1.31), t(74)= 1.110, $p > .05$, the result of independent sample t-test assuming equal variance (p=.19 larger than .05) showed that there was no significant difference in students' post-test scores for meiosis question between the first version (+CLT) and the second version (-CLT) of multimedia program. All analysis result for meiosis was presented in Table 4.7.

**Table 4.7** Independent sample t-test result for **meiosis** findings

| **Variable** | **Versions** | **N** | **M** | **SD** | **t** | **P** | **Effect Size** |
|---|---|---|---|---|---|---|---|
| Score | Version I | 29 | 347.24 | 43.58 | 336 | p>.05 | .09 |
| | Version II | 28 | 343.57 | 38.51 | | | |
| Post test | Version I | 37 | 3.75 | 1.60 | -1.110 | p>.05 | .25 |
| | Version II | 39 | 3.38 | 1.31 | | | |
| Mental effort | Version I | 37 | 3.64 | 1.76 | -1.823 | p>.05 | .42 |
| | Version II | 39 | 4.35 | 1.63 | | | |
| Library use | Version I | 37 | 2.64 | 3.19 | -1.033 | p>.05 | .24 |
| | Version II | 39 | 3.43 | 3.43 | | | |
| Learning Time | Version I | 37 | 1157.02 | 350.17 | .640 | p>/05 | .14 |
| | Version II | 39 | 1109.54 | 295.66 | | | |
| Main phase time | Version I | 34 | 42.52 | 32.47 | .708 | p>.05 | .17 |
| | Version II | 37 | 37.29 | 29.79 | | | |
| Main phase error | Version I | 32 | 3.09 | 4.25 | 2.137 | p<.05 | .64 |
| | Version II | 34 | 1.32 | 2.02 | | | |
| Each phase error | Version I | 33 | 9.90 | 7.49 | -.039 | p>.05 | .009 |
| | Version II | 38 | 9.97 | 6.49 | | | |

### 4.1.3.3 Instructional Efficiency for Meiosis

Instructional efficiency measure was conducted into two ways. Independent sample t-test was conducted to find out the instructional efficiency between conditions. All assumptions were justified for this test. For the first one, the score gained from multimedia and the mental effort during learning phase was used to calculate the efficiency and for the second one the score on the cell achievement test and the mental effort during learning phase was used to calculate efficiency measure and both presented in Table 4.8.

**Instructional efficiency- Learning phase:** An independent sample t-test was conducted to compare the instructional efficiency between the first version (+CLT) and the second version (-CLT). The result of independent sample t-test assuming equal variance (p=.1 larger than .05) showed that there was no significant difference in instructional efficiency between the first version (+CLT) (M=0.13, SD=.94), and the second version (-CLT) (M= -0.12, SD= .95). t(74)= 1.223, $p >$ .05.

**Instructional efficiency- Test phase (8 questions):** An independent sample t-test was conducted to compare the instructional efficiency between the first version (+CLT) and the second version (-CLT). The result of independent sample t-test assuming equal variance (p=.45 larger than .05) showed that there was significant difference in instructional efficiency between the first version (+CLT) (M=0.24 SD=1.01), and the second version (-CLT) (M= -0.22, SD= 0.91), t(74)= 2.131, p < .05 in favor of the first version (+CLT) of multimedia.

**Table 4.8** Efficiency measure of learning and test phase for **meiosis**

| **Efficiency** | **Versions** | **N** | **X** | **SD** | **t** | **P** | **Effect Size** |
|---|---|---|---|---|---|---|---|
| Instructional efficiency learning phase | Version I | 37 | 0.13 | .94 | 1.223 | P<0.5 | .28 |
| | Version II | 39 | -0.12 | .95 | | | |
| Instructional efficiency test phase | Version I | 37 | 0.24 | 1.01 | 2.231 | p>0.5 | .51 |
| | Version II | 39 | -0.22 | .91 | | | |

**4.2.**The Effects of Individual Difference and Cognitive Load on Learning Process and Learning Outcome (Research Question 1.2, 1.3 & 1.4, Study II)

To give an answer for the first research question, the following analysis was conducted. The result of the statistical analysis for the second study was presented.

### 4.2.1 Assumptions of Analysis

Three types of analysis were used to analyze data. These are Analysis of Covariance (ANCOVA), Analysis of Variance (ANOVA) and Kruskall Wallis non parametric test. ANOVA has three assumptions: Normality, equality of variances and independency of scores on the dependent variable. In addition to this assumption, ANCOVA has homogeneity of slopes assumption.

The assumption has been checked before the analysis. These three analysis procedures used as follows:

- If all assumption has been meet, ANCOVA was used to analyze data
- If ANCOVA assumptions were not meet, ANOVA assumptions were checked and used to analyze data
- If ANOVA assumption were not meet, Kruskall Wallis non-parametric test was used to analyze data

Normality assumption was checked via skewness and kutosis value. Although some of the dependent variable was not in the acceptable range, it was assumed that all dependent variable was normally distributed among conditions because of small sample size.

For the equality of variance assumption, Levene’s Test of Equality was used. If there was no equality of variance for each dependent variable, non parametric test was used to analyze data.

Independency of scores was examined. It was assumed that all students did their tests by themselves. The researcher and teacher observed all students participating in the study.

Homogeneity of slope test evaluated if there was an interaction between independent variables (IVs) and covariance (CV). For each dependent variable the interaction between independent variables (versions and working memory capacity, versions X working memory capacity) and covariance (prior knowledge) was tested.

### 4.2.2 Data Analysis for Mitosis and Meiosis

#### 4.2.2.1 Prior Knowledge for Mitosis and Meiosis

A cell achievement test was administrated to find out students' prior knowledge at the beginning of the study, two ways analysis of variance was conducted to find out difference in prior knowledge of students across conditions. The result of two way ANOVA showed that there was no significant difference in students' prior knowledge between two version of multimedia, working memory capacity and interaction between two versions of multimedia and working memory capacity, $F(1, 41) = .815$, $p=.37$; $F(2, 41)= 2.968$, $p=.06$; $F(2, 41)= 2.678$, $p= .08$, respectively. Although there was no significant difference with regard to the students' prior knowledge, the p value for WMC and interaction between WMC and two versions of multimedia was very close to significance level, hence, researcher decided to take into account the prior knowledge as a covariance.

#### 4.2.2.2 General Outcomes for Mitosis and Meiosis

Students learned mitosis and meiosis in two class hours. Hence, some of the variables such as mental effort, score, learning time, post-test and library use were measured at the end of the session.

Two way analysis of covariance (two way ANCOVAs) with between subjects factor was conducted by controlling students' prior knowledge. The independent variables were versions, included two levels, the first version (+CLT) and the second version (-CLT) and working memory capacity, included three levels, high, medium and low working memory capacity. For all statistical tests a significance level of .05 was maintained.

**Score:** Because the assumption of homogeneity of slopes violated, two ways ANOVA was used to analyze data. Main effect was found for multimedia versions (F (1, 41) = 4.26, p= 0.04, *η2 p=.09*. The strength of relationship between multimedia versions and score was medium. Students' score in the first version (+CLT) was higher (M=602.31 SD= 36.12) than that was in the second version (-CLT) of multimedia program (M=498.37, SD= 35.04). No main effect was found for working memory capacity (F (2, 41) = 0.84, p= 0.43, *η2 p=.04*) and no interaction effect was found for working memory capacity and multimedia versions (F (2, 41) = 0.04, p= 0.95, *η2 p=.0.002)* on the score gained from multimedia. In other words, there was no significant difference among students having different working memory capacity on the score gained from multimedia. The ANOVA result was presented in Table 4.9.

**Table 4.9** ANOVA result for the score gained from multimedia

| | **Condition** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | The first version (+CLT) | | | | | | The second version (-CLT) | | | | | |
| | High<br>n=6 | | Medium<br>n=8 | | Low<br>n=9 | | High<br>n=9 | | Medium<br>n=8 | | Low<br>n=7 | |
| | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD |
| Score | 630 | 78.7 | 612.5 | 141.6 | 564.4 | 208.1 | 523.3 | 143.0 | 527.5 | 172.1 | 444.2 | 225.8 |

The high WMC students had highest mean (*M* = 630.00), the medium WMC students had s smaller mean (*M* = 612.50) and the low WMC students had smallest mean (*M* = 564.44) for the score in the first version (+CLT) of multimedia. On the other hand, the medium WMC students had highest mean (*M* = 527.50), the high WMC students has a smaller mean (*M* = 523.33) and the low WMC students had smallest mean (*M* = 444.28) for the score in the second version (-CLT) of multimedia.

ANCOVA's with pre-test as a covariance are used in subsequent analyses and estimated marginal means are presented. Table 4.10 provides an overview of the general outcomes.

**Post-test:** No main effect was found for multimedia versions ($F$ (1, 40) = 0.36, $MSE$ = 1.94, $p$ = .55), working memory capacity (F (2, 40) = 1.16, MSE = 6.29, p = .32) and no interaction effect was found for working memory capacity and multimedia versions ((F (2, 40) = 1.22, MSE = 0.55, p = .30) on the post-test. The high WMC students had highest adjusted mean (M = 6.96), the low WMC students had smaller adjusted mean (M = 6.29) and the medium WMC student had the smallest adjusted mean (M = 5.90) for post-test in the first version (+CLT) of multimedia. On the other hand, the medium WMC students had highest adjusted mean (M = 6.83), the high WMC students had smaller adjusted mean (M = 6.53) and the low WMC students had smallest adjusted mean (M = 4.55) for post-test in the second version (+CLT) of multimedia. Regardless of the students' WMC, adjusted mean was found higher for the first version (+CLT) (M = 6.38) than that was in the second version (-CLT) of multimedia (M = 5.97) for post-test.

**Mental effort:** No main effect was found for multimedia versions ($F$ (1, 40) = 0.65, $MSE$ = 1.98, $p$ =.42), working memory capacity ($F$ (2, 40) = 0.08, $MSE$ = 0.26, $p$ = .91) and no interaction effect was found for working memory capacity and multimedia versions ($F$ (2, 40) = .86, $MSE$ = 2.62, $p$ = 42) on invested mental effort. The medium WMC students had highest adjusted mean ($M$ = 5.36), the high WMC students had smaller adjusted mean ($M$ = 4.88) and the low WMC students had smallest adjusted mean ($M$ = 4.80) for mental effort in the first version (+CLT) of multimedia. On the other hand, the high WMC students had highest adjusted mean ($M$ = 5.01), the low WMC students had smaller adjusted mean ($M$ = 4.78) and medium the WMC had smallest adjusted mean ($M$ = 3.99) for mental effort in the second version (-CLT) of multimedia. Regardless of the students' WMC, adjusted mean was found higher for the first version (+CLT) (*M* = 5.01) compared to that was in the second version (-CLT) of multimedia (*M* = 4.59) for the mental effort.

**Learning time:** No main effect was found for multimedia versions (*F* (1, 40) = 0.15, *MSE = 70440.47*, *p* = 69), working memory capacity (*F* (2, 40) = 0.81, *MSE* = 364568, 97, *p* =.42) and no interaction effect was found for working memory capacity and multimedia versions (*F* (2, 40) = 1.39, *MSE* = 627939, 25, *p* = .26) on the learning time spent during learning. The high WMC students had highest adjusted mean (*M* = 2930.36), the low WMC students has the smaller adjusted mean (*M* = 2739.11) and the medium WMC students had smallest adjusted mean (*M* = 2323.42) for the learning time in the first version of multimedia. On the other hand, the low WMC students had highest adjusted mean (*M* = 2978.56), the medium WMC students had smaller adjusted mean (*M* = 2749.08) and the high WMC students had smallest adjusted mean (*M* = 2552.22) for learning time in the second venison of multimedia. Regardless of the students' WMC, adjusted mean was found higher for the first version (+CLT) (*M* = 2741.29) compared to that was in the second version (-CLT) of multimedia (*M* = 2536.21) for the learning time spent during learning.

**Library use:** No main effect was found for versions of multimedia (*F* (1, 40) = 0.52, *MSE* = 45.90, *p* = .47), working memory capacity (*F* (2, 40) = 1.36, *MSE* = 119.92, *p* = .26) and no interaction effect was found for working memory capacity and multimedia versions (*F* (2, 40) = 2.32, *MSE* = 204.37, *p* = .11) on the frequency of library use. The high WMC students had highest adjusted mean (*M* = 12.71), the medium WMC students had smaller adjusted mean (*M* = 7.83) and the low WMC students had smallest adjusted mean (*M* = 4.21) for the frequency of library use in the first version (+CLT) of multimedia. On the other hand, the medium WMC had highest adjusted mean (*M* = 16.16), the high WMC had smaller adjusted mean (*M* = 8.91) and low WMC students had smallest adjusted mean (*M* = 6.37) for the frequency of library use in the second version (-CLT) of multimedia. Regardless of the students' WMC, adjusted mean was found lower for the first version (+CLT) ($M$ = 8.25) compared to that was in the second version (-CLT) of multimedia ($M$ = 10.27) for library use.

**Table 4.10** ANCOVA result for the general outcomes

| | Condition | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | The first version (+CLT) | | | | | | The second version (-CLT) | | | | | |
| | High n=6 | | Medium n=8 | | Low n=9 | | High n=9 | | Medium n=8 | | Low n=7 | |
| | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD |
| Post-test | 6.96 | 3.93 | 5.90 | 2.0 | 6.29 | 1.90 | 6.53 | 1.56 | 6.83 | 2.90 | 4.55 | 3.19 |
| Mental effort | 4.88 | 1.47 | 5.36 | 1.76 | 4.80 | 1.71 | 5.01 | 1.83 | 3.99 | 2.00 | 4.78 | 1.41 |
| Learning time | 2930.3 | 1088.5 | 2323.3 | 817.8 | 2739.19 | 530.5 | 2552.2 | 549.6 | 2749.0 | 384.8 | 2928.5 | 391.0 |
| Library use | 4.21 | 6.18 | 7.83 | 11.97 | 12.71 | 9.41 | 8.29 | 7.96 | 16.16 | 11.07 | 6.37 | 5.74 |

Note: Estimated marginal means are presented with pre-test as a covariance

#### 4.2.2.3 Mitosis Findings

**Main phase time: A** Kruskal-Wallis test was used to compare the six conditions on the main phase time spent in the two versions of multimedia. No effects of condition was found, H (5) = 6.95, $p$=.22. The medium WMC students had highest mean rank (mean rank= 25.44), the low WMC students had smaller mean rank (mean rank= 24.78) and the high WMC students had smallest mean rank (mean rank= 22.42) for the main phase time spent in the first version (+CLT) of multimedia. On the other hand, the high WMC students had highest mean rank (mean rank= 24.00), the medium WMC students had smaller mean rank (mean rank= 23.44) and the low WMC had smallest mean rank (mean rank= 23.36) for the main phase time spent in the second version (-CLT) of multimedia. Regardless of the students' WMC, mean rank was found higher for the first version (+CLT) (mean rank= 24.39) compared to that was in the second version (-CLT) of multimedia (mean rank= 23.63) for the main phase time spent. The mean number of conditions is presented in Table 4.14.

**Main phase error:** A Kruskal-Wallis test was used to compare the six conditions on the main phase error. No effects of condition were found, H (1)= 2.79, p=.09. The medium WMC students had highest mean rank (mean rank= 23.88), the low WMC students had smaller mean rank (mean rank= 21.89) and the high WMC students had smallest mean rank (mean rank= 16.50) for the main phase error in the first version (+CLT) of multimedia. On the other hand, the low WMC students had highest mean rank (mean rank= 30.64), the high WMC students had smaller mean rank (mean rank= 28.22) and the medium WMC had smallest mean rank (mean rank= 21.56) for the main phase error in the second version (-CLT) of multimedia. Regardless of the students' WMC, mean rank was found lower for the first version (+CLT) (mean rank= 21.17) compared to the second version (-CLT) of multimedia (mean rank= 26.71) for main phase error. The Kruskal Wallis result was presented in Table 4.11.

**Table 4.11** Mean numbers for the time spent for main phase and the main phase error for mitosis

| | Condition | | | | | |
|---|---|---|---|---|---|---|
| | The first version (+CLT) | | | The second version (-CLT) | | |
| | High n=6 | Medium n=8 | Low n=9 | High n=9 | Medium n=8 | Low n=7 |
| Main phase time | 22.42 | 25.44 | 24.78 | 24.00 | 23.44 | 23.36 |
| Main phase error | 16.50 | 23.88 | 21.89 | 28.22 | 21.56 | 30.64 |

**Each phase error:** A main effect was found for multimedia versions (*F* (1, 40) = 4.53, *MSE = 1764.98*, *p* = .03, $\eta$2p = .10). The strength of relationship between multimedia versions and each phase error was medium. The adjusted mean for each phase error rate was found significantly lower (M= 15.40) in the first version

(+CLT) compared to that was in the second version (-CLT) (M= 27.90) of multimedia. However, no main effect was found for working memory capacity (*F* (2, 40) = 1.97, *MSE* = 789.98, *p* =.15) and interaction effect for working memory capacity and multimedia versions (*F* (2, 40) = .05, *MSE* = 21, 88, *p* = .94) on the number of error for each phase.

The low WMC students had highest adjusted mean (*M* = 22.63), high WMC students has the smaller adjusted mean (*M* = 12.44) and the medium WMC students had smallest adjusted mean (*M* = 11.44) for the number of effort for each phase in the first version (+CLT) of multimedia. On the other hand, the low WMC students had highest adjusted mean (*M* = 37.68), the medium WMC students had smaller adjusted mean (*M* =23.83) and the high WMC students had smallest adjusted mean (*M* = 22.40) for the number of error for each phase in the second version (-CLT) of multimedia. Estimated marginal measn are presented in Table 4.12.

**Table 4.12** The result for each phase error of mitosis

| | **Condition** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | The first version (+CLT) | | | | | | The second version (-CLT) | | | | | |
| | High n=6 | | Medium n=8 | | Low n=9 | | High n=9 | | Medium n=8 | | Low n=7 | |
| | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD |
| Each phase error | 12.44 | 7.71 | 11.14 | 6.83 | 22.63 | 23.72 | 22.4 | 19.05 | 23.63 | 18.14 | 37.68 | 29.55 |

Note: Estimated marginal means are presented with pre-test as a covariance

#### 4.2.2.4 Meiosis Findings

**Main phase time:** A Kruskal-Wallis test was used to compare the six conditions on the main phase time spent. No effects of condition was found, H (5) = 8.62, *p*=.12. The low WMC students had highest mean rank (mean rank= 34.50), the medium WMC students had smaller mean rank (mean rank= 17.75) and the high WMC students had smallest mean rank (mean rank= 17.50) for the main phase time spent in the first version (+CLT) of multimedia. On the other hand, the low WMC students had highest mean rank (mean rank= 25.86), the medium WMC students had smaller mean rank (mean rank= 24.00) and the high WMC had smallest mean rank (mean rank= 21.94) for the main phase time spent in the second version (-CLT) of multimedia. Regardless of students' WMC, mean rank was found lower for the second version (-CLT) (mean rank= 23.77) compared to that was in the first version (+CLT) of multimedia (mean rank= 24.24) for the main phase time spent. The result was presented in Table 4.16.

**Each phase error:** A Kruskal-Wallis test was used to compare the six conditions on each phase error. A significant effect of condition was found, H (5) = 8.62, *p*=.12. Multiple comparisons among groups were conducted with Mann Whitney U test. The test result comparing the high WMC/first version (+CLT) and high WMC/second version (-CLT) were significant, z= -2.893, p=0.002 and showed a significantly lower error rate for the high WMC/first version (+CLT) (mean rank= 3.92) than the high WMC/second version (-CLT) (mean rank= 10.72). The test comparing the high WMC/first version (+CLT) and low WMC/second version (-CLT) were found significant, z=-2.152, p=0.03 and showed a significantly lower error rate in each phase for the high WMC/first version (+CLT) (mean rank= 4.50) than the low WMC/second version (-CLT) (mean rank= 9.14).

The test comparing the low WMC/first version (+CLT) and the high WMC/second version (-CLT) were found significant, z= -2.610, p= 0.009 and showed a significantly lower error rate for the low WMC/first version (+CLT) (mean rank= 6.22) than the high WMC/second version (-CLT) (mean rank=12.78). In addition, the test comparing the low WMC/first version (+CLT) and the low WMC/second version (-CLT) were found significant, z= -2.122, p= 0.03 and showed a significantly lower error rate in each phase for the low WMC/first version (+CLT) (mean rank= 6.28) than the low WMC/second version (-CLT) (mean rank=11.36). The result was presented in Table 4.13.

**Table 4.13** Mean numbers for the main phase time and each phase error of meiosis

| | Condition | | | | | |
|---|---|---|---|---|---|---|
| | The first version (+CLT) | | | The second version (-CLT) | | |
| | High n=6 | Medium n=8 | Low n=9 | High n=9 | Medium n=8 | Low n=7 |
| Main phase time | 17.50 | 17.75 | 34.50 | 21.94 | 24.00 | 25.86 |
| Each phase error | 14.50 | 23.25 | 18.17 | 32.67 | 20.56 | 33.29 |

**Main phase error:** No main effect was found for multimedia versions ($F$ (1, 40) = 0.5, $MSE$ = 15.70, $p$ = .46), working memory capacity ($F$ (2, 40) = 0.97, $MSE$ = 27.79, $p$ = .39) and no interaction effect was found for working memory capacity and multimedia versions (($F$ (2, 40) = 0.18, $MSE$ = 5.38, $p$ = .332) on the main phase error. The low WMC students had highest adjusted mean ($M$ = 3.23), the high WMC students had smaller adjusted mean ($M$ = 2.81) and the medium WMC student had the smallest adjusted mean ($M$ = 0.38) for the main phase error in the first version (+CLT) of multimedia. On the other hand, the low WMC students had highest adjusted mean ($M$ = 4.93), the high WMC students had smaller adjusted mean ($M$ = 2.62) and the medium WMC students had smallest adjusted mean ($MD$ = 2.50) for the main phase error in the second version (-CLT) of multimedia. Regardless of the students' WMC, adjusted mean was found lower for the first version (+CLT) ($M$ = 2.17) compared to that was in the second version of multimedia ($M$ = 3.35) for the main phase error. The estimated mariginal means was presented in Table 4.14.

**Table 4.14** The result for main phase error of meiosis

| | Condition | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | The first version (+CLT) | | | | | | The second version (-CLT) | | | | | |
| | High n=6 | | Medium n=8 | | Low n=9 | | High n=9 | | Medium n=8 | | Low n=7 | |
| | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD |
| Main phase error | 2.81 | 2.63 | .38 | 1.06 | 3.32 | 5.54 | 2.62 | 5.72 | 2.50 | 5.73 | 4.93 | 7.84 |

Note: Estimated marginal means are presented with pre-test as a covariance

#### 4.2.2.5 Instructional Efficiency Measurement

Instructional efficiency measure was conducted into two ways. Two ways ANOVA was conducted to find out the instructional efficiency between conditions. For the first one, the score gained from multimedia and the mental effort during learning phase was used to calculate the efficiency and for the second one the cell achievement test score and the mental effort during learning phase was used to calculate efficiency and presented in Table 4.15.

**Instructional efficiency- Learning phase:** Two ways ANOVA was used to compare the instructional efficiency between the first (+CLT) and the second version (-CLT). No main effect was found for multimedia versions (F (1, 41) = 0.65, p= 0.42, *η2 p=.01),* working memory capacity (F (2, 41) = 0.43, p= 0.64, *η2 p=.02)* and no interaction effect was found for working memory capacity and multimedia versions (F (2, 41) = 0.58, p= 0.57, *η2 p=.0.02* on the instructional efficiency for learning phase.

**Instructional efficiency- Test phase:** Two ways ANOVA was used to compare the instructional efficiency between the first (+CLT) and the second version (-CLT). No main effect was found for multimedia versions (F (1, 41) = 0.16, p= 0.68, *η2 p=.004),* working memory capacity (F (2, 41) = 0.16, p= 0.84, *η2 p=.008)* and no interaction effect was found for working memory capacity and multimedia versions (F (2, 41) = 1.27, p= 0.29, $\eta 2\ p=.0.05$ on the instructional efficiency for test phase.

**Table 4.15** Efficiency measure of learning and test phase for mitosis and meiosis

| | Condition | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Efficiency | High (+CLT) n=6 | | High (-CLT) n=9 | | Medium (+CLT) n=8 | | Medium (-CLT) n=8 | | Low ( +CLT) n=9 | | Low (-CLT) n=7 | |
| | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD |
| Learning phase | .32 | .74 | -.13 | 1.04 | .02 | .91 | .25 | 1.19 | 0.07 | 1.4 | -.51 | 1.34 |
| Test phase | .12 | 1.14 | -.15 | .78 | -.29 | 1.03 | .53 | 1.35 | -.01 | .97 | -.17 | 1.04 |

## 4.3. Students' Perception of Goal Based Scenario Designed 3D Constructivist Multimedia Learning Environment (Research Question 3, Study I)

To answer the third research question, students' perception of goal based scenario centered designed 3D multimedia learning environments, regardless of its different version, investigated both qualitatively and quantitatively Actual and preferred forms of constructivist multimedia learning environment survey was administrated to find out their perception. In addition, data gathered from reflective journals and focus group interviews were analyzed to understand their perception about the GBSc3DM in depth.

### 4.3.1 Assumptions of Paired Sample t-test

The data gathered from 74 students were analyzed using matched pairs t-test to investigate their perception on actual experience and their preferences with regard to goal based scenario designed multimedia learning environments. Matched pairs sample t-test has two assumptions: normality and independency of scores on the dependent variable.

For normality assumption, the difference between actual and preferred forms of CMLES for all subscales were calculated and then skewness and kurtosis values presented in descriptive way in Table 4.9. The value for skewness was approximately acceptable range for all subscales; however, kurtosis value was higher than the acceptable value which was ±1.0.

**Table 4.16** Descriptive statistics for each paired subscales of CMLES (N= 73)

| CMLES | Mean | SD | Range | Min | Max | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| Negotiation | -.1288 | .8335 | 5.40 | -1.3 | 3.6 | 1.240 | 4.699 |
| Inquiry Learning | -.2712 | .6095 | 3.00 | -2.0 | 1.0 | -.287 | .118 |
| Reflective Thinking | -3397 | .7451 | 4.80 | -3.4 | 1.4 | -.796 | 3.414 |
| Authenticity | -2795 | .7540 | 4.60 | -2.6 | 2.0 | -.353 | 1.626 |
| Complexity | -1660 | .7736 | 5.20 | -2.2 | 2.0 | -.688 | 3.429 |
| Challenge | .4215 | .6785 | 3.00 | -1.4 | 1.6 | -.347 | .164 |

The kurtosis values were not acceptable range for a normal distribution. However, each pairs had more than 30 cases so it was accepted as normally distributed according to central limit theorem. (Green & Salkind, 2008).

For the independency assumption, independency of scores was examined. This assumption was met one of the assumptions of the study. It was assumed that all participants fill in the forms by themselves. The researcher and teacher observed all students participating in the study.

### 4.3.2 Students' Perception of Their Actual Experiences and Preferences in Learning form GBSc3DM

Cronbach's alpha was calculated to test the reliability of the both forms of CMLES. For students' non-responses, unintentional skips on some items of the survey, this study processed these as ‘‘missing’’ data. The data gathered from 5 of the students were disregarded due to the high degree of incompleteness. In addition, 4 students who did not fill more than 50 % of the questions were excluded. Despite of being incomplete, 5 students' responses were not excluded because missing data by individual case totally was 8.2 % (one but different item were missing in each case) and mean substitution was used for missing data since it is considered an appropriate approach for likert type scales (Raaijmakers, 1999). Mean substitution is data imputation method for missing value in that a missing value for one variable is replaced with the mean value of that variable calculated for all persons answering the item (Hair, Black, Babin, Anderson & Tathem, 2006; Raaijmakers, 1999). For each subscale, reliability values were calculated for both actual and preferred form and presented in Table 4.17.

**Table 4.17** Cronbach's alpha value for subscales in actual and preferred form of CMLES (N=73)

| Scale | Actual (α) | Preferred (α) |
|---|---|---|
| Negotiation | .74 | .86 |
| Inquiry Learning | .78 | .82 |
| Reflective Thinking | .85 | .85 |
| Authenticity | .82 | .64 |
| Complexity | .75 | .65 |
| Challenge | .69 | .74 |

*Alpha Reliability for Actual .92 and for Preferred 89.*

Cronbach's alpha reliability coefficient was used as an index of scale for internal consistency. As shown in Table 4.10, the alpha values support satisfactory degree of reliability for the subscales except for the authenticity and complexity for preferred forms of the CMLES and challenge for actual form of CMLES. With the individual student as a unit of analysis, the alpha reliability ranges from .69 to .85 for the actual form and from .64 to .86 for the preferred form. This suggests that all scales except for the subscale of authenticity and complexity of the preferred form of CMLES and challenge for actual form of CMLES possess satisfactory internal consistency. Although .6 has been considered as a questionable value for consistency, it is generally accepted as a reliable in educational research. As a whole, the actual and preferred form of CMLES has an excellent and good reliability, .92 and .89 respectively (George & Mallery, 2003).

Matched pairs t-test was conducted to investigate students' perception of actual and their preferred learning environment. As presented in Table 4.18., the result of this study showed that there was a significant difference between students' perception of actual experiences and their preferences for negotiation, reflective thinking, authenticity and challenge. Cohen *d* was calculated to reveal the effects size of each subscale.

Both forms of CMLES consist of mainly two main parts. The first part tries to assess students' perception of their actual experiences and their preferences on *learning with multimedia* and the second part of the form consist of question assessing students' perception of *multimedia program* itself. The t-test result was presented separately for two parts of CMLES form.

**Table 4.18** Comparison of students' actual experience and preferences in GBSc3DM

| Scale | Version | X | SD | df | t | Effect size |
|---|---|---|---|---|---|---|
| Negotiation | Actual | 3.76 | .71 | 72 | -1.320 | .15 |
| | Preferred | 3.89 | .90 | | | |
| Inquiry Learning | Actual | 3.63 | .78 | 72 | -3.802* | .44 |
| | Preferred | 3.90 | .76 | | | |
| Reflective Thinking | Actual | 3.70 | .81 | 72 | -3.896* | .45 |
| | Preferred | 4.04 | .73 | | | |
| Authenticity | Actual | 4.07 | .71 | 72 | -3.166 | .37 |
| | Preferred | 4.35 | .54 | | | |
| Complexity | Actual | 4.29 | .64 | 72 | -1.833 | .21 |
| | Preferred | 4.46 | .54 | | | |
| Challenge | Actual | 4.58 | .76 | 72 | 5.307* | .62 |
| | Preferred | 4.15 | .69 | | | |

*$p$ < .001, effect size *cohen d*

**Learning with Multimedia:** It consists of mainly three subscales, *negotiation, inquiry learning and reflective thinking.* The result of matched pair t-test revealed statistically significant difference (p <.001) between preferred and actual scores for *inquiry learning and reflective thinking*. The findings for the first part of the scale indicated that while most of the students perceived that they between *often and sometimes* engaged in negotiation (M=3.76), most perceived that they *sometimes* engaged in inquiry learning (M=3.63) and reflective thinking (M=3.70). However, students preferred having more opportunities to engage in *negotiation* (M=3.89), *inquiry learning* (M=3.90) and *reflective thinking* (M=4.04) in learning with multimedia.

**Negotiation:** The result of the matched pair t-test indicated that the mean score for actual experiences (M=3.76, SD=.71) was not significantly lower than the mean score for their preferences (M=3.89, SD=.90), $t$ (72) = -1.320, $p$ > .001. The effect size index, $d$, was .15. Students expressed that learning with multimedia between *often and sometimes* allowed them to discuss with each other on how to conduct investigations and exchange ideas. They even preferred the learning environment allowed them more opportunities to engage in this process.

**Inquiry Learning:** The result of the matched pair t-test indicated that the mean score for actual experiences (M=3.63, SD=.78) was significantly lower than the mean score for their preferences (M=3.90, SD=.76), $t$ (72) = -3.802, $p$ < .001. The effect size index, *d*, was .44. *S*tudents felt that they *sometimes* find out answers to questions by investigation and solve problems on their own. They even preferred having more opportunities to involve in inquiry learning process.

**Reflective Thinking:** The result of the matched pair t-test indicated that the mean score for actual experiences (M=3.70, SD=.81) was significantly lower than the mean score for their preferences (M=4.04, SD=.73), $t$ (72) = -3.896, p < .001. The effect size index, *d*, was .45. Students felt that they between *often and sometimes* had chances to think deeply about their own ideas, new ideas and reflect on learning while learning with multimedia. The students even preferred to more engage in *reflective thinking* process.

**Multimedia Program:** It consists of mainly three subscales, *authenticity, complexity and challenge*. The result of the matched pair t-test revealed statistically significant difference (p <.001) between preferred and actual scores for *challenge*. Based on the literature, it was expected that preferred scores for multimedia program was higher than the actual scores however, all subscales result except for challenge showed consistent pattern with literature. This unexpected finding for challenge was discussed in the next chapter. The findings for the second part of the scale indicated that they *often* found multimedia program as *authentic* (M=4.07) and *complex* (M= 4.29) and they between *often and always* found it *challenging* (M=4.58). However, students preferred multimedia program to be more *authentic* (M=4.35), *easy to use* (M=4.46), however, they preferred the multimedia program to be less *challenging* (M=4.15).

**Authenticity:** The result of the matched pair t-test indicated that the mean score for actual experiences (M=4.07, SD=.71) was not significantly lower than the mean score for their preferences (M=4.35, SD=.54), $t$ (72) = -3.116, $p$ > .001. The effect size index, *d,* was .37. Students felt *often* that the tasks are realistic, representing a wide range of information, and relevant to their lives. They even preferred multimedia program to be more authentic.

**Complexity:** The result of the matched pair t-test indicated that the mean score for actual experiences (M=4.29, SD=.64) was not significantly lower than the mean score for their preferences (M=4.46, SD=.54), $t$ (72) = -1.833, $p$ > .001. The effect size index, *d,* was .21. Students found the multimedia program *often* interesting, fun, and fairly easy to use. They even preferred multimedia program to be more easy to use.

**Challenge:** The result of the matched pair t-test indicated that the mean score for actual experiences (M=4.58, SD=.76) was significantly greater than the mean score for their preferences (M=4.18, SD=.69), $t$ (72) = 5.307, $p$ < .001. The effect size index, *d,* was .62. Students found the multimedia program *between often and always* challenging that it allowed students to generate new ideas and questions, however; they preferred the multimedia program to be less challenging.

### 4.3.3 Students' Perception on Roles, Goals and Missions

Among 82 students, 79 students expressed their positive opinions about learning the content with *a mission and goals* in reflective journals. Three students did not express any negative or positive opinion and *they* stated that they can learn in any condition. The students having positive opinions expressed that learning the content with a *mission and goal* increased their interest toward content. Most of them indicated that this forced them to be more ambitious to complete the given task. They also mentioned that learning content with a *mission* makes learning process more enjoyable and long lasting. One student stated that *"While you have a* *mission, you feel that you have responsibility, and so you should learn better and do your best. In such a condition, you will learn better [S-1].”* Another student stated that *“You begin to do something to reach a goal. If I make a mistake it does not make me sad, because I am aware of the fact that I learn something.* [S-2]”

The other student expressed that “*Learning the content with a mission encouraged me to do the task, so this increases my ambition. I try to do my best to accomplish the task.* [S-3]”

The *role* given to the student in the multimedia was a scientist. Among 82 students, only three students expressed that the *role* was not important for them. Although most of the students have good impression with their *roles,* about half of them (40 students) expressed that the role was easy and it would be better to allow them to define the role’s characteristics before starting the program. One of the students expressed that “*The role gives me a sense of responsibility and makes me ambitious to complete the given task.* [S-4]” Another student stated that

> “*The role is fun and exciting. It helps me to understand the content easily. Being a scientist in the program increased my curiosity, and at the last, when I finished the task, I proud of myself and I believed in my intelligence. In sum, giving roles is more instructive.* [S-5]’’

Generally, they expressed that learning with *goals, missions and roles* increase their attention and encourage them to achieve the given task.

Among 82 students, 70 students expressed positive opinion toward learning with multimedia program. Six students mentioned that they could learn in any learning environment. Two students stated that although it was good experience learning with multimedia program, they learn by writing.  All students having positive perceptions conveyed that learning with multimedia makes learning easier compared to traditional classroom instruction, and it is easy to lose attention while they are in traditional classrooms. They indicated that they are responsible for their own learning in multimedia, and this makes learning more meaningful for them.

They also mentioned that learning with multimedia program makes learning easy, long lasting and fast. While they learn these topics in classroom they just memorize them, but they learned the content with multimedia program. Some statements from students responses in reflective journal are as follows: One student stated

> *"Learning with multimedia makes learning more enjoyable, faster and long lasting. I can easily lose my attention in the classroom but it is not the case for multimedia.* [S-6]"

Another student expressed that "*I can visualize the process with multimedia, and so it makes easier for me to understand the topic,*[S-7]*"*

*One of the students expressed that "I spend so much effort to solve the problem and to complete the given task, so I have to learn the content. But, it is not the case for the classroom, I just memorize the information.* [S-8]'

The interview data supports the findings from reflective journals in that all students expressed that learning with *scenarios* is much better than traditional classroom instruction. Learning with *scenarios* makes learning more meaningful for them. They also expressed that learning with *scenarios* show them why the content is important for them. This result showed us that students were aware of why they were learning this content, and what the importance of the content was for the real life. One student stated that "*The scenario has been developed based on real life so I have learned why it is important for our life.* [S-9]"

Another student indicated that "*It is the first time for me to understand why I need to learn mitosis and meiosis, and how it is important for our life.* [S-10]" This is the most important purpose of the goal based scenario.

## 4.4. Students' Satisfaction and Motivation on Cognitive Load in Learning from Goal Based Scenario (Research Question 2, Study I)

To answer the second research question, reflective journals and interviews data were analyzed. Students were asked to express their opinions on multimedia design whether there were things that make it more difficult or easier to focus while learning from the multimedia. Also, they were asked to express their thoughts and feelings about multimedia learning environment. Only 47 students answered this question very detailed in their reflective journals. The students used the first version (+CLT), expressed positive opinions about the program. One of the students stated that

> "*Narration makes it easy for me to understand, because it makes easier to involve in the learning process. So, I can easily adapt and then everything goes on automatically*. [S-11]"

Another student stated that "*The only thing that helped me to focus is the narration*. [S-12]" Students' opinions with regard to the second version (-CLT) were different. One of the students expressed that "*Yes, I could not focus my attention because of the classic music in the background of the program. However, the animations make it easy for me to focus on.* [S-13]"

The other students indicated that "*I believe that meioses should be designed as mitosis. The animations should be narrated, because narration makes learning easier*. [S-14]"

Although students expressed that using animation in both versions were very beneficial for them, they stated that violating **modality** and **coherence** principles made it difficult for them to learn from the multimedia and decreased their motivation. Students mostly expressed their satisfaction and motivation on **modality** and **coherence** principles in reflective journals. However, it is not possible to draw conclusion from reflective journals about other principles applied in the multimedia. Therefore, the data gathered through the interviews were used to draw conclusions for the other principles.

The students should sequence the main phases in mitosis and meiosis. In the first version, both pictures and text were given to students, however, in the second version, only the text was presented. With regard to the **multimedia** principle, 14 students stated that they prefer to use text only. However, the other eight students stated that they preferred pictures. Five of them stated that both are convenient for them. They expressed that they are engaged deeply learning while there are pictures and text, and this increase their interest toward the program. One student mentioned that "*When I worked with pictures, I invest more effort to understand*. [S-13]"

However, they expressed that if they know the content, working with text only condition is more beneficial for them. One student indicated that *"If I know the content, I do not need to look at pictures to sequence the phases in correct order*. [S-15]"

The **multimedia** principle also applied in the design of library. Although most of the students expressed their opinion about the design of sequencing the main phases, only some students who used the library expressed their opinions about the **multimedia** principle applied in design of the library. In the library design of the second version (-CLT), each hyperlink appeared on a new window. Nine students expressed that this feature which is called the **split attention**, hurt their motivation and attention. This made the learning procedures more stressful for them and so it affected their satisfaction of the program in negative ways. One of the students indicated that

> "*When each time a new page opens on the screen, this makes it stressful for me and seeing the information on the same page would be more beneficial for me*. [S-16]"

In terms of the **redundancy**, in the design of the first version (+CLT) the choice was given students for both subtitle and audio narration. They can select one of them or use both. However, in the second version (-CLT), there were subtitle and background music without choice. 11 students stated that they followed only audio narration and ignored the subtitles in the first version (+CLT) of multimedia. One of the students expressed that "*The audio narration is enough for me to understand the animation. The voice tone that is used is very good so I can easily focus on the content.* [S-17]"

Two of them stated that both reading subtitle and hearing voice make it difficult for them to understand the content so they preferred the audio narration choice.

Eight of the students preferred both subtitle and audio narration. One student expressed that using both subtitles and voice simultaneously make the content long lasting and helps me to ignore classroom noise. Although students watch animation either by narration or by subtitle, all of them expressed that narration was much more preferable for them, and increased their motivation toward learning. One student stated that

> "*For example, my interest was decreased when I learn meiosis. When I tried to read subtitles I felt that I could not catch up with the content and this made it even more difficult for me to learn.* [S-18]"

## 4.4. Summary of the Results

The summary of this chapter is presented into two parts. Firstly, the findings of the first study are summarized. Then, the result of second study is presented.

The result of the first study showed that the principles aiming to reduce extraneous cognitive load can enhance both learning process and the learning outcome. It is found that the students in the first version (+CLT) made significantly lower error in sequencing the each phase of mitosis and increased the score gained from multimedia in mitosis, decreased the invested mental effort and the time spent for sequencing main phases than the students in the second version (-CLT) of multimedia. The principles also significantly increased the efficiency of the learning phase in the first version (+CLT) of multimedia in mitosis. However, the only significant difference was found for the main phase error in meiosis in favor of the second version (-CLT) of multimedia. On the other hand, the principles also significantly increased the efficiency of the test phase in the first version (+CLT) of multimedia in meiosis.

The result of the first study showed that the principles of cognitive load aiming to reduce cognitive load increase the students' motivation and satisfaction in a positive ways. On the other hand, violating those principles affect the students' motivation and satisfaction in negative ways. Generally, nearly all students expressed that goal based scenario as an effective instructional approach and stated positive opinion about context, roles and mission given in the scenario.

The result of the second study showed that the principles aiming to reduce extraneous cognitive load increased the students' scores gained from multimedia and decreased the number of error sequencing each phase in mitosis in the first version (+CLT) of multimedia. The effects of working memory capacity were only found out in the number of error in sequencing each phase of meiosis. The high WMC/first version (+CLT) and the low/ first version (+CLT) made significantly lower error in sequencing the each phase of meiosis than the high WMC/second version (-CLT) and low WMC/second version.

# CHAPTER 5

# DISCUSSION, CONCLUSION AND IMPLICATIONS

The findings of the study were presented in detail in previous chapter. In the light of the findings, the aims of this chapter are to discus and interpret the findings and implications and recommendations for further research. .

## 5.1. Overview

Goal based scenario is one of the instructional method that the constructivists paradigm offers. Goal based scenario has provide a complex learning environment by engaging students in investigating and deciding processes. By doing so, students know not only why they need to know the content but also to learn how to use that knowledge (Schank et.al., 1994).

Goal based scenario offers realistic environments for complex learning tasks and has the potential to motivate learners, however, the severe risk of this approach is that the task complexity is high and if the learners cannot handle the task complexity, because of overload on working memory capacity, it might hinder learning (Van Merriënboer, Kirschner, & Kester, 2003). To eliminate this overload, the limitation of learners' working memory should be taken into account. Cognitive load theory provides valuable guidelines on how to deal with this overload (Van Merriënboer, Kirschner, & Kester, 2003). In addition to CLT, the cognitive theory of multimedia learning (Mayer, 2005) also provides guidelines aim at reducing ineffective cognitive load or extraneous cognitive load which hampers learning. Therefore, it is very important to take into account the principles that developed by CTML and CTL while using GBS as an instructional approach for computer based learning environment. The combination of these might be expected to increase both effectiveness and efficiency of the instructions.

For the present study, both qualitative data and quantitative data were collected separately in such a way that qualitative data were collected through reflective journals and interviews and quantitative data were collected through test, forms and log files separately. Quantitative data were analyzed through a series of independent sample t-test, matched pairs t-test and two way analysis of variance-covariance, kruskal Wallis to investigate the effects of principles on learning processes and learning outcome. On the other hand, the data gathered through reflective journals and interviews were subject to content analysis. The research questions were focused and deductive coding was used to draw themes from interview and reflective journals. Through the content analysis, main themes were withdrawn and then the data were interpreted under these themes to provide insights how the extraneous cognitive load affects students' motivation and satisfaction.

In the following chapter, I will discuss all results of this study and the possible reasons for these results. At the end of the chapter, the implications and the recommendations for further research were presented.

## 5.2. Discussion and Conclusion

Design principles aim to reduce extraneous cognitive load in multimedia learning has been widely investigated among researchers in laboratory setting. However, it is pointed out that if those principles cannot be demonstrated in classroom environment with students, as it is in laboratory settings, their practical value for education and their theoretical values for multimedia learning are limited (Harsmkap et al., 2007). In actual classroom settings, students involved in learning activities longer time compared to laboratory settings and it is important to examine both learning process and learning outcome to understand the effects of implementing these principles for actual classroom settings.

### 5.2.1 The Effects of the Cognitive Load Principles on Learning Process and Learning Outcome (Research Question 1.1, Study I)

Students learned mitosis and then meiosis in line with the curriculum in regular biology courses. Teacher made a brief introduction to arouse students' interest towards the content, *mitosis and meiosis*, and made some technical terms clear for them because it is known that technical terms or unknown verbs can affect learning outcome (Van Gog et al., 2006, 2008; Dunsworth & Atkinson, 2007). In addition, a dictionary part was added to both versions of multimedia. Students were allowed to ask questions for ten minutes. After that, the teacher' role was a guider throughout the study and students used the multimedia program to complete the given tasks. Since all process takes place in *"cells"*, a small 3D game was designed to provide opportunities for students to be familiar with cell environments for the first week. In addition, the game was used as a motivational component to increase uninterested but the potential learners' interest so that they can engage in learning activities (Schaller et al., 2001). Their task was to collect glucoses to prepare cells for division process and eradicate viruses in cells. Time and score gained from that part of the multimedia did not taken into account in analysis.

The combination of those principles was used to design the multimedia learning environments. Therefore, it can be inferred that studying those principles one at a time or combining those well known principles in a more complex learning environments for actual classroom setting increase the effectiveness and efficiency of learning processes. As indicated before, most of the studies has been conducted in laboratory settings and follow strict experimental design such as one variable at a time. Therefore, the interpretation derived from the present study result was discussed based on findings of each principle in the literature.

Students completed the tasks in the multimedia program for two weeks. As it was expected from study, students invested significantly lower mental effort in mitosis in favor of the first (+CLT) of multimedia. Cognitive load theory and cognitive theory of multimedia learning based their assumption on limited working memory capacity. It is assumed that principles such as split attention, modality, and redundancy can help students to invest less mental effort which is considered ineffective or hinder learning (Sweller, Chandler, Tiermey & Cooper, 1990; Sweller et al., 1998; Kalyuga et al, 2003; Tindall-Ford, Kalyuga, Chandler & Sweller, 1997). In addition, it is expected that principles aiming to reduce mental effort which is extraneous would increase students' performance. Two types of performance data were collected. The first one was the score gained from the multimedia program and the other one gained from the factual knowledge test. For the first one, the students had to sequence the main phases of mitosis and meiosis in the correct order, and then should sequence each event of main phases correctly. There are four main phases of mitosis needs to be sequenced into correct order and eight main phases for meiosis. After that, each main phase's events needs to be sequenced correctly and the number of events vary across main phases. For example, there are four sub items for the first main phase of the mitosis and students get 10 points for each right answer and lost 10 point for wrong answers. For the second one, test score was computed based on five questions about mitosis and eight question about meiosis in cell achievement test.

There was statistically significant difference in scores gained from multimedia between the first version (+CLT) and the second version (-CLT) of multimedia in mitosis. In addition, significant difference was found for mental effort between conditions. The students performed significantly better and invested significantly lower mental effort in the first version (+CLT) compared to the second version (-

CLT) of multimedia for mitosis. However, significant difference was not found for test scores between two versions of multimedia. The test scores was found similar between the first (+CLT) and the second version (-CLT) of multimedia in mitosis. Paas and Van Merriënboer (1993) state that only measuring learning outcome provide information about the effectiveness of the instruction. On the other hand, combining mental effort with performance data can give valuable information about instructional efficiency of treatment and practical value of the treatments for education. In original measure of instructional efficiency, invested mental effort in test and test performance was used to calculate the efficiency. However, most of the researcher used adaptive measure of instructional efficiency by combining mental effort invested in learning and learning performance or test performance.

As pointed out by Van Gog and Paas (2008), original efficiency measure can give information about the instructional efficiency; however, adaptive efficiency measure yield valuable information about learning efficiency. The authors also stated that learning efficiency measure could be used when performance are similar between conditions and when the researchers aim to reduce the extraneous cognitive load, otherwise, efficiency measure could show contradicting result. Adaptive efficiency measure was used for present study since it aims to investigate the effects of instructional format reducing extraneous cognitive load and to find out the effects of this intervention in both learning process and the learning outcome.

Instructional efficiency or learning efficiency which was computed by invested mental effort in learning and score gained from multimedia was found statistically significant in favor of the first version (+CLT) for mitosis. The students performed significantly better and invested significantly lower mental effort in the first version (+CLT). In addition, instructional efficiency for the learning phase was found significant in favor of the first version (+CLT) in learning mitosis. That is, applying the cognitive load principles increase learning efficiency when the students learning mitosis. In literature, adaptive instructional efficiency measure has been conducted in two ways. Mental effort invested in learning phase combined with performance in learning (Corbalan, Kester, & Van Merriënboer, 2006; Salden, Paas, Broers, & Van Merriënboer, 2004; Salden, Paas, & Van Merriënboer, 2006) and the mental effort combined with test score to calculate the instructional efficiency (Tindall-Ford, Chandler, & Sweller, 1997; Van Merriënboer, Schuurman, De Croock, & Paas, 2002). Instructional efficiency computed with learning outcome in learning process and invested mental effort in training is mainly studied in adaptive learning environment. It was found that dynamic task selection (Salden et al., 2004), adaptive task selection (Salden et al., 2006) and personalized task selection with shared control (Corbalan et al., 2006) result in higher efficiency than, non-dynamic task selection, non adaptive task selection and personalized task selection with program control, respectively. The current study was designed as a game based learning environment; hence, there was no adaptation process based on mental effort in learning. As it was expected, principles implemented in complex learning environments have significantly increased the learning efficiency in the first (+CLT) version of multimedia compared to the second version (-CLT) of multimedia in mitosis.

On the other hand, the efficiency measure computed with invested mental effort in learning and test performance was not found significantly different between the first version (+CLT) and the second version (-CLT) of multimedia for mitosis. However, it was found high for the first version (+CLT) and low for the second version (-CLT) of multimedia. This result might be explained by the nature of the measurement conducted in learning phase and test phase. In learning phase, the students need to sequence main phases and events occurred in each phases and it was expected students to apply newly acquired knowledge in order to complete the given task. However, the question asked in cell achievement test was much more difficult questions requiring learners to transfer their knowledge. Therefore, it can be concluded that applying principles aiming to reduce extraneous cognitive load can help schema construction for newly acquired knowledge in learning mitosis. This conclusion was supported with additional data recorded during the learning phase in mitosis. The students did statistically significant lower error for sequencing each phase in the first version (+CLT) of multimedia than the second version (-CLT) in mitosis. Although it was not significant, error rate for main phase was found lower in the first version (+CLT) compared to the second version (-CLT).of multimedia for mitosis.

The implementation of principles aiming to reduce extraneous cognitive load result in lower error rate for sequencing each phase, lower mental effort and lower error rate for main phases in the first version (+CLT) compared to second version (-CLT) in learning mitosis. Based on these results, it can be concluded that the principles implemented in multimedia enhance learning process and result in significantly higher efficiency in first version (+CLT) of multimedia compared to the second version (-CLT). It can be concluded that applying the principles both increase the effectiveness and efficiency of learning processes for mitosis in the study.

Students learned meiosis in the second week of study. In addition to the variable measure during mitosis, learning time was calculated for meiosis. Learning time or time on task has been considered as an objective online measure of cognitive load (Van Gog & Paas, 2008). It is stated that the leaning time between conditions can interfere with the performance and the difference in learning time between conditions might be the reason for difference found in performance between conditions (Van Gog et al., 2006). If a constant time was given to participants to complete the given task in all experimental condition, there was no need for measuring time spent during the learning. However, the multimedia program developed for the present study was a self paced material. Since there was no time limitation, the times spent for the learning vary among students in all conditions. Therefore, the learning time was measured and analyzed across conditions in meiosis in order to eliminate the possible interference of the time spent during learning.

There was no statistically significant difference in the scores gained from multimedia between the first version (+CLT) and the second version (-CLT) in meiosis. In addition, there was no significant difference for the learning time, the performance on test, the frequency of library use, the errors rate for sequencing each phase, time spent for sequencing main phase and invested mental effort. On the other hand, significant difference was found in error rate for sequencing main phases in favor of the second version (-CLT) of multimedia. Although the standard deviation was found higher than the mean score and interpretation of this result was risky, it can be concluded that text only condition was found better than the picture and text condition for meiosis. In order to sequence the main phase students were provided with text and picture in the design of the first version (+CLT); however, text only condition was given to students in the second version of multimedia (-CLT). It was found that text only format result in lower error rate and time for sequencing main phase than the text and picture format in meiosis. On the other hand, the reverse pattern was found for mitosis in that picture and text condition result in lower error rate than text only condition. It can be inferred that having both picture and text was became redundant when students learned meiosis based on well known principle, expertise reversal effect. This result can be supported by qualitative finding of this study such that students expressed that if they knew the content the text condition was enough for them, however, if they did not know the content they benefit from pictures.

The possible reasons for the difference between mitosis and meiosis can be explained by expertise reverasal affect, the similarities between mitosis and meisosis and the students’ characteristics and additional avtivity given to students. Firstly, according to expertise reversal effect, the superiority of instructional format reducing extraneous cognitive load such as redundancy, split attention, modality for novice or inexperienced learners may disappear or reverse for experienced learner (for a review, Kalyuga et al., 2003). It is asserted that some information became redundant with increased knowledge level, interferes with learning process and needs to be eliminated. For example, it was found that inexperienced electric trainees benefited more from the diagrams incorporated with textual information for electric circuits than diagram only condition (which assumes to reduce split attention), on the other hand, more experienced trainees performed significantly better in diagram only condition for electric circuit problem (Kalyuga, Chandler & Sweller, 1999). In this study, it can be inferred that picture might became redundant while sequencing main phases because of students' increased knowledge level during instruction. In addition, the effects of instructional formats were disappeared between the first version (+CLT) and the second version (-CLT) of multimedia in learning meiosis compared to mitosis.

Secondly, mitosis and meiosis are two sub units of cell division process and mitosis was given before the meiosis in biology textbooks and school curriculum. Although mitosis is not a prerequisite content that needs to be learned before meiosis, mitosis was given to the students before meiosis in line with the biology curriculum. However, there are some similarities between mitosis and meiosis process; hence, it can be inferred that having learned mitosis, the students knowledge level was increased and that eliminate the benefits of instructional formats reducing extraneous cognitive load for meiosis which was found during mitosis.

Thirdly, students' characteristics and additional activity report given as homework could be additional factors that affect the results between mitosis and meiosis. The students were accepted to this school (Anatolian High School) as a result of a very competitive exam, and those are high achiever students in Ankara. In addition, all students returned their homework on time and except for two students all got full score. Therefore, it would be inferred that their knowledge level has been increased rapidly in mitosis before learning meiosis.

Actually, it could be expected that the effects of instructional formats reducing extraneous cognitive load would be much more influential for meiosis than mitosis because of meiosis higher complexity than mitosis. Intrinsic cognitive load is related with the complexity of content to be learned and it is asserted that the effects of instructional formats reducing extraneous cognitive load or increasing germane load are more influential when the content is complex and needs to be learned simultaneously (Ayres, 2006a, 2006b; Sweller et al., 1998). Meiosis is more complex than mitosis in terms of element interactivity, however, the research was conducted in natural learning environment in line with course curriculum and order of the content was not changed during the study. As a result, the possible effects of task order on results cannot be controlled for this study.

Two types of instructional efficiency measure were conducted for meiosis also. Instructional efficiency or learning efficiency which was computed by invested mental effort and score gained from multimedia was not found statistically significant between the first version (+CLT) and the second version (-CLT) of multimedia in meoisis. However, it was found high for first version (+CLT) and low for the second version (-CLT) of multimedia. On the other hand, the efficiency measure computed with invested mental effort in learning and test performance was found significantly different in favor of the first version (+CLT) of multimedia. The principles implemented in the complex learning environment have significantly increased the learning efficiency for the test phase in the first version (+CLT) of multimedia compared to that was in the second version (-CLT) of multimedia in meiosis.

As stated previously, the question asked in cell achievement test was much more difficult questions requiring learners to transfer their knowledge than the task given to the students in the multimedia learning environments. It was expected that the students apply newly acquired knowledge in order to complete the given task and scores gained from multimedia was calculated based on these performance. The instructional efficiency calculated based on invested mental effort in learning and scores gained from the multimedia was not found significantly different between two versions of multimedia in meiosis. In addition, there was no significant difference in almost all variables measured during learning phase between two versions of multimedia in meiosis. On the other hand, instructional efficiency computed with invested mental effort during learning and test performance was found significantly higher in the first version (+CLT) of multimedia compared to that was in the second version (-CLT). This result can be explained by additive feature of intrinsic cognitive load, extraneous cognitive load and germane cognitive load (Paas & Kester, 2006) in that both groups learned meiosis so it can be assumed that intrinsic cognitive load results from task complexity was similar across conditions. On the other hand, extraneous cognitive load was manipulated between conditions and it can be said that the reduction of extraneous cognitive load in instruction would reduce the ineffective mental load and provide opportunities for students to engage in more constructive process which is effective for learning (e.g germane) in the present study. In other words, the cognitive load principles aming at reduction of extraneous cognitive load decreases the ineffective mental effort invested in learning process. This effort is ineffective and it does not contribute to the construction of schema or actual learning. Since instrinsic, extraneous and germane cognitive load are considered as an additive, the reduction of ineffective or extranous load provide opportunities for learners engage in more constructive process. Therefore, the instructional efficiency for the test phase was found higher in the first version (+CLT) compared to the second version (-CLT) in meiosis. In other words, reducing extraneous or ineffective cognitive load provides opportunities for the students to increase the instructional efficiency for the test phsse in favor of the first version (+CLT). This conclusion should be investigated further by administrating different scale measuring intrinsic, extraneous and germane cognitive load at the same time.

### 5.2.2 The Effects of Individual Difference and Cognitive Load on Learning Process and Learning Outcome (Research Question 1.2, 1.3 & 1.4, Study II).

Working memory capacity as an individual difference variable was also investigated in the second study. Students were divided based on their working memory capacity as a high, moderate and low, assigned to the first version (+CLT) and the second version (-CLT) of the multimedia. Eventhough the students were divided as a high, medium and low WMC, the finding were mainly discussed for high WMC and low WMC students because the comparison of high and low WMC students is more frequently studied and discussed in research studies. The students learned mitosis and meiosis in one week in two class hours. Some of the variables were recorded for the whole process. These are: *score, post-test, learning time, mental effort and library use.* The other variables which are *main phase time, main phase error and each phase error* were measured both for mitosis and meiosis separately.

Among the variables measured for whole process, a main effect of multimedia versions was found only for the score gained from multimedia. No main effect was found for multimedia versions, working memory capacity and interaction between working memory capacity and multimedia versions in variables measured for whole process. The students attending in the first version (+CLT) gained significantly better score than the students attending the second version (-CLT) of multimedia program. In previous study, the same significant difference was found between the first version (+CLT) and the second version (-CLT) of multimedia. Although there is no significant difference between versions on mental effort, post-test score and learning time, these variables was found higher in the first version (+CLT) than the second version (-CLT) of multimedia. It can be concluded that, despite of being not statistically significant, applying cognitive load principles aming at reduction of cognitive load increased the performance and invested mental effort. It is pointed out that if the performance and cognitive load has been increased at the same time, the mental effort can be considered as germane cognitive load (Van Gog et al., 2006). In addition, the learning time is considered as an objective online measure of cognitive load (Van Gog & Paas, 2008). As it is found, the learning time and mental effort was found higher in the first version (+CLT) and than that was in the second version (-CLT) of multimedia. It can be concluded that applying cognitive load principles increase the students' performance and provide opportunites for them to invest mental effort which is effective.

However, the frequency of library use is found lower in the first version (+CLT) than that was in the second version (-CLT) of multimedia. This result is consistent with the first study result such that the students need to look for more additional resources when cognitive load principles were not implemented (e.g second version of multimedia (-CLT)). To explain in another way, the students store upcoming information in order to process the given task. When cognitive load principles implemented, they are able to handle incoming information because the information was designed to not overload working memory capacity and the students have enough capacity to store and manipulate information to do the task without looking for additional information. On the other hand, when cognitive load principles were not implemented, the upcoming information can overload working memory and the students need to look for additional resources when doing the task following the instruction. It can be conluded that applying the principles of cognitive load help students to engage in learning process and not overload their working memory capacity.

Although there was no significant difference in variables measured for whole process, it can be concluded that both high and low working memory capacity students benefited more from the first version (+CLT) than second version (-CLT) of multimedia To illustrate, adjusted mean for post-test score for high, moderate and low WMC students are 6.96, 6.29 and 5.90 in the first version (+CLT), however, it is 6.53, 6.83 and 4.55 in the second version (-CLT) of multimedia respectively. The similar result was found in previous research study in that elderly and young age groups benefit most from bimodal condition of instructional format and invested less mental effort, particularly; elderly participants benefit more from bimodal condition (Van Gerven et al., 2003). On the contrary, in more recent study, there was no significant difference for modality and variability of worked example between elderly and young participants and they invested less mental effort in both conditions (Van Gerven et al., 2006). In addition, it is found that students having high and low visual span benefit from split attention principle (Mayer & Sims, 1994). It can be said that the students having different WMC benefit more from the cognitive load principles aiming at reduction of extraneous cognitive load in the multimedia design. Therefore, the principles of cognitive load should be taken into account in designing learning environments in order to meet the needs of different individuals' characteristics.

Main phase time, main phase error and error of each phase were measured for mitosis. No main effect for multimedia versions, working memory capacity and interaction between working memory capacity and multimedia versions for main phase time and main phase error. Only main effect of multimedia versions was found for each phase error. The students in the first version (+CLT) made significantly lower error in sequencing each phases than that was in the second version (-CLT) of multimedia. This result is consistent with the first study. Although no main effect for WMC was found, the mean score for each phase error of high and low WMC students might illustrate how those students affected by different version of multimedia. High WMC student made the lower error in sequencing each phase in both versions compared to low WMC students. In addition, the error rate was increased in the second version of multimedia both for high and low WMC students. The similar result was found in main phase error for both high and low WMC students in that high WMC student made lower error in both versions of multimedia compared to low WMC students. Although it is not statistically significant, it can be inferred that both high and low WMC students performed better in the first version (+CLT) of multimedia. In other words, applying cognitive load principles decrease the error rate made in learning mitosis and increase the learning processes.

Main phase time, main phase error and error of each phase were measured for meiosis also. No main effect was found for main phase time and main phase error between two versions. A main effect of condition was found in each phase error rate. High WMC students in the first version (+CLT) made significantly lower error in sequencing each phases than the high WMC students and the low WMC students in the second version (-CLT) of multimedia. Also, low WMC students attending the first version (+CLT) of multimedia made significantly lower error than the high WMC and the low WMC students attending the second version (-CLT) of multimedia.

The effect of WMC was only obtained in each phase error rate. The possible reason for this finding might be related to the task itself. In other words, meiosis had 8 sub phases and each phase has several sub items needs to be sequenced correctly. This task is relatively difficult than the other task given in the learning environment. That is why the only difference of condition for WMC was found for this variable. In addition, this task demanded more attention to maintain task goal. In previous research, the difference between high WMC and low WMC can only observed when task demanded more attention to complete the task (Kane & Engle, 2003). In another study, performance difference between high and low WMC students found out in anti saccade task than the pro saccade task (Kane, Bleckley, Conway & Engle, 2001). In conclusion, the task characteristic requiring demanded attention for a task is an important factor that reveals performance difference between the high WMC and the low WMC participants.

The influence of working memory capacity as an individual difference has been explored for different tasks and context. The findings is somewhat mixed. The effects of WMC on different task such as divided attention (Colflesh &Conway, 2007) and selective attention in dichotic listening (Conway, Cowan &Bunting, 2001) has been explored. It is found that based on the task demand the high WMC participants and low WMC participants show different performance in that 60% of low WMC students report their name and only 20% of high WMC reported hearing their name in selective attention dichotic listening (Conway et al, 2001). On the other hand, 66.7% of high WMC heard their name compared to 34.5% of low spans heard their name in divided attention dichotic listening (Colflesh &Conway, 2007). To explain these findings, Colflesh and Conway (2007) expressed that the high WMC is able to configure their attention based on *task goal*. On the other hand, the low WMC participants are more inclined to be affected by salient distractor in selective attention dichotic listening.

In another study, the effects of WMC and reading purposes on reading comprehension for young participants have been explored (Cankaya, 2007). No effects of reading purposes and WMC were found on reading comprehension. However, the low WMC participants made significantly more evaluative judgment while reading for game purposes than the test condition. However, in previous research conducted with adult participants showed that low WMC participants produced less predictive inferences than high WMC participants (Linderholm & Van den Broek, 2002). Cankaya (2007) explained this contradicting finding as an effect of age differences in both samples.

The effects of domain knowledge and working memory capacity on cognitive performance were also investigated among researcher. It is pointed out that high level of working memory capacity enhances the contribution of domain knowledge on cognitive performance (Hambrick &Engle, 2002). On the other hand, no effect of WMC was found on world problem performance in another study (Gonultas, 2004).

In conclusion, both the high and the low WMC students in the first version (+CLT) of multimedia made significantly lower error in sequencing each phase than the high and the low WMC students in the second version (-CLT) of multimedia. It was expected that high WMC students performed better in both versions of multimedia. In other words, it is assumed that high WMC students are able to adjust their attention by zooming out and zooming in based on the task demand. Therefore, it is assumed that the high WMC students in the second version (-CLT) of multimedia performed relatively similar as the performance of the high WMC students in the first version (+CLT) of multimedia. Contrary to this prediction, the result of this study showed that high WMC students performed better when cognitive load principles applied in the learning environments. Therefore, it can be concluded that working memory capacity act as enhancer assumption is partially confirmed (Hambrick & Engle, 2002) and increase the effects of cognitive load principles on performance. As it is expected, high WMC students attending the first version (+CLT) of multimedia made significantly lower error than the low WMC students attending the second version (-CLT) of multimedia. No significant difference was found between the high and the low WMC students in error for each phase in the first version (+CLT) of multimedia. However, based on the enhancer assumption, it can be expected that the effects of the cognitive load principles would be strong for high WMC students.

Low WMC students attending the first version (+CLT) of multimedia made lower error than the high WMC and low WMC students attending the second version (-CLT) of multimedia. It is assumed that the low WMC students performed better in the first version of multimedia (+CLT) compared to the second version of multimedia because the cognitive load principles was applied in designing first version and so the low WMC learners has enough capacity to store and process the information. The result is consistent with this assumption. However, the low WMC students in the first version (+CLT) of multimedia made lower error than the high WMC student attending second version of multimedia (-CLT). In addition, low WMC students performed similar as the high WMC students in the number of each phase error of meiosis in the first version (+CLT). The reason for this result might be related to the task purposes and individual characteristics. The learning environment was designed as a game based learning environment and so the low WMC learner tried to maintain and coordinate their attention in order to complete the given task in the first version (+CLT) of multimedia. As pointed out by Cankaya (2007), low WMC students in game condition purposes make significantly more evaluative judgment than the test condition in verbal protocol task. Furthermore, low WMC readers produced more predictive inferences than the high WMC group in verbal protocol task and free recall. In addition, the participants' characteristics such as age play important role in findings in that in a previous research it is found that low WMC adults made lower predictive judgment than high WMC adults' participants. The target group is also teenagers in current study therefore it can be expected that the young low WMC students performed differently than low WMC adult participants. As it is found in this study, the low WMC students performed similarly with the high WMC students in the number of errors in meiosis.

Generally, it can be said that both the high and the low WMC students benefit more from the first version (+CLT) of multimedia compared to the second version (-CLT) of multimedia.

### 5.2.3 Students' Perception of Goal Based Scenario Designed 3D Constructivist Multimedia Learning Environment (Research Question 3, Study I)

In line with the second research question, this study attempted to reveal how learners' motivation, satisfaction and mental efforts were affected by goal based scenario centered two different multimedia learning environments which were designed with CLT principles and without CLT principles.

Applying cognitive load theory principles in designing multimedia learning environment affected students' motivation and satisfaction in a positive way. Although GBSc3DM is considered as an effective instructional approach for most of the students, students who used the second version (-CLT) expressed that violating modality, coherence and split attention principles affected their motivation and satisfaction negatively in using the second version (-CLT) of the program. However, Tabbers et al (2004) did not find any difference in motivation between audio and text condition in multimedia presentation. The findings of meta-analysis about the modality effect on achievement conducted by Ginns (2005) indicated that moderate to large average effect for more complex, system-paced instructional materials, but smaller average effects for self-paced or less complex instructional materials. The findings of this study support the meta-analysis findings in that the two versions of multimedia used in this study were self paced, on the other hand, the animations in both versions were system-paced. In addition, in the design of the first version (+CLT), modality principle was considered for animations. As students indicated that was one of the reasons why they were more satisfied and motivated with the first version (+CLT) of the multimedia.

The earlier research findings about multimedia principle showed that presenting both words and pictures are better for increasing learner understanding than presenting words alone (Mayer & Moreno, 2002). However, using multimedia and choice principles in the material did not affect students' motivation and satisfaction very much in this study. Some students indicated that pictures became redundant for them when their knowledge levels increase. This finding might be explained by the expertise reversal effect which has been studied in CLT framework in that some instructional formats become ineffective when the learners knowledge increase during the learning phase (Kalyuga et al., 2003) which was supported with quantitative data from mitosis and meiosis. It can be concluded from this finding that using both pictures and text has been beneficial for learners in increasing their interest and engage them in deep learning processes. However, when students' knowledge levels increase, the pictures become redundant, and do not affect their interest toward learning material.

Violating split attention principle affected the students' satisfaction negatively. In other words, students expressed that it was stressful for them when each page was opened in a new window. Although it was found in many studies that links in onscreen reference appeared in second browser windows that covers the related information on the initial screen destruct learning process (Clark & Mayer, 2003), the findings of this study indicate that this may also affect learners' satisfaction in negative ways.

Applying the principles that reduce the extraneous cognitive load resulted in lower mental efforts for the first version (+CLT) of the multimedia compared to the second version (-CLT) which we did not implement the principles for mitosis and meiosis. Based on the findings from both qualitative and quantitative data, it can be inferred that despite of the task complexity, applying cognitive load principle increased students' motivation and satisfaction, and alleviated the amount of mental load that imposed by the learning material. On the other hand, students invested higher mental effort in the second version (-CLT), and the material affected their motivation and satisfaction in negative ways.

The relationship between motivation and mental effort was investigated in CLT framework by task involvement equation proposed by Paas, Tuovinen, Van Merrriënboer and Darabi (2005). They indicated that motivation, mental effort, and performance are positively related. However, it was found that motivation, mental effort and performance was not positively related in this study. As pointed out by Corbalan (2008), the mental effort is used as a general concept in task involvement, and there is no distinction between the invested mental effort of extraneous, intrinsic and germane load.

One of the recent arguments has been made on adaptive and original instructional efficiency measure which is analogous to task involvement (Van Gog &Paas, 2008). In instructional efficiency, invested mental effort was subtracted from performance except for that the same procedure was used to calculate efficiency measure as in task involvement measure. The difference between adaptive and original measures of instructional efficiency is that the former used mental effort invested in learning, the latter used mental effort invested in doing test to calculate efficiency measure. It was claimed that if the purpose of intervention is to decrease extraneous cognitive load, invested mental effort in learning could be used to calculate efficiency measure since it is expected that invested mental effort result from extraneous cognitive load might be similar in both learning and test phase. However, when the researcher aims to apply instructional format that increase germane load in learning, it is asserted that the original measure should be used because the aim of instructional formats is to increase invested mental effort in learning; in contrast, decrease invested mental effort in test phase to get higher performance score.

Similar conclusion can be drawn from for task involvement measure also. If the researcher aims to apply instructional format to reduce extraneous cognitive load, task involvement measure should not be used because this type of mental effort do not positively related with performance. However, when the aim of instructional format is to increase germane cognitive load in learning phase, the higher investment of mental effort is expected to positively related with performance and so they can be used to calculate task involvement measure.

In one of the study, it is found that using germane load in task involvement for adaptive learning system produces significant result (Corbalan, Kester & Van Merrriënboer, 2008). In another study, the significant finding in task involvement between instructional conditions attributed to capability of those formats in inducing germane cognitive load (Darabi, Nelson & Paas, 2007). Therefore more research should be conducted to find out more comprehensive findings on the relationships among motivation, task involvement, performance and mental efforts resulting from different types of cognitive load for different instructional conditions. It is also suggested that experimental findings should be supported by qualitative data to validate and optimize the findings in depth.

In conclusion, the findings of this study show that violating cognitive load principles in multimedia learning environment affects not only students' motivation but also their satisfaction in negative ways. In addition, it can be concluded that applying cognitive load principles reduced their mental effort and increase their motivation and satisfaction in this study. Even though the instructional approach (GBS) used in the material increased students' motivation and satisfaction, when extraneous cognitive load principles were not implemented in the design, it reduced students' motivation and satisfaction.

### 5.2.4 Students' Satisfaction and Motivation on Cognitive Load in Learning from Goal Based Scenario ( Research Question 2, Study I).

In line with the third research question, the findings of this study showed that goal based scenario was perceived as an effective approach in designing multimedia learning environments. Most students indicated that GBS motivated them to finish the task, and some stated mission forced them to finish the material which is the result of extrinsic motivation. Similarly, Schaller et al., (2001) found that GBS provides extrinsic motivation for uninterested but the potential learners, especially when program's appeal increased by narratives, games, simulations, and creative play activities. On the other hand, some students mentioned that the scenarios gave them responsibilities so that they were intrinsically motivated to learn and to achieve the mission. In line with this finding, Zumbach & Reimann (2002) found that goal based scenario increased intrinsic motivation of the students compared to tutorial and strategy group. It can be concluded that goal based scenario increased both intrinsic and extrinsic motivation of students in the learning environments.

Students' perception and preferences of learning with goal based scenario centered multimedia program and multimedia itself was investigated by two forms of CMLES survey.

Students generally perceived that they were *often and sometimes* engaged in *negotiation, inquiry learning and reflective thinking* while learning with multimedia program. Although there was significant difference in *inquiry learning* and *reflective thinking* between preferred and actual form of CMLES, the effect size is small and between small and medium for all subscales. On the contrary, in previous research, all subscales for learning with multimedia were found significant and effect size was also very large (Maor & Fraser, 2005).

With regard to the multimedia program, it was found that students perceived the multimedia program *often authentic, complex and challenging*. The multimedia program was developed on scientific facts and the students were informed about why they need to learn mitosis and meiosis processes and how much these processes important for human beings. This might affects their perception in terms of authenticity and they found the multimedia often authentic. The design approaches used to develop learning environment such as user centered and participatory design might increase the ease of use. Although there was significant difference in challenging between actual and preferred forms of CMLES, the effects size was medium. The comparison between students' preferences and actual experiences for challenging scale has shown a different pattern while comparing with the other scales. Mean score for students' preferences was found higher for *negotiation, inquiry learning, reflective thinking, authenticity, complexity* than actual experiences, in contrast, it was found lower for challenging scale. The possible reason was discussed in following part.

The current study was limited in time with 4 course hours in two weeks and it was the first time for students to engage in learning with multimedia processes. Except for the introduction made by teachers, students do not involve in classroom activities and they were mainly used multimedia learning environment during the class hours. There was only one multimedia program was used during the study. In previous study, students engage in a longitudinal study by using three programs with different content and engage in group work, whole class discussion and they prepared a presentation about what they had learned form program (Maor &Fraser,2005). Therefore, it can be assumed that some of the activities like discussion, reflective thinking and inquiry learning activities that support the learning process were not embedded in learning with multimedia. Therefore, their preferences were found higher compared to their perception of actual experiences in learning with multimedia.

Students had an active role during class hour by using the multimedia program, hence, it can be inferred that examining students perception and preferences of multimedia itself might yield more comprehensive findings. In addition, it is stated that CMLES highlights the multimedia influence on teaching and learning through the authenticity and complexity scales (Wu et al., 2009). There was no significant difference between actual and preferred from of CMLES between authenticity and complexity. In previous research, there was a significant difference in *complexity* between actual and preferred form in previous research (Mayer & Fraser, 2005) and the second higher score for preferred form of constructivist learning environment survey (Chuang & Tsai, 2005; Lee & Tsai, 2005). This can be due to the design approaches used in this study. In other words, participatory and user centered design approach was used (Corry et al., 1997) and based on students (different from participants for this study)' preferences the program was revised and changed. Thus, they found multimedia program easy to use, fun and interesting. Students' mean score for actual experiences was found significantly higher than their preferences for challenge. It can be inferred that the multimedia program challenges and stimulates students to think by providing opportunities to generate new ideas and new questions.

Students' characteristics could be additional factor to affect the results. The students were accepted to this school (Anatolian High School) as a result of a very competitive exam, and those are high achiever students in Ankara. On the other hand, different results were obtained when the same study was conducted with students from a general high school. For example, no significant difference was found for inquiry learning, however, significant result was found for reflective thinking and negotiation (Kilic & Yildirim, 2009). It can be assumed that the students expected learning with multimedia provide much more opportunities for them to involve in inquiry learning and reflective thinking processes.

There were also some limitations. It was the first time for students to engage in learning process with multimedia for regular course at schools. Therefore, it can be assumed that the novelty of the learning environment cause this result rather than the specific nature of learning environment (Fraenkel & Wallen, 2001). In addition, the validity CMLES has been tested for its reliability. Factor analysis for this questionnaire could not be done because of inadequate instructional materials and inexperienced teachers in both constructivist oriented classroom and use of multimedia. The content validity was ensured with two experts. Although some researcher claims that factor analysis is a technique used for developing an instrument and there is no need to conduct factor analysis for adapted instruments from foreign language (Ergin, 1995), it is still considered a limitation for validity in this study.

In conclusion, the students engage in investigate and decide process to complete the given task, hence, it can be concluded that the students were active during the learning process and it allowed them to generate new ideas and help them to think. However, the learning process with multimedia needs to be improved and different activities such as group discussion, preparing reflective presentation about content should be embedded to engage students in inquiry learning and reflective thinking process in order to promote higher order thinking skills.

## 5.3. Implication and Suggestion for Practice

Even though the findings of this study cannot be generalized beyond this study, following recommendation has been offered to teachers and instructional designers based on the findings of this study.

- Goal based scenario is an effective instructional approach to increase the students interest toward learning in the multimedia learning environments. Learning with scenario increase the students' motivation by relating the content with the real world and make learning much more meaningful than the direct instruction. GBS provides opportunities to know how and why they need to learn the content. Therefore, teachers and instructional designers can develop scenarios to teach the content in lessons to make learning more meaningful for the students.

- Although cognitive load principles have been widely used in the multimedia learning environment, this theory can be used to design classroom materials in order to improve instruction.

- Based on the findings, it can be offered that cognitive load principles should be used in developing learning environments in order to decrease invested mental effort, increase the effectiveness of learning environments and motivation and satisfaction of the students. In addition to the instructional method, it is suggested teachers or instructional designers should take into account the principles of cognitive load principles in designing learning environment.

- While considering limitation of working memory capacity of students, it becomes more important to apply cognitive load principles for secondary schools because high school students attend at least 6 courses in a day. They learn different content from different subject area nearly in all courses. Based on the finding, it can be suggested that these principles become more important in the initial learning phase of the content. In other words, the students do not develop a schema yet when the content is new; hence, they need to spend much more effort to learn the newly acquired content and the effects of limitation of working memory capacity become more influential at this initial stage. Therefore, teachers or instructional designer should take into account principles of cognitive load especially for initial phase of learning.

- Our curriculum is designed based on units. Each unit has sub contents. For example, cell division unit was selected for the present study. Under this unit, students learned mitosis and meiosis process. It is found that the effects of cognitive load principles are much more influential in learning mitosis than meiosis. The principles of cognitive load should be taken into account in the design of instruction especially for initial phase of learning.

- Individual difference should be taken into account as an important factor in teaching and learning environment. As partially confirmed by this study, applying cognitive load principles enhance the effectiveness of the learning process for students having high and low working memory capacity.

## 5.4. Implication and Suggestion for Further Research

- The present study was conducted as a part of regular curriculum. Students learned mitosis and then meiosis in ecological settings. Therefore, the possible effects of task order on result obtained from mitosis and meiosis cannot be controlled. For follow up studies, the find out possible effects of task order on result, the task order should be counterbalanced

- Extraneous cognitive load was measured by one item. New instrument has been developed to measure intrinsic, extraneous and germane cognitive load in the multimedia learning environments. Therefore, new instrument can be used to measure these three types of cognitive load so that the researchers can make inferences about the germane cognitive load.

- Cognitive load measurement scale was administrated at the end of the mitosis and meiosis in the first study. It was also used at the end of the learning phase in the second study. Since the purpose of this study is to find out the effects of cognitive load principles which is based its assumption on short time processing capacity, administrating the scale during the learning process after each task rather than at the end of the learning process might provide much more information about the effect of this principle on learning process for learners having different working memory capacity.

- Individual difference in working memory capacity was investigated in the present study, however, the effects of individual difference cannot be found among variables because of insufficient power. As it is pointed out in the literature, to find out the effects of individual difference researcher should work with about 100 individuals.

- Cognitive load measurement was conducted at the end of the learning processes. Therefore, instructional efficiency measurement gives us information about the learning efficiency but not instructional efficiency. For follow up studies, cognitive load measurement can be done both during learning and test phase in order to find out both learning and instructional efficiency.

- Similar design in different subject area, different grade level and different school type should be conducted to examine the effects of the design in different settings.

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# APPENDIX A

## CELL ACHIEVEMENT TEST
## HÜCRE BÖLÜNMESİ BAŞARI TESTİ

Adı Soyadı: Cinsiyeti:

Sınıfı- Şube:

20 çoktan seçmeli sorudan oluşan bu test için toplam cevaplama suresi 20 dakikadır. Her soru eşit puan değerindedir. Yanlış cevaplarınızın sayısı doğru cevaplarınızın sayısını etkilemeyecektir. Aşağıdaki her soru için doğru olan şıkkı soru kâğıdı üzerine işaretleyiniz

**1.** Hücrelerde DNA'nın kendini eşlemeye başlamasının sebebi olarak aşağıdakilerden hangisi kabul edilmektedir?

A) Çekirdeğin fazla büyümesi
B) Stoplazma ile çekirdek arasındaki oranın sabit kalması
C) Hacim/yüzey oranının artması
D) Dokuların aşınması ve bozulması

**2.** Mitoz bölünmede aynı kalıtım materyaline sahip iki hücrenin oluşması için aşağıdakilerden hangi olayın gerçekleşmesi şarttır?

A) Mitokondrilerin çoğalması
B) ATP sentezinin artması
C) İğ ipliklerinin oluşması
D) DNA'nın kendisini eşlemesi

**3.** Aşağıdaki safhaların hangisinde DNS eşlenmesi gerçekleşir?

*A)* Interfaz B) Profaz
C) Metafaz D)Anafaz

**4.** 20 kromozomlu bir bir hayvan hücresi 2 defa mitoz ve 1 defa mayoz bölünme geçirdiğinde bölünmeler sonucu oluşan hücre sayısı ve bu hücrelerdeki kromozom- kromatit sayısı aşağıdakilerden hangisine eşit olur?

A) 4 hücre, 40 kromozom, 20 kromatit
B) 8 hücre, 20 kromozom, 40 kromatit
C) 16 hücre, 20 kromozom, 40 kromatit
D) 8 hücre, 40 kromozom, 20 kromatit

**5.** : Yapılarında DNA ve protein bulunur
II. Interfazda kısalıp kalınlaşmamış kromatin iplikçikler halinde görülürler.
III. DNA iplikçiğinin yalnızca bir kısmı proteinlerle paketlenerek kromozomu oluşturur.
IV. Kromozomlann kendi eşini yapması DNA eşlenmesi ile mümkündür.

*Kromozomlarla ilgili olarak yukarıdaki* ifadelerden hangisi veya hangileri yanlıştır

A) I ve II B) III ve lV
*C) Yalnız IV* *D) Yalnız III*

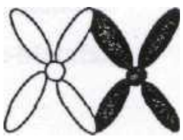
**6.** Aşağıdakilerden hangisi 20 kromozomlu bir hücrenin mayoz bölünme sırasında tetrat sayısını ve mayoz bölünme sonucunda meydana gelen hücrelerdeki DNA sayısını ifade etmektedir.

A) 10, 20 B) 10, 10

*C) 20, 10* *D) 20, 20*

*DİKKAT* 7. ve 8. Soruları aşağıdaki çekle gore cevaplayınız.

1 2 3 4



A B

**7.** Yukarıdaki şekilde mayozun profaz evresinde tetrat oluşturmak üzere yan yana gelmiş kromozomlar görülmektedir.

I))1 anadan 2 babadan gelmiş homolog kromozomlardır

II) A ve B homolog kromozomlardır.

III) 3 ve 4 bir homolog kromozoma ait

kardeş kromatidlerdir.

IV) A ve B kardeş kromatidlerdir.

Şekille ilgili olarak yukarıda verilen ifadelerden hangileri doğrudur?

A) I, II B) II, III

C) III, IV D) I,IV

**8.** Şekille ilgili olarak aşağıdaki ifadelerden hangisi yanlıştır?

A) A'da iki DNA iplikçiği mevcuttur.

B) 3 ve 4. taşıdığı genler bakımından aynıdır.

C) 1 ve 2 arasında krossing-over görülebilir.

D) Mayozun metafaz-I safhasında A ve B birlikte ekvator düzleminde bulunur.

**9.** Bir dişi bireyin diploid vücut hücresinde 2n= 32 kromozom bulunmaktadır. Aynı türün erkek bireyinin gamet formülü aşağıdakilerden hangisidir?

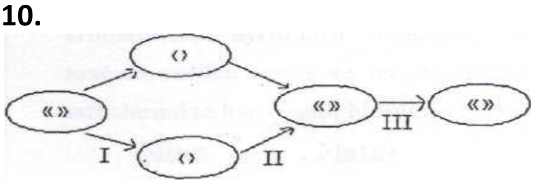
A) (15+x) veya (15+y)

B) (16+x)yeya(16+y)

C) (14+x)veya(14+y)

D) (31+x)veya(31+y)

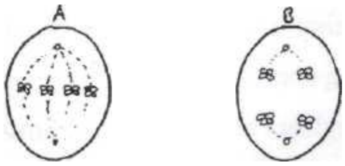
**10.**




Şekilde numaralandırılmış olaylar aşağıdakilerden hangisinde doğru olarak verilmiştir

| | *I* | *II* | *III* |
|---|---|---|---|
| *A)* | *Mitoz* | *Döllenme* | *Mayoz* |
| *B)* | *Mayoz* | *Döllenme* | *Mitoz* |
| *C)* | *Bölünme* | *Mitoz* | *Döllenme* |
| *D)* | *Mayoz* | *Mitoz* | *Mitoz* |

**11.**




Yukarıdaki olaylar hangi bölünmenin hangi safhasına aittir?

| | *A* | *B* |
|---|---|---|
| *A)* | *Mitoz-Metafaz* | *Mayoz-Anafaz I* |
| *B)* | *Mayoz-Metafaz II* | *Mitoz- Anafaz* |
| *C)* | *Mitoz- Metafaz* | *Mayoz-Anafaz II* |
| *D)* | *Mayoz-Metafaz I* | *Mitoz-Anafaz* |

**12.** Aşağıdaki olalardan hangisi mayoz bölünmede görülen ve genetik çeşitliliği sağlayan bir olaydır?

*A) DNA eşlenmesi*

*B) Her kromozomun iki kromatitten oluşması*

*C) Ana ve babaya ait kromatidlerin parça değiştirmesi*

*D) Kardeş. kromatitlerin ayrılması*

**13.** I) Mitoz bölünme ile oluşan 13. hücrelerde homolog kromozomların her ikisi de bulunur.

II) Mayoz bölünmede önce kromatitler, sonra kromozomlar ayrılır.

III)Mitoz bölünmede yalnız kardeş kromatitler ayrılır

IV) Mayoz bölünme sonunda oluşan yavru hücrelerdeki kromozom sayısı ana hücredeki kromozon sayısına eşittir.

Yukarıdaki ifadelerden hangisi doğrudur?

A ) I ve IV B ) I, III, IV

C ) II, III, IV D) I ve III

**14.** Aşağıdakilerden hangisi II. Mayoz bölünme evresine ait bir özelliktir?

A) DNA eşlenmesinin olması

B) Homolog kromozomların birbirinden ayrılması

C) Homolog kromozomların sinapsis yapması

D) Kromatitlerin birbirinden aynlması

**15.** Aşağıdaki ifadelerden hangisi hem mayoz hem de mitoz bölünmedeki olayları tanımlamak için uygundur?

A) Homolog kromozomlar ayrılır.

B) Diploid hücreler meydana gelir.

C) DNA'nin eşlenmesiyle kromatitler meydana gelir.

D) Tetratlar meydana gelir

**16.** Sentromerlerin bölünerek kromatitlerin ayrılmaya başlaması olayı aşağıda verilen mitoz ve mayoz bölünme safhalarından hangisinin bittiği gösterir?

| | Mitoz | Mayoz |
|---|---|---|
| A ) | Metafaz | Metafaz I |
| B ) | Anafaz | Anafaz I |
| C ) | Metafaz | Metafaz II |
| D ) | Anafaz | Anafaz II |

**17.** Mitoz bölünmede aşağıdaki olaylardan hangisi hayvan hücrelerinde görülmeyip sadece bitki hücrelerinde gerçekleşir?

A) Kromozomlann kısalıp kalınlaşması

B) Hücre Plağının oluşması

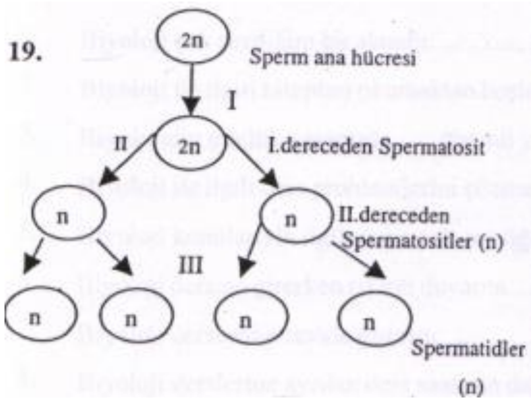
C) Kromatitlerin kutuplara çekilmesi

D) Çekirdek zarının kaybolması

**18.** Yapısında homolog kromozomların her ikisini de bulundurmayan insan hücresi, aşağıdakilerden hangisidir?

A) Akyuvar  B) Kas

C) Sinir  D) Yumurta




**19.** Yukarıda sperm hücrelerinin meydana geliş şekli verilmiştir. Buna göre I, II ve III numaralı aşamalarda görülen bölünmeler aşağıdakilerden hangisinde doğru oalrak verilmiştir?

| | I | II | III |
|---|---|---|---|
| A) | Mitoz | Mitoz | Mayoz |
| B) | Mitoz | Mayoz | Mayoz |
| C) | Mayoz | Mitoz | Mitoz |
| D) | Mayoz | Mayoz | Mitoz |

**20.** 12 üreme ana hücresinde mayoz bölünme sonucu en çok kaç tane yumurta hücresi oluşabilir?

A) 12  B) 24

C ) 36  D) 48

# APPENDIX B

## REFLECTIVE JOURNAL I
## YANSITICI GÜNCE

Öğrenci No:

Mitoz bölünme konusunu çoklu ortam (multimedya) kullanarak öğrendiniz. Bu öğrenme sürecindeki öğrenme deneyimlerinize ilişkin görüşleriniz, dersin geliştirilmesi ve daha iyi hale getirilmesi için büyük önem taşımaktadır. Bu nedenle, aşağıdaki soruları çoklu ortamla öğrenme deneyiminizi dikkate alarak cevaplayınız lütfen. Cevaplarınız sadece çoklu ortamı daha etkin hale getirmek için kullanılacaktır ve gizli tutulacaktır.

Sorular:

1. Sınıf ortamında işlenen bir ders ile çoklu ortam kullanılarak işlenen dersi karşılaştırarak her iki öğrenme ortamına karşı duygu ve düşüncelerinizi yazınız.
2. Mitoz bölünmeyi, kullandığınız çoklu ortamda size verilen bir özel görev (misyon) doğrultusunda gerçekleştirdiniz. Sizce özel görevi yerine getirerek öğrenmenin olumlu veya olumsuz yönleri var mıdır? Varsa bunlar nelerdir? Açıklayınız.
3. Çoklu ortamla gerçekleşen öğrenme deneyimleriniz hakkındaki duygu ve düşüncelerinizi açıklayınız?
4. Çoklu ortamdaki özel görevinizi yerine getirmek için oynadığınız rolünüze ilişkin olumlu veya olumsuz görüşlerinizi yazınız.
5. Kullandığınız çoklu ortam tasarımında dikkatinizi yoğunlaştırmanızı kolaylaştıran veya güçleştiren unsurlar var mıydı? Varsa bunlar nelerdir? Açıklayınız.

# APPENDIX C

## REFLECTIVE JOURNAL II
## YANSITICI GÜNCE

Öğrenci No:

Mayoz bölünme konusunu çoklu ortam (multimedya) kullanarak öğrendiniz. Bu öğrenme sürecindeki öğrenme deneyimlerinize ilişkin görüşleriniz, dersin geliştirilmesi ve daha iyi hale getirilmesi için büyük önem taşımaktadır. Bu nedenle, aşağıdaki soruları çoklu ortamla öğrenme deneyiminizi dikkate alarak cevaplayınız lütfen.Cevaplarınız sadece çoklu ortamı daha etkin hale getirmek için kullanılacaktır ve gizli tutulacaktır.

Sorular:

1. Mayoz bölünmeyi, kullandığınız çoklu ortamda size verilen bir özel görev (misyon) doğrultusunda gerçekleştirdiniz. Sizce özel görevi yerine getirerek öğrenmenin olumlu veya olumsuz yönleri var mıdır? Varsa bunlar nelerdir? Açıklayınız.
2. Çoklu ortamda öğrenme ile gerçekleşen öğrenme deneyiminize ilişkin olarak motivasyonunuz ve memnuniyetinize ilişkin olumlu yada olumsuz duygu ve düşüncelerinizi açıklayınız.
3. Çoklu ortamdaki özel görevinizi yerine getirmek için oynadığınız rolünüze ilişkin olumlu veya olumsuz görüşlerinizi yazınız.
4. Kullandığınız çoklu ortam tasarımında dikkatinizi yoğunlaştırmanızı kolaylaştıran veya güçleştiren unsurlar var mıydı? Varsa bunlar nelerdir? Açıklayınız.

# APPENDIX D

## MITOSIS ACTIVITY REPORT
## EKOLOJİK DENGE ÜSSÜ MİTOZ BÖLÜNME RAPORU

Öğrenci No:

Sevgili Arkadaşım,

Bir bilim insanı olarak gerçekleştirdiğin hücre bölünmeleriyle insanoğlunu içinde bulunduğu bu olumsuz durumdan kurtarmış bulunmaktasın. Artık vücut hücreleri kendilerini yenileyebilmekte ve türlerin nesilleri devam edebilmektedir. Şimdi bu durumun kalıcılığı sağlamak ve benzer bir olayın tekrarı halinde insanoğlunun neler yapabileceğini belgelemek adına bir rapor sunman gerekmektedir.

Aşağıdaki temel soruları cevaplandırdığında bu raporu da hazırlamış olacaksın.

1. Bitki ve hayvan hücrelerinde büyüme, gelişme, yıpranan ve yaşlanan dokuların yenilmesi ve yaraların onarılmaması neden gerçekleşmiyordu?
2. Hücrede bölünmeye başlamadan önce ne gibi hazırlıkların olması gerekir?
3. Bölünme başlangıcında kaybolmaya başlayıp bölünme tamamlandığında yeniden oluşan yapılar hangileridir.
4. Hücre bölünmesinin başlamasından bölünme tamamlanıncaya kadar kromozom hareketleri nasıl oldu?
5. Bölünme sonunda elde ettiğin kalıtım maddeleri (kromozomları) birbirleriyle aynı sayıda ve yapıda mı?

6. Bölünme sonucunda bir hücreden kaç hürce elde edebildin? Bu elde ettiğin hücrelerin, bölünmeyi başlattığın hücrelerden farkı neydi?
7. Hücre bölünmeye başlarken oluşup, bölünme tamamlandığında kaybolan ve kromozomların hareketini sağlayan yapı hangisidir? Bölünme süreci boyunca bu yapının hareketleri nasıl oldu?

# APPENDIX E

## MEIOSIS ACTIVITY REPORT
## EKOLOJİK DENGE ÜSSÜ MAYOZ BÖLÜNME RAPORU

Öğrenci No:

Sevgili Arkadaşım,

Küresel ısınma yüzünden kumral tenli insanların nesli hızla tükenmek üzereyken üreme hücrelerinde meydana getirdiğin mayoz bölünme sayesinde esmer ten rengine sahip bireyler yetiştirilebilecek. Hücre Üretim Merkezinde farklı kalıtsal bilgilere sahip bireylerin oluşması için gereken hücreleri elde ettin. Böylelikle bilim insanları küresel ısınmaya karşı daha dayanıklı olan esmer ten rengine sahip bireylerin artmasını sağlayabilecek. Şimdi kumral tenli bireylerin küresel ısınmadan etkilenmemeleri için yapılacak çalışmalar tamamlanıncaya kadar esmer tenli bireylerin yetişmesi gerekiyor. Bu nedenle yaptıklarını belgelemek için bir rapor sunman gerekmektedir.

Aşağıdaki temel soruları cevaplandırdığında bu raporu da hazırlamış olacaksın.

1. Oluşan üreme hücrelerinin kromozom sayısı ile üreme ana hücresinin kromozom sayılarını karşılaştırdığında neler söyleyebilirsin?
2. Üreme hücrelerinin kromozom yapısı ile üreme ana hücrelerinin kromozom yapıları arasında farklılıklar var mı? Eğer böyle bir durum söz konusuysa, kromozom yapısındaki bu değişiklik sizce mayoz bölünmenin hangi olayından kaynaklanmaktadır.
3. Hücre bölünmesinin başlamasından bölünme tamamlanıncaya kadar kromozom hareketleri nasıl oldu?
4. Mitoz ve Mayoz bölünme gerçekleştirdiğin hücrelerin 2n= 2 kromozomu vardı. Bu hücredeki 2n= 20 kromozom olsaydı mitoz geçirdiğinde kaç hücre oluşurdu. Oluşan hücrelerin kromozom sayısı ne olurdu.

5. Mayoz II başlarken kromozomlar neden kendilerini yeniden kopyalayamıyor.
6. Krossing over ile yeni gen bileşimlerine sahip kromozomları taşıyan üreme hücrelerinin meydana gelmesi canlılık açısından neden önemlidir.
7. Mitoz ve Mayoz hücre bölünmeleri gerçekleştirilirken ne gibi farklılıklar görüldü

# APPENDIX F

## SUBJECTIVE RATING SCALE
## BİLİŞSEL YÜK ANKETİ

**Öğrenci No:**

Bu anket, multimedyayı kullandığınız sırada harcadığınız zihinsel çabayı ölçmektedir. Bu görevi yerine getirirken ne kadar zihinsel çaba sarf ettiniz?

| Çok çok az | Çok az | Az | Kısmen az | Ne az ne fazla | Kısmen fazla | Fazla | Çok fazla | Çok çok fazla |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

# APPENDIX G

## CONTRUCTIVIST MULTIMEDIA LEARNING ENVIRONMENT SURVERY ACTUAL FORM
## OLUŞTURMACI ÇOKLU ORTAM ÖĞRENME ORTAMLARI ANKETI

***Öğrenci Asıl Form***

***Sınıfımda gerçekten ne oluyor?***

### YÖNERGELER

### 1. Anketin Amacı

Bu anket işlediğiniz dersin ve kullandığınız yazılımın önemli bulduğunuz yönlerini belirtmeniz amacıyla kullanılmaktadır. Bu anketteki soruların doğru ya da yanlış bir cevabı bulunmamaktadır. Sizin sadece işlene derse ve yazılıma ilişkin fikirlerinizi öğrenmek önem taşımaktadır. Cevaplarınız, biyoloji öğretiminin geliştirilmesine katkıda bulunacaktır.

### 2. Test Rehberi

Anket 30 maddeden oluşmaktadır. Her bir madde için, size en uygun olan seçeneği  yuvarlak içine alın. Örneğin;

| Bu sınıfta..... | Hiçbir zaman | Nadiren | Bazen | Genellikle | Her zaman |
|---|---|---|---|---|---|
| 1.Diğer öğrencilere sorular sorarım | 1 | 2 | 3 | 4 | 5 |

- Eğer, diğer öğrencilere her zaman soru sorduğunuz düşünüyorsanız, 5'i yuvarlak içine alınız
- Eğer, diğer öğrencilere hiç bir zaman soru sormadığınız düşünüyorsanız, 1'i yuvarlak içine alınız
- Ya da size 2. 3. ve 4. (Nadiren, Bazen, Genellikle)seçeneklerden en uygun görünen seçeneği yuvarlak içine alınız.

**3. Cevabınızı nasıl değiştireceksiniz?**

Eğer cevabınızı değiştirmek istiyorsanız, işaretlediğiniz yuvarlağın üzerine bir çarpı atın ve yeni bir numarayı yuvarlak içine alın Örneğin;

| Bu sınıfta..... | Hiçbir zaman | Nadiren | Bazen | Genellikle | Her zaman |
|---|---|---|---|---|---|
| 1.Diğer öğrencilere sorular sorarım | 1 | 2 | | 4 | 5 |

**4. Kişisel Bilgiler**
Lütfen, aşağıdaki kutulara gereken bilgileri yazınız. Bu ankete vereceğiniz cevaplar gizli tutulacak ve kimseye açıklanmayacaktır.

a. Ad, Soyad:

b. Sınıf c. Cinsiyet: Erkek ☐ Bayan ☐

**5. Anketi tamamlama**

Şimdi sayfayı çevirin ve lütfen her bir soruyu cevaplayınız.

## Bölüm 1: Sınıf Ortamında Öğrenme Süreci

Aşağıda belirtilen öğrenme etkinliklerinin derslerinizde hangi sıklıkta gerçekleştiğini lütfen belirtiniz

| **İletişim Kurmayı Öğrenme** | Hiçbir zaman | Nadiren | Bazen | Genellikle | Her zaman |
|---|---|---|---|---|---|
| Bu sınıfta.... | | | | | |
| 1. diğer öğrencilerle konuşma şansı bulurum. | **1** | **2** | **3** | **4** | **5** |
| 2. diğer öğrencilerle nasıl araştırma yapılacağı konusunda tartışırım. | **1** | **2** | **3** | **4** | **5** |
| 3. diğer öğrencilere kendi düşüncelerini açıklamalarını söylerim. | **1** | **2** | **3** | **4** | **5** |
| 4. diğer öğrenciler düşüncelerimi açıklamamı isterler. | **1** | **2** | **3** | **4** | **5** |
| 5. diğer öğrenciler kendi düşüncelerini benimle tartışırlar. | **1** | **2** | **3** | **4** | **5** |
| **Araştırmayı Öğrenme** | | | | | |
| Bu sınıfta.... | | | | | |
| 6. soruların yanıtını araştırarak bulurum. | **1** | **2** | **3** | **4** | **5** |
| 7. kendi düşüncelerimi test etmek için araştırma yaparım. | **1** | **2** | **3** | **4** | **5** |
| 8. yeni sorulara yanıt bulmak için yaptığım araştırmaları izleyen başka çalışmalar yaparım. | **1** | **2** | **3** | **4** | **5** |
| 9. problemleri araştırmak için kendi yöntemlerimi oluştururum. | **1** | **2** | **3** | **4** | **5** |
| 10. bir probleme birden fazla bakış açısını dikkate alarak yaklaşırım. | **1** | **2** | **3** | **4** | **5** |
| **Düşünmeyi Öğrenme** | | | | | |
| Bu sınıfta.... | | | | | |
| 11. nasıl öğrendiğim konusunda derinlemesine düşünme olanağı bulurum | **1** | **2** | **3** | **4** | **5** |
| 12. kendi fikirlerim hakkında derinlemesine düşünme fırsatı bulurum | **1** | **2** | **3** | **4** | **5** |
| 13. yeni fikirler hakkında derinlemesine düşünme olanağı bulurum | **1** | **2** | **3** | **4** | **5** |
| 14. "nasıl daha iyi öğrenebilirim" konusunda derinlemesine düşünürüm | **1** | **2** | **3** | **4** | **5** |
| 15. Kendi anlayışlarım/görüşlerim üzerinde derinlemesine düşünürüm | **1** | **2** | **3** | **4** | **5** |

## Bölüm 1I: Çoklu Ortam (Multimedya) Programları

Aşağıda belirtilen ifadelerin multimedyada hangi sıklıkta yaşandığınısize en uygun gelen seçeneği işaretleyerek belirtiniz.

| **İlgililik –Anlamlılık** | Hiçbir zaman | Nadiren | Bazen | Genellikle | Her zaman |
|---|---|---|---|---|---|
| Çoklu ortam programıyla çalışırken, çoklu ortamın.... | | | | | |
| 16. gerçek yaşam ortamlarının ne kadar karmaşık olduğunu gösterdiğini fark ettim. | **1** | **2** | **3** | **4** | **5** |
| 17. bilgiyi anlamlı bir biçimde sunduğunu fark ettim. | **1** | **2** | **3** | **4** | **5** |
| 18. benim için anlamlı olan bilgileri verdiğini fark ettim. | **1** | **2** | **3** | **4** | **5** |
| 19. gerçeğe uygun etkinlikler sunduğunu fark ettim. | **1** | **2** | **3** | **4** | **5** |
| 20. geniş bir bilgi yelpazesine sahip olduğunu fark ettim. | **1** | **2** | **3** | **4** | **5** |
| **Kullanım Kolaylığı** | | | | | |
| Çoklu ortam programıyla çalışırken, . | | | | | |
| 21. çoklu ortamın, ilginç bir ekran tasarımına sahip olduğunu fark ettim. | **1** | **2** | **3** | **4** | **5** |
| 22. çoklu ortamın menüleri arasında gezinmenin kolay olduğunu anladım. | **1** | **2** | **3** | **4** | **5** |
| 23. çoklu ortamı kullanmanın eğlenceli olduğunu fark ettim. | **1** | **2** | **3** | **4** | **5** |
| 24. çoklu ortamı kullanmanın kolay olduğunu fark ettim. | **1** | **2** | **3** | **4** | **5** |
| 25. çoklu ortamın nasıl kullanılacağını öğrenmenin kısa zaman aldığını fark ettim. | **1** | **2** | **3** | **4** | **5** |
| **Zorluk Düzeyi** | | | | | |
| Çoklu ortam programıyla çalışırken, oklu ortamın.... | | | | | |
| 26. beni düşündürdüğünü fark ettim. | **1** | **2** | **3** | **4** | **5** |
| 27. karmaşık ama anlaşılır olduğunu fark ettim. | **1** | **2** | **3** | **4** | **5** |
| 28. kullanımın kendi sınırlarımı zorlayarak öğrenmemi sağladığını fark ettim. | **1** | **2** | **3** | **4** | **5** |
| 29. yeni fikirler üretmemde yardımcı olduğunu fark ettim. | **1** | **2** | **3** | **4** | **5** |
| 30. yeni sorular üretmeme yardımcı olduğunu fark ettim | **1** | **2** | **3** | **4** | **5** |

# APPENDIX H

## CONTRUCTIVIST MULTIMEDIA LEARNING ENVIRONMENT SURVERY PREFFERED FORM

## OLUŞTURMACI ÇOKLU ORTAM ÖĞRENME ORTAMLARI ANKETI

***Öğrenci Tercih Formu***

***Sınıfımda neler olmalı?***

**1. Anketin Amacı**

Bu anket işlediğiniz dersin ve kullandığınız yazılımın önemli bulduğunuz yönlerini belirtmeniz amacıyla kullanılmaktadır. Bu anketteki soruların doğru ya da yanlış bir cevabı bulunmamaktadır. Sizin sadece işlene derse ve yazılıma ilişkin fikirlerinizi öğrenmek önem taşımaktadır. Cevaplarınız, biyoloji öğretiminin geliştirilmesine katkıda bulunacaktır.

**2. Test Rehberi**

Anket 30 maddeden oluşmaktadır. Her bir madde için, size en uygun olan seçeneği yuvarlak içine alın. Örneğin;

| Bu sınıfta..... | Hiçbir zaman | Nadiren | Bazen | Genellikle | Her zaman |
|---|---|---|---|---|---|
| 1.Diğer öğrencilere sorular sormalıyım | 1 | 2 | 3 | 4 | 5 |

- Eğer, diğer öğrencilere her zaman soru sorduğunuz düşünüyorsanız, 5'i yuvarlak içine alınız
- Eğer, diğer öğrencilere hiç bir zaman soru sormadığınız düşünüyorsanız, 1'i yuvarlak içine alınız

- Ya da size 2. 3. ve 4. (Nadiren, Bazen, Genellikle)seçeneklerden en uygun görünen seçeneği yuvarlak içine alınız.

**3. Cevabınızı nasıl değiştireceksiniz?**

Eğer cevabınızı değiştirmek istiyorsanız, işaretlediğiniz yuvarlağın üzerine bir çarpı atın ve yeni bir numarayı yuvarlak içine alın Örneğin;

| Bu sınıfta..... | Hiçbir zaman | Nadiren | Bazen | Genellikle | Her zaman |
|---|---|---|---|---|---|
| 1.Diğer öğrencilere sorular sormalıyım | 1 | 2 | 3 | 4 | 5 |

**4. Kişisel Bilgiler**

Lütfen, aşağıdaki kutulara gereken bilgileri yazınız. Bu ankete vereceğiniz cevaplar gizli tutulacak ve kimseye açıklanmayacaktır.

a. Ad, Soyad:

b. Sınıf c. Cinsiyet: Erkek ☐ Baya ☐

**5. Anketi tamamlama**

Şimdi sayfayı çevirin ve lütfen her bir soruyu cevaplayınız.

## Bölüm 1: Çoklu Ortam Programlarıyla Öğrenme Süreci

Aşağıda belirtilen öğrenme etkinliklerinin derslerinizde hangi sıklıkta gerçekleşmesini tercih ederdiniz? Lütfen belirtiniz

| **İletişim Kurmayı Öğrenme** | Hiçbir zaman | Nadiren | Bazen | Genellikle | Her zaman |
|---|---|---|---|---|---|
| Bu sınıfta.... | | | | | |
| 1. diğer öğrencilerle konuşma şansı bulmalıyım. | **1** | **2** | **3** | **4** | **5** |
| 2. diğer öğrencilerle nasıl araştırma yapılacağı konusunda tartışmalıyım. | **1** | **2** | **3** | **4** | **5** |
| 3. diğer öğrencilerin kendi düşüncelerini açıklamalarını söylemeliyim. | **1** | **2** | **3** | **4** | **5** |
| 4. diğer öğrenciler düşüncelerimi açıklamamı istemeliler. | **1** | **2** | **3** | **4** | **5** |
| 5. diğer öğrenciler kendi düşüncelerini benimle tartışmalılar. | **1** | **2** | **3** | **4** | **5** |
| **Araştırmayı Öğrenme** | | | | | |
| Bu sınıfta.... | | | | | |
| 6. soruların yanıtını araştırarak bulmalıyım. | **1** | **2** | **3** | **4** | **5** |
| 7. kendi düşüncelerimi test etmek için araştırma yapmalıyım. | **1** | **2** | **3** | **4** | **5** |
| 8. yeni sorulara yanıt bulmak için yaptığım araştırmaları izleyen başka çalışmalar yapmalıyım. | **1** | **2** | **3** | **4** | **5** |
| 9. problemleri araştırmak için kendi yöntemlerimi oluşturmalıyım. | **1** | **2** | **3** | **4** | **5** |
| 10. bir problemi birden fazla bakış açısını dikkate alarak yaklaşmalıyım. | **1** | **2** | **3** | **4** | **5** |
| **Düşünmeyi Öğrenme** | | | | | |
| Bu sınıfta.... | | | | | |
| 11. nasıl öğrendiğim konusunda derinlemesine düşünme olanağı bulmalıyım. | **1** | **2** | **3** | **4** | **5** |
| 12. kendi fikirlerim hakkında derinlemesine düşünme fırsatı bulmalıyım. | **1** | **2** | **3** | **4** | **5** |
| 13. yeni fikirler hakkında derinlemesine düşünme olanağı bulmalıyım. | **1** | **2** | **3** | **4** | **5** |
| 14. "nasıl daha iyi öğrenebilirim" konusunda derinlemesine düşünme olanağı bulmalıyım. | **1** | **2** | **3** | **4** | **5** |
| 15. kendi anlayışlarım/görüşlerim üzerinde | **1** | **2** | **3** | **4** | **5** |

## Bölüm 1I: Çoklu Ortam (Multimedya) Programları

Aşağıda belirtilen ifadelerin multimedyada hangi sıklıkta rçekleşmesini tercih ederdiniz? Lütfen belirtiniz .

| **İlgililik –Anlamlılık** | Hiçbir zaman | Nadiren | Bazen | Genellikle | Her Zaman |
|---|---|---|---|---|---|
| Çoklu ortam programıyla çalışırken, çoklu ortamın.... | | | | | |
| 16. gerçek yaşam ortamlarının ne kadar karmaşık olduğunu gösterdiğini fark etmeliyim. | **1** | **2** | **3** | **4** | **5** |
| 17. bilgiyi anlamlı bir biçimde sunduğunu fark etmeliyim. | **1** | **2** | **3** | **4** | **5** |
| 18. benim için anlamlı olan bilgileri verdiğini fark etmeliyim. | **1** | **2** | **3** | **4** | **5** |
| 19. gerçeğe uygun etkinlikler sunduğunu fark ettim. | **1** | **2** | **3** | **4** | **5** |
| 20. geniş bir bilgi yelpazesine sahip olduğunu fark etmeliyim. | **1** | **2** | **3** | **4** | **5** |
| **Kullanım Kolaylığı** | | | | | |
| Çoklu ortam programıyla çalışırken, . | | | | | |
| 21. çoklu ortam ilginç bir ekran tasarımına sahip olmalı. | **1** | **2** | **3** | **4** | **5** |
| 22. çoklu ortamın menüleri arasında gezmek kolay olmalı. | **1** | **2** | **3** | **4** | **5** |
| 23. çoklu ortam kullanmak eğlenceli olmalı. | **1** | **2** | **3** | **4** | **5** |
| 24. çoklu ortamı kullanmak kolay olmalı | **1** | **2** | **3** | **4** | **5** |
| 25. çoklu ortamın nasıl kullanılacağını öğrenmek kısa zaman almalı. | **1** | **2** | **3** | **4** | **5** |
| **Zorluk Düzeyi** | | | | | |
| Çoklu ortam programıyla çalışırken, oklu ortamın.... | | | | | |
| 26. beni düşündürmeli. | **1** | **2** | **3** | **4** | **5** |
| 27. karmaşık ama anlaşılır olmalı. | **1** | **2** | **3** | **4** | **5** |
| 28. kendi sınırlarımı zorlayarak öğrenmemi sağlamalı. | **1** | **2** | **3** | **4** | **5** |
| 29. yeni fikirler üretmeme yardımcı olmalı. | **1** | **2** | **3** | **4** | **5** |
| 30. yeni sorular üretmeme yardımcı olmalı. | **1** | **2** | **3** | **4** | **5** |

# APPENDIX I

## INTERVIEW SCHEDULE WITH STUDENTS

Merhaba arkadaşlar,

Sizinle biyoloji dersi kapsamında MİTOZ ve MAYOZ bölünmeyi çoklu ortam materyali (multimedya) kullanarak işledik. Bu konuları öğrenirken farklı ekran tasarımlarına sahip iki çoklu ortam yani "oyun 1" ve "oyun 2'yi" kullandınız. Bu iki oyun arasında ekran tasarımları açısından çeşitli farklılıklar bulunmaktaydı. Benim amacım, kullandığınız her iki tip çoklu ortamın ekran tasarımlarındaki farklılıklara ilişkin görüşlerinizi, olumlu ve olumsuz bulduğunuz yönleri ve gerekçelerini öğrenmek. Açıklamalarınız doğrultusunda çoklu ortam tasarımlarında olumlu veya olumsuz gördüğünüz özellikler belirlenebilecek ve gelecekte yapılacak çoklu ortam tasarımları verdiğiniz bilgiler doğrultusunda geliştirilecektir.

Burada konuşulan her şey gizli kalacak, sadece akademik amaçla kullanılacak ve adınız hiçbir şekilde açıklanmayacaktır. Görüşme yaklaşık olarak yarım saat -45 dakika sürecek. Bunun dışında sormak istediğiniz bir şey varsa görüşmeye başlamadan önce yanıtlayabilirim. Eğer izin verirseniz görüşmemizi kaydetmek istiyorum.

Özgeçmiş Soruları:

Adınız Soyadınız:

1. Hazırladığımız ve sizin kullandığınız çoklu ortam materyalinde Mitoz ve Mayoz bölünme konuları bir senaryo çerçevesinde sunulmuştur. Konuyu öğrenirken bir amaç doğrultusunda bir görevi yerine getirmeye çalıştınız

Yazılımda /Materyalde kullanılan senaryo yaklaşımı ile öğrenme deneyiminin sizce olumlu ve olumsuz tarafları nelerdir? Neden?

2. Oyun1 de "Mitoz ve Mayoz " bölünmenin anlatıldığı animasyonları hem sesli hem de altyazılı olarak izleme seçeneğiniz vardı. Siz hangi seçeneği tercih ettiniz? Neden?
3. Tercih ettiğiniz seçeneğin olumlu veya olumsuz gördüğünüz tarafları nelerdir?
4. Oyun 2 de "Mitoz ve Mayoz" bölünmenin anlatıldığı animasyonları sadece altyazılı olarak izlediniz. Okuyarak animasyonları takip etmeniz konuyu öğrenirken sizi nasıl etkiledi?
5. Animasyonları okuyarak takip etmeniz olumlu ya da olumsuz gördüğünüz tarafları nelerdir?
6. Oyun 2 de "Mayoz Bölünme" anlatılırken arkadaki fon müziği konuyu öğrenirken sizi nasıl etkiledi?
7. Oyun 1 de "Mitoz ve Mayoz" bölünmenin ana evrelerini sıralarken her bir ana evrenin resmi bulunurken, oyun 2 de her bir ana fazın sadece ismi yer almıştı. Ana fazlara ait resimlerin kullanılması evreleri sıralamanızda etkili oldu mu? Nasıl?
8. Oyun 2 de " Mitoz ve Mayoz" bölünme anlatılırken ekranda açılan" Bunları Biliyor musunuz" bilgi kutucukları hakkındaki olumlu ve olumsuz görüşleriniz nelerdir?
9. Oyun1 ve Oyun 2 deki "Kütüphane" linki farklı ekran tasarımlarına sahipti. Örneğin, oyun1 de resimler kullanılırken, oyun 2 de resimler kullanılmamaktaydı. Veya oyun 1 'de her bilgi " sorular, konular, sözlük,.." aynı sayfa üzerinde açılırken, oyun 2 de her bilgi "sorular, konular, sözlük" farklı sayfalarda açılmaktaydı. Bu ve buna benzer özellikler kütüphaneyi kullanmanızı nasıl etkiledi?
10. Kullandığınız yazılımları genel anlamda değerlendirdiğinizde, bir yıl sonra Biyoloji dersini alacak arkadaşlarınıza Oyun1 ve Oyun2 hakkında olumlu ve olumsuz yönleri ile ilgili nasıl bilgi verirsiniz? Neler söylersiniz?

# APPENDIX J

## INTERVIEW CITATIONS OF STUDENTS

[S-1]: Bir misyonunuz olduğunda, sorumluluğunuz olduğunu hissediyorsunuz ve bu nedenle daha iyi öğrenmeliyim deyip en iyiyi yapıyorsunuz. Böyle bir durumda daha iyi öğreniyoruz.

[S-2]: Amacıma ulaşmak için bir şeyler yapmaya başlıyorum. Bir hata yaptığımda bu beni üzmüyor çünkü ben bir şeyler öğrendiğimin farkındayım

[S-3]: Konuyu bir misyonla öğrenmek beni verilen görevi tamamlamam için heveslendiriyor. Buda benim hırsımı arttırıyor ve görevi başarmak için en iyiyi yapmaya çalışıyorum.

[S-4]: Rolüm bana sorunluluk duygusu hissettiriyor ve buda verilen görevi tamamlaman için hırslandırıyor.

[S-5]: Rolüm hem eğlenceli hamda heyecanlıydı. Konuyu daha kolay anlamamı sağladı. Bilim insani olmak merakımı arttırdı ve en sonunda görevi bitirmemi sağladı. Kendimle gurur duydum ve zekâma inanmaya başladım. Sonuç olarak. Rol vermek daha öğretici.

[S-6]: Çoklu ortam ile öğrenmek öğrenmeyi hem daha zevkli hem daha hızlı hem de kalıcı kılıyor.  Benim sınıf ortamında çok rahat dikkatim dağılıyor fakat bu çoklu ortamda öyle olmuyor.

[S-7]: Çoklu ortamla öğrenirken süreçleri görselleştirebiliyorsun ve bu konuyu anlamamı kolaylaştırıyor

[S-8]: Verilen problemi çözmek için çok caba sarf ettim ve konuyu öğrenmek zorunda kaldım. Ama bu sınıf ortamı için geçerli değil sadece bilgileri ezberliyorum.

[S-9]: Kurgu gerçek hayatla ilişkilendirildiği için ben bu konunun bizim için neden önemli olduğunu öğrendim

[S-10]: İlk defa mitoz ve mayoz bölünmeyi neden öğrenmeme gerektiğini ve hayatimiz için önemini anladım.

[S-11]: Sesin kullanımı anlamamı kolaylaştırdı çünkü öğrenme surecinin içinde olmamı kolaylaştırdı. Bu nedenle, daha kolay adapte oldum ve her şey otomatik olarak devam etti.

[S-12]: Evet, dikkatimi arkada çalan klasik müzik yüzünden odaklayamadım. Ama animasyonlar dikkatimi yoğunlaştırmamı kolaylaştırdı.

[S-13]: Ben mayozun mitoz gibi tasarımlanması gerektiğine inanıyorum. Animasyonlar seslendirilmeli çünkü seslendirme anlamayı kolaylaştırıyor

[S-14]: Ben resimlerle çalıştığımda anlamak için daha fazla caba sarf ediyorum.

[S-15]: Konuyu bildiğim zaman resimlere bakma gereksinimi duymuyorum doğru sıralama yapmak için.

[S-16]: Her defasında yeni bir sayfanın başka bir pencerede açılması beni strese soktu. Ve bilgileri tek bir pencere üzerinde görmenin daha yararlı olduğunu düşünüyorum.

[S-17]: Ses animasyonları anlamak için yeterli. Kullanılan ses tonu çok iyiydi ve rahatlıkla odaklanmamı sağladı.

[S-18]: Örneğin ben mayozu öğrenirken ilgim azaldı Altyazıları okumaya çalışırken konuyu kaçırdığımı düşünmem anlamamı daha da zorlaştırdı.

## CURRICULUM VITAE

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### EDUCATION

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|---|---|---|
| **Ph.D.** | Middle East Technical University, Faculty of Education, Department of Computer Education and Instructional Technology | **2003-2009** |
| **B.A.** | Ankara University, Faculty of Educational Science, Department of Computer Education and Instructional Technology, 2002, Ankara, | **1998-2002** |
| **High School** | Bingöl Anatolian High School | **1991-1998** |

### PROFESSIONAL EXPERIENCE

| | |
|---|---|
| **2009 (5 months)** | **Visiting Scholar,** Arizona State University, Learning Science Research Lab (Fellowship from Prime Ministry State Planning Organization) |
| **2008 (7 months)** | **Visiting Scholar,** Open University of The Netherlands, Center for Learning Sciences and Technologies (Fellowship from The Scientific and Technological Research Council of Turkey) |
| **2002-Present** | Research Assistant**,** METU, Faculty of Education, Department of Computer Education and Instructional Technology |

**2000-2002** **Trainee student,** Computer Center**,** Ankara University, Faculty of Educational Science

## PROJECT

- Youth in transition: becoming active citizens through social interaction, artistic development and technology - (Youth - SocArTech), Youth in Action Programme (EU Project), 2009 (Partner, in progress)

- The Effects of Cognitive Load in Goal-Based Scenario Centered Multimedia on Learning of the Learners with High and Low Working Memory Capacities, The Scientific and Technological Research Council of Turkey (TUBITAK) under grant SOBAG 107K150 project, 2007

- Çocuk Dostu Okul Projesi, Ministry of Education and UNESCO, 2006

- Bilgisayar Öğretmenliğine İlişkin Beklentilerin Bilgisayar Öğretmenleri, Okul Yöneticileri ve Diğer Öğretmenlerin Algıları Açısından İncelenmesi, Scientific Research Project, 2006

- E-campus project, Middle East Technical University, 2004

## PUBLICATIONS

### International Book Chapters

Yıldırım, Z. & **Kilic, E.** (2008). Pre service computer teachers as game designers: Goal-Based Scenario centered 3D educational game development process. In Ferdig, R. E. (Ed.) Handbook of Research on Effective Electronic Gaming in Education,. Information Science Reference (formerly Idea Group Reference), Hershey, PA

### Journal Papers

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Eteokleous, N., Krausz, A., & **Kilic. E.(** submitted to Journal of Educational Computing Research). The Application of a Virtual-Social Curriculum: Developing Teenagers Cultural competency, and Social Skills

**International and National Conference Paper**

**Kilic, E.,** Yildirim, Z. (2010). The Effects of Cognitive Load in Learning from Goal Based Scenario centered 3D Multimedia Learning Environment, will be presented at American Educational Research Association (AERA) Annual Meeting, 30 April- 4 May, USA, 2010.

**Kilic, E.,** Yildirim, Z. (2010). Evaluating working memory capacity and cognitive load in learning from goal based scenario centered 3D multimedia, will be presented at World Conference on Educational Sciences, 4-8 February, Turkey, 2010.

**Kilic, E.,** Yildirim, Z. (2009). Evaluation of Goal Based Scenario Centered Constructivist Multimedia Regarding Negotiation, Inquiry Learning, Reflective Thinking, Authenticity, Complexity and Challenge, American Educational Research Association (AERA) Annual Meeting, 13-17th April, USA, 2009.

**Kilic, E.,** Yildirim, Z. (2009). Cognitive Load & Goal Based Scenario Centered 3D Multimedia Learning Environment: Learners' Satisfaction, Motivation and Mental Effort, 3th International Cognitive Load Theory Conference, 1-4th May, The Netherlands, 2009.

Yildirim, Z., Yalcinalp, S., & **Kilic, E.** (2009) Computer Teachers' Other Subject Area Teachers' and Administrators' Perceptions of Computer Teachers and Their Teaching Profession, European Conference on Educational Research, Vienna, Australia, 25-30 September, European Educational Research Association, Glasgow, UK, 2009.

**Kilic, E**. & Yildirim, Z. (2008). Understanding Net Generation: Students' Profiles on Using Information and Communication Technologies and Their Preferences of Playing Games. European Conference on Educational Research, Göteborg, Sweden, 8-12th September, European Educational Research Association, Glasgow, UK, 2008.

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Çağıltay, K., Bakar, A., Baran B. & **Kilic, E.** (2004). Ideas of Academics about Internet aided education, New Information Technologies in Education 2nd International Workshop (NITE'2004), Dokuz Eylül University, Izmir, Turkey,

## RESEARCH INTEREST

- Cognitive Development
- Cognitive Load
- Developing, Designing and Evaluating Educational Software
- E-Learning
- Human Memory
- Human Computer Interaction
- Instructional Message Design
- Multicultural Learning