THE EFFECT OF AN INSTRUCTION DESIGNED BY COGNITIVE LOAD THEORY PRINCIPLES ON 7TH GRADE STUDENTS' ACHIEVEMENT IN ALGEBRA TOPICS AND COGNITIVE LOAD

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ABSTRACT

THE EFFECT OF AN INSTRUCTION DESIGN BY COGNITIVE LOAD THEORY PRINCIPLES ON 7th GRADE STUDENTS' ALGEBRA ACHIEVEMENT AND COGNITIVE LOAD

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The purpose of this study was to investigate the effect of an instruction designed by the Cognitive Load Theory (CLT) principles on 7th grade students' achievement in Algebra topics and cognitive load. Two groups (experimental and control) from a public school in İstanbul took part in the study. Each group had 40 students; totally 80 students were included in the study. A quasi-experimental research design was utilized. The study was conducted in totally six weeks in 2010-2011 fall semester. The instruction designed by CLT principles was used in the experimental group, while the instruction recommended by the MONE was used in the control group of the study. For each Algebra unit, the researcher developed Teachers' Guidelines and Students' Booklets for using in the experimental group. At the end of each unit, the Subjective Rating Scale (SRS) was used to measure students' cognitive load for both groups. After the completion of the treatment, the Algebra Achievement Test (AAT) developed by the researcher was administrated to the groups. The Students Questionnaire (SQ) was administrated to the experimental group for finding about student's views and opinions related to the treatment. Students' interviews were conducted at the end of the treatment. Both descriptive and inferential statistical (MANOVA) techniques were used for analyzing quantitative data. Further, content analysis was used for analyzing the qualitative data. Statistical mean difference was obtained for all tests in favor of experimental group and the findings of quantitative data analysis results were supported by the qualitative data analysis results. It can be concluded that the instruction designed by CLT principles is effective for the Algebra teaching.

Keywords: Cognitive Load Theory, Cognitive Load, Subjective Measure of Cognitive Load, Algebra Achievement, Efficiency of Instruction.

ÖZ

BİLİŞSEL YÜK KURAMI İLKELERİNE GÖRE GELİŞTİRİLMİŞ BİR ÖĞRETİMİN 7. SINIF ÖĞRENCİLERİN CEBİR BAŞARISINA VE BİLİŞSEL YÜKLERİNE ETKİSİ

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Bu çalışmanın amacı Bilişsel Yük Kuramı (BYK) ilkelerine göre geliştirilmiş bir dersin 7. sınıf öğrencilerin Cebir başarısına ve bilişsel yüklerine etkisini incelemektir. İstanbul'daki bir devlet okulundan iki grup (deney ve kontrol grubu olmak üzere) çalışmada yer almıştır. Her bir grupta 40 öğrenci bulunmakta olup; çalışmaya toplamda 80 öğrenci katılmıştır. Çalışmada yarı deneysel araştırma yöntemi kullanılmıştır. Çalışma 2010-2011 öğretim yılı sonbahar döneminde toplam 6 hafta uygulanmıştır. BYK ilkelerine göre hazırlanmış öğretim tasarımı deney grubunda; MEB tarafından önerilen mevcut program ise kontrol grubunda kullanılmıştır. Her bir Cebir konusu için araştırmacı tarafından Öğretmen ve Öğrenci Kitapçıkları geliştirmiştir. Her bir konunun sonunda Bilişsel Yük Ölçegi (BYÖ); uygulamanın sonunda ise Cebir Başarı Testi (CBT) her iki gruba da uygulanmıştır. Sadece deney grubunda bulunan öğrencilere uygulama ile ilgili olarak anket uygulanmış ve görüşmeler yapılmıştır. Nicel verilerin analizinde betimsel ve çok değişkenli istatistik (MANOVA) kullanılmıştır. Nitel veriler için içerik analizi kullanılmıştır. Bütün testlerin ortalamalarında, deney grubu lehine anlamlı fark bulunmuş ve nitel bulgularla da desteklenmiştir. BYK ilkelerine göre gerçekleştirlmiş öğretimin, Cebir öğretimi için etkili olduğu söylenebilir.

Anahtar Kelimeler: Bilişsel Yük Kuramı, Bilişsel Yük, Bilişsel Yük Ölçümü, Cebir Başarısı, Öğretimin Verimliliği.

To my son,

Ahmet Levent TAKIR

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ABBREVIATION	
CLT	: Cognitive Load Theory
ICL	: Intrinsic Cognitive Load
ECL	: Extraneous Cognitive Load
GCL	: Germane Cognitive Load
WM	: Working Memory
STM	: Short Term Memory
LTM	: Long Term Memory
AAT	: Algebra Achievement Test
SRS	: Subjective Rating Scale
SQ	: Student Questionnaire
IS	: Interview Schedule
MAG	: Mathematics Achievement Grades
SES	: Socioeconomic Status
SPSS	: Statistical Package for Social Sciences
MANOVA	: Multivariate Analysis of the Variance
MONE	: Ministry of Education
E	: Efficency
N	: Sample size
M	: Mean
SD	: Standard deviation
Df	: Degree of freedom
F	: F statistics
t	: T statistics
p or Sig.	: Significance Level

D^2	: Mahalanobis Distance
ICC	: Intra-Class Correlation

CHAPTER I

INTRODUCTION

This study aimed to investigate the effect of an instruction designed by the CLT principles on 7^{th} grade students' achievement in Algebra topics and cognitive load. This chapter contains the theoretical background, purpose, and significance of the study. The definitions of important concepts that are considered in the rest of the dissertation are presented at the end of the chapter.

1.1 Background to the Study

The Cognitive Load Theory (CLT) has emerged over the last decade as an influential theory of educational psychology and instructional design. The CLT originated in the 1980s through the work of John Sweller and his colleagues at the University of New South Wales (Clark, Nguyen, & Sweller, 2005; Paas, Renkl, & Sweller, 2003).

The CLT is a theoretical framework grounded in the learner's cognitive architecture (Janssen, Kirschner, Erkens, Kirschner, & Paas, 2010) that assumes that working memory (WM) is very limited in terms of being able to store and process information (Cowan, 2005; Miller, 1956; Paas, Van Gog, & Sweller, 2010) and long term memory (LTM) has an unlimited capacity, being able to store an almost limitless amount of information. The CLT predicts learning outcomes by taking into consideration the capabilities and the limitations of this architecture (Plass, Moreno, & Brünken, 2010).

As understood from its definition, CLT differs from other instructional theories with its emphasis on human cognitive architecture. It considers knowledge of human cognitive architecture to be critical for instructional design and effectiveness of an instruction depends heavily on whether it takes the characteristics of human cognition into account.

Cognitive load can be defined as a multidimensional construct representing the load that performing a particular task imposes on the learner's cognitive system (Paas, Tuovinen, Tabbers, & Van Gerven, 2003; Paas & Van Merrienboer, 1994). The roles of the WM and LTM in human architecture allow to categorize the source of the cognitive load as *intrinsic*, *extraneous*, and *germane* cognitive loads (Paas et al., 2003). If load is imposed by the number of information elements and their interactivity, it is called *intrinsic* (ICL). If it is imposed by the manner in which the information is presented to learners and by the learning activities required of learners, it is called *extraneous* or *germane*. Whereas extraneous load (ECL) is imposed by information and activities that do not contribute to the processes of schema construction and automation; germane load (GCL) is related to information and activities that foster these processes (Paas, Renkl, & Sweller, 2004).

An increase in ECL reduces the WM resources available to deal with ICL and hence reduces GCL. Decreasing ECL frees resources to deal with ICL and thus increases GCL. When ICL is high, it is important to decrease ECL; otherwise, the combination of both might exceed the maximum cognitive capacity and thus prevent the GCL to occur. From an instructional design point of view, it is important to consider communication of ECL and GCL, because the reduction of ECL can free cognitive resources for an increase in GCL (Paas et al., 2003; Paas et al., 2010; Schnotz & Kürschner, 2007).

There are many assessment techniques of the cognitive load. The common technique among the CLT researchers is s*ubjective rating scale technique* which is based on the assumption that *''people are able to introspect on their cognitive processes and to report the amount of mental effort expended''* (F Paas et al., 2003). Paas and van Merrienboer (1994) have used a rating scale for measuring perceived task difficulty by using a 9-point Likert scale ranging from very, very low mental effort (1) to very, very high mental effort (9).

Efficiency is an important issue that should be considered in CLT research. It can be defined as a property of instructional products that results in faster learning, better learning, or both (Clark et al., 2005). Paas & Van Merrienboer (1993) suggests a calculation approach for combining the measures of mental load and performance that allows to obtain information on the relative efficiency of instructional conditions.

The CLT has generated a range of techniques intended to achieve the purpose of reducing the ECL and maximizing the GCL. CLT was applied in several contexts and studied by using randomized, controlled experiments. The empirical results of these studies led to the demonstration of several instructional techniques which are called *CLT Effects*. As discussed in previous paragraphs, CLT differs from the other instructional theories with its emphasis on human cognitive architecture, further; CLT differs from the other instructional theories by the methodology it uses.

There are many CLT effects that instructional designers can consider when they plan an instruction. One of them is the *worked example effect* which was also the main effect of this study. It is a technique that decreases the ECL by replacing some practice exercises with a series of worked examples, each followed by similar practice exercise (Clark et al., 2005). A *completion problem* is a partial worked example where the learner has to complete some key solution steps (Sweller, Ayres, & Kalyuga, 2011a). It is a hybrid between practice assignment and a worked example. Like worked example, completion examples reduces cognitive load; schemas can be acquired by studying the work-out portions (Clark et al., 2005). Completion examples were used in this study especially the topics that thought to be difficult, to satisfy smooth transition from examples to practice exercises.

The basic underlined principle of the *modality effect* is that ‘‘complex visuals are understood more efficiently when explanatory words are presented in an audio modality than when presented in a written modality’’ (Clark et al., 2005). Therefore, it is very important to consider verbal explanations during the lesson hours. The *redundancy effect* of the CLT occurs when unnecessary, additional information is presented to learners (Sweller, 2010) or when identical information is presented in multiple forms, which decreases rather than increases learning (Pawley, Ayres, Cooper, & Sweller, 2005). Redundancy effect is an important factor when designing instruction (Chandler & Sweller, 1991) and, in its many forms, has a detrimental effect on learning (Kalyuga, Chandler, & Sweller, 2001; Sweller & Chandler, 1991).

Expertise reversal effect occurs when an instructional procedure that is effective for novices in comparison to an alternative instruction that becomes less effective as expertise increases. This effect is very important especially in classrooms where there are mixture of novice and experienced learners. Expertise reversal effect has important considerations together with the *guidance fading effect* of the CLT. This effect suggests that learners should first be presented worked examples, followed by completion problems and then full problems assignments (Renkl & Atkinson, 2003) which was used in this dissertation.

In summary, CLT can be applied to a broad range of learning environments by linking the design characteristics of instruction to the principles of human cognitive architecture.

1.2 Purpose of the Study

As described previously, the human cognitive architecture is concerned with the manner in which cognitive structures are organized. The relations between the WM and the LTM, in conjunction with the cognitive processes that support learning, are of critical importance for designing an instruction. Kirschner et al. (2006) expressed that the architecture of the LTM provides the ultimate justification for instruction: the aim of all instruction is to alter the LTM. If nothing has changed in the LTM, nothing has been learned. They concluded that any instructional recommendation that does not specify what has been changed in the LTM, or that does not increase the efficiency with which relevant information is stored in or retrieved from the LTM, is likely to be ineffective.

From the WM perspective, Kirschner et al. (2006) described that any instructional theory that ignores the limits of WM when dealing with novel information or ignores the disappearance of those limits when dealing with familiar information is unlikely to be effective. They maintain that learners, especially novices, are unable to effectively process information due to the limits of WM, hence the learning suffers (Tobias & Duffy, 2009).

The human cognitive architecture has obvious implications for the amount of guidance and assistance provided to the learners. Instruction should be explicit and clear. Based on this architecture, there seems to be no purpose or function to withholding information from the learners so that they can discover it for themselves (Tobias & Duffy, 2009). According to Clark et al. (2005) the learners' engagement of an instruction is not directed toward schema acquisition and automation; so it can impose an ECL. They suggested the use of directive rather than student centered approaches for novice learners. As they stated, the instructional designers should prepare directive lessons for novice learners that provide brief content segments including explanations, examples, and practices, and further, the instructional designers should prepare more student centered lessons for more experienced learners.

The worked example, completion example, split attention, modality, expertise reversal, redundancy, and guidance faded effects of the CLT are the central CLT effects of this dissertation and were used for preparing classroom materials and implementation process.

By considering the CLT effects and human cognitive architecture principles, an instruction was designed and implemented in 7th grade Mathematics classroom. The purpose of the study was to investigate the effect of this instruction designed by the CLT principles on 7th grade students' achievement in Algebra topics and cognitive load. More specifically, the study aimed to determine whether the CLT treatment has an effect on students' Algebra achievement and cognitive load and find out the efficiency score of the instruction in terms of the students' achievement and cognitive load measures. Further, another aim of the study was to reveal the perceptions of the students who were exposed to instruction designed by CLT principles about the treatment.

1.3 Significance of the Study

Conducting a research study on investigation of the effects of an instruction developed by CLT principles on students' Algebra achievement and cognitive load is valuable from the several perspectives.

The current mathematics curriculum that is used in primary schools in Turkey was developed in 2004. The underlining principle of the curriculum is that "Every child can learn mathematics''. It highlights the importance of a learning environment where the students research, discover, and solve problems, as well as share and debate their solutions and approaches (Bulut, 2005). Babadoğan and Olkun (2006) argue that constructivist pedagogies are adopted in the curriculum. These constructivist pedagogies are active learning, use of manipulative, cooperative learning, and the use of realistic and authentic tasks (Babadogan & Olkun, 2006). The curriculum gives importance to conceptual learning as well as computational skills.

The CLT states that if the learners have no relevant schemas for a topic, this leads to WM overload. For this reason, the CLT suggests that student-centered methods should be implemented after the learners gain some experience. Classroom activities and group works must be considered at the end of the lessons. In other words, constructivist theories might create more efficient and effective instructional environments if they are combined with the CLT principles.

In the experiment conducted for this study, the information was presented in as few modes as needed to make the Algebra topics understandable. Interesting but not directly related or unnecessary content was never the starting point of the lectures. The instruction was dependent on the ''less is more'' principle, or a minimalist approach which was easily integrated with the constructivist learning environments.

Generally, classrooms in primary schools in Turkey include a mixture of novice and experienced learners. However, the instructional techniques that are adequate for novices may be redundant for the more experienced learners. Similarly, the instructional techniques adequate for experts may lead to WM overload for the novices. For example, mathematics problems in daily life situations proposed by mathematics curriculum might be motivating and helpful for novice learners. However, for more experienced learners, it would be unnecessary in other words redundant to read the entire problem. Therefore, the effects, especially the guidance faded effect of the CLT would be helpful to organize instruction according to the prior knowledge of the learners.

Tatar and Dikici (2008) concluded the students' learning difficulties in mathematics classrooms as (1) deficiencies in instruction, (2) abstract topics, (3) lack of interpretation of verbal explanations, and (4) lack of prior knowledge. As described previously, CLT gives the importance to design effective instructional environments by considering its effects and to take into account students' prior knowledge. Further, CLT effects provide empirical evidence suggestions for dealing with complex topics, in other words, it provides suggestion for dealing with ICL which is directly related with the complexity of a topic. Therefore, carrying out this study might provide effective ways for mathematics teaching and learning, and be beneficial for primary school mathematics curriculum.

Bednarz (1996) defines Algebra as a ‘‘mini-culture’’ within the wider culture of mathematics. This definition allows integrating Algebra as a set of activities and a language. Usiskin (1995) defines Algebra as the language of generalization. Algebra is very important, not only in mathematics, but also in all areas and at every stage of life. Algebra is everywhere; from the solutions of encountered problems in daily events to solutions of the problems in other sciences (Dede, Yalın, & Argün, 2002). Algebraic concepts and ideas is considered not only as an area of mathematical knowledge to be learned in schools, but also as an indispensable and integral part of mathematics literacy (Erbaş & Ersoy, 2005). Given the importance of Algebra in the students' educational lives beyond, it is crucial to developed more advance Algebra instructions based on the CLT principles. These principles, if successful, can then be extended to other topics, subjects, and courses.

As ''Re-conceptualizing School Algebra" (1997, as cited in Dede & Argün, 2003) reports, the obscures in the Algebra learning of students are explained by the *epistemological obstacle* (an obstacle intrinsically related to the nature of the content itself), *psycho-genetic obstacle* (an obstacle due to the intrinsic characteristics of the children's development), and *didactic obstacle* (an obstacle related to the instruction). *Epistemological obstacle* is directly related to the intrinsic cognitive load (ICL) defined by the CLT. *Psycho-genetic obstacle* can be considered as the limitations of the students' WM. *Didactic obstacle*, as related to the extraneous cognitive load (ECL), can be controlled by using the principles, effects, and instructional guidelines of the CLT. The CLT effects, such as worked example effect, split attention effect, and modality, can help in managing didactic obstacles and provide a new approach for effective Algebra instruction for teachers and curriculum developers.

Previous research on CLT in Algebra topics included one Algebra topic together with one or two CLT effects in experimental settings (Ayres, 2006; Cooper & Sweller, 1987; Kalyuga & Sweller, 2004; Pawley et al., 2005; Sweller, 1988; Sweller & Cooper, 1985). In the current study, more than one Algebra topics were considered with multiple CLT effects in a real classroom environment. Therefore, the results of this study might provide valuable suggestions for especially for the teachers.

The previous research studies related to CLT restricted to only multimedia learning environment in Turkey. Therefore, this study may open the way of research studies that will conducted in classroom environment settings.

1.4 Definitions of the Terms

This section provides the definitions and descriptions of the critical concepts used in the study.

Cognitive Load Theory: Cognitive Load Theory is a set of instructional principles and evidence based guidelines that offer efficient methods to design and deliver instructional environments in ways that utilize the limited capacity of WM (Clark et al., 2005).

Cognitive Load Theory Principles: Cognitive Load Theory emphasizes the necessity for instructional techniques to be designed in alignment with the basic operational principles of the human cognitive system. These are *the information store principle, the borrowing and reorganizing principle, the randomness as genesis principle, the narrow limit of change principle, the environmental organizing,* and *linking principle* (Sweller et al., 2011a).

Cognitive Load Theory Effects: Cognitive Load Theory effects provide the instructional recommendations generated by Cognitive Load Theory. There are many Cognitive Load Theory effects. In this thesis, (a) worked example effect, (b) completion example effect, (c) split-half effect, (d) modality effect, (e) redundancy effect, (f) experimental reversal effect, and (f) guidance faded effect of the Cognitive Load Theory were used for preparing Students' Booklets.

Instruction Based on Cognitive Load Theory: Instruction planned and implemented according to the principles and effects of the Cognitive Load Theory.

Instruction Based on the Recommendations of MONE: Instruction based on the curricula and teaching-learning environments suggested by the MONE.

Algebra Achievement: In this study, achievement test developed by the researcher was used to assess the degree of achievement of objectives.

Cognitive Load: Cognitive load is the cognitive capacity actually allocated to the task. The basic assumption of the study is learners are able to introspect on their cognitive processes and to report the amount of mental effort expended (Paas & Van Merrienboer, 1993).

Subjective Rating Scale: Subjective Rating Scale is a 9-point symmetrical scale ranging from 1 (very, very low mental effort) to 9 (very, very high mental effort) developed by Paas & Van Merrienboer (1993). Subjective Rating Scale was used to measure students' cognitive load in this study.

Efficiency of Instruction: Efficiency is a property of the instructional products that results in faster learning, better learning or both (Clark et al., 2005).

Efficiency Metric: The visual representation of the efficiency is called the efficiency metric. The student scores for cognitive load and performance are standardized, yielding a *z* score for cognitive load and a *z* score for performance. Then, an instructional condition efficiency score (*E*) is computed by using the formula, $E = \frac{z_{performance} - z_{mental\ effort}}{\sqrt{2}}$. The efficiency metric is used to display the information on a Cartesian Axis, performance (vertical) and cognitive load (horizontal) (Clark et al., 2005; Sweller et al., 2011a).

CHAPTER II

REVIEW OF THE LITERATURE

This chapter consists of the literature on Cognitive Load Theory. The theoretical background of the Cognitive Load Theory is considered in the first five sections. The research studies on Cognitive Load Theory effects are considered in the sixth section. Summary of the reviewed literature is given at the end of the chapter.

2.1 Cognitive Load Theory

Cognitive Load Theory (CLT) is based on the principle developed by Miller (1956) knowing as number 7±2 items can only process at one time in human brain. Based on the researches, instructional scientists has expanded and refined the rule of 7±2 into a comprehensive set of instructional principles called CLT (Clark et al., 2005).

CLT originated in the 1980s through the work of John Sweller and his colleagues at the University of New South Wales (Clark et al., 2005; F. Paas et al., 2003). CLT has developed from a theory in its early beginnings that focused on problem solving to a more recent re-conceptualization as a learning theory with an evolutionary biological base (Ayres & Gog, 2009).

According to the Chandler and Sweller (1991), CLT suggests effective instructional material facilitates learning by directing cognitive resources toward activities that are relevant to learning rather than toward preliminaries to learning.

Kirschner (2002) defined CLT as providing guidelines to assist in the presentation of information in a manner that encourages learner activities that optimize intellectual performance.

According to the Van Gerven, Paas, Van Merrienboer, and Schmidt (2002), CLT is aimed at developing training material that efficiently makes use of the available cognitive processing capacity and stimulates the learner's ability to use acquired knowledge and skills in new situations.

Van Bruggen, Kirschner, and Jochems (2002) defines CLT as ‘‘CLT is concerned with the limitations of WM (working memory) capacity and the measures that can be taken to promote learning that is the construction of schemata, by imposing adequate levels of cognitive load’’(p.122).

For Van Gog, Paas, and Van Merrienboer (2004), CLT is concerned with the learning of complex cognitive tasks, in which learners may be overwhelmed by the number of interactive information elements that need to be processed simultaneously before meaningful learning can commence.

Clark et al. (2005) defined CLT as ‘‘a universal set of instructional principles and evidence based guidelines that offer the most efficient methods to design and deliver instructional environments in ways that best utilize the limited capacity of WM’’(p.342). CLT is designed to accommodate the limits and exploit the strengths of the WM.

Schnotz and Kürschner (2007) stated that the fundamental claim of the CLT is that without knowledge about the human cognitive architecture, the effectiveness of instructional design is likely to be random. More specifically, CLT argues that many traditional instructional techniques do not adequately consider the limitations of the human cognitive architecture. Accordingly; as they stated, CLT tries to integrate knowledge about the structure and functioning of the human cognitive system with principles of instructional design.

Janssen, Kirschner, Erkens, Kirschner, and Paas (2010), F. Paas, Van Gog, and Sweller (2010), and Plass, Moreno, and Brünken (2010) also stressed the issue that CLT is a theoretical framework grounded in the learner's cognitive architecture and learning environments for complex cognitive tasks can only be effective and efficient when they are designed in such a way that they facilitate changes in learners' LTM (long term memory). Further, Janssen et al. (2010) associated the changes in learners' LTM with schema construction and schema automation. Therefore, all these definitions imply that CLT is concerned with techniques for managing WM load in order to facilitate the changes in LTM associated with schema construction and automation (Kirschner, 2002; Paas et al., 2010; Sweller et al., 2011a).

As understood from all these above definitions, the key aspect of the CLT is the relation between LTM and WM, and how instructional materials interact with this cognitive system (Verhoeven, Schnotz, & Paas, 2009). It implies that instruction needs to consider the limitations of WM, therefore, information can be stored effectively in LTM (Chandler & Sweller, 1991; Sweller, 1988, 1994; Sweller & Chandler, 1991).

All of the definitions of the CLT stressed the suggestions of the CLT about the effective instructional environments and the dependency of the CLT on human cognitive architecture. In the following paragraphs, the human cognitive architecture is discussed to understand the features of the CLT better.

2.1.1 Human Cognitive Architecture: Working Memory (WM) (Short Term Memory-STM) and Long Term Memory (LTM)

The term *cognitive architecture* has been defined as the organizations of the cognitive structures (Paas et al., 2003).

The major characteristics of human memory are its strength or durability, capacity (number of items of information stored in memory), and speed of access (Kalyuga, 2009). The human cognitive architecture includes two main memory systems: working memory (WM) or short term memory (STM) and long term memory (LTM). All human learning and work activities rely on two of these two memory systems and their partnership (Clark et al., 2005).

Working memory (WM) is a system that allowed several pieces of information to be held in mind at the same time and interrelated (Pickering, Phye, & Corporation, 2006). Slavin (1991) stated that WM is where the mind operates on information, organizes it for storage or discarding, and connects it to other information. Baddeley et.al. (1986) considered WM as a system for the temporary holding and manipulation of information during the performance of a range of cognitive tasks.

Hitch and Baddeley (1974) developed a WM system providing strong base for wide range studies on WM. Their model assumes to have the three main components of the WM: *phonological loop*, *visual-spatial pad*, and *central executive*. *Phonological loop* is a store capable of holding phonological information over a matter of seconds. The *visual-spatial pad* is the system that plays an important role in acquisition of visual and spatial knowledge. The

.*central executive* is the most important and complex component of the WM. It help to directing attention to relevant information and coordinating cognitive actions (Baddeley, 2006).

Baddeley extended the model and added one more component to the WM system which is called the *episodic buffer* in 2000. This component assumed to hold together integrated episodes and to provide the interface between inputs having a range of different codes (Pickering et al., 2006). Episodic buffer considered as to be the basis of conscious awareness which link the components of WM with LTM (Pickering et al., 2006). Figure 2.1 shows the current model of the WM developed by Hitch and Baddeley (2006).

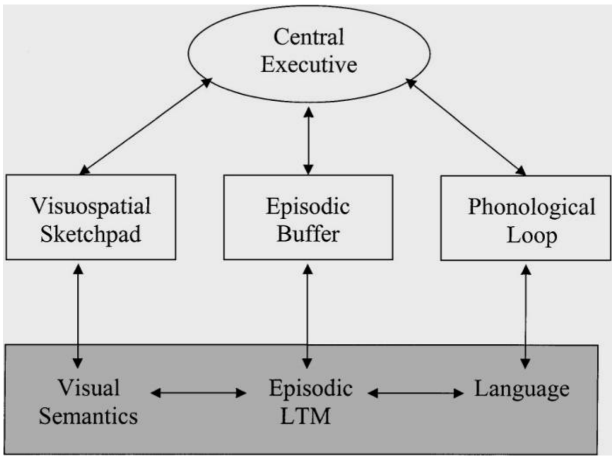


Figure 2.1. The current WM model developed and by Hitch and Baddeley. *Source:* (Hitch and Baddeley 2006 as cited in van Bruggen et al., 2002).

There are other WM models developed by various theorists such as Cowan (2005) and Ericsson and Kintsch (1995). Cowan's model regards WM not as a separate system from the LTM, instead as a subsystem of the LTM. In Ericsson and Kintsch theory, LTM knowledge structures associated with components of WM form a LTM-WM structure that is capable of holding virtually unlimited amount of information (Kalyuga, 2009).

Long term memory (LTM) is a part of the memory system where the information is kept for long periods of time. LTM is thought to be a very large-capacity and very long-term memory store (Slavin, 1991). It is the repository for more permanent knowledge and skills and includes all things in memory that are not currently being used but which are needed to understand (Kirschner, 2002).

Clark et al. (2005) defined LTM as ‘‘a relatively permanent mental repository of knowledge and skills in the form of schema that provide the basis for expertise’’(p.347).

Theorists divide LTM into three parts: *episodic memory*, *semantic memory*, and *procedural memory*. *Episodic memory* is memory of personal experiences. *Semantic memory* contains the facts and generalized information such as concepts, principles, or rules and how to use them; and problem-solving skills and learning strategies; in other words, it retains most things that are learned in schools. *Procedural memory* refers to knowing how to do things (Slavin, 1991).

These two memory systems (WM and LTM) work together. As learning takes place in WM, the new knowledge and skills are stored in LTM. As learner gain expertise in domain, his/her knowledge repository in LTM expands (Clark et al., 2005).

As discussed previously, CLT assumes a cognitive architecture consisting of a WM that is limited in capacity when dealing with novel information. Further, CLT also assumes that limited capacity WM becomes effectively unlimited when dealing with familiar material, previously stored in an immense LTM holding many *schemas* that vary in their degree of *automation* (Paas et al., 2003). These two important concepts of the human memory system will be discussed in the following section.

2.1.2 Schema Construction and Automation

Piaget (1952 as cited in Khateeb, 2008) defines a schema as a coordinated combination between cognitive functions and physical actions that work together to respond to any perceived experience that could be related to the schema. *Schema* is a memory structure located in LTM that is the basis for expertise, categorizes elements of information according to the manner in which they will be used (Chi et al. 1981 as cited in Sweller, Merrienboer, & Paas, 1998).

From the CLT perspective, schemas have two functions. One of these is to provide a mechanism for knowledge organization and storage. This function is essential to organizing existing knowledge in a categorized mode, or more specifically in a schematic way (Skemp, 1971 as cited in Khateeb, 2008). The other function is to reduce WM load (Pawley et al., 2005). Schemas allow many elements to be treated as a single element in WM; as a result, more WM capacity becomes free (Sweller, 2003).

Automation is an important process in the construction of schemas (Sweller et al., 1998). Automaticity is the status of any knowledge or skill that has been used so many times that it can be activated from LTM and applied using minimal WM resources (Clark et al., 2005). Automaticity occurs with extensive practice. With sufficient practice, a procedure can be carried out with minimal WM load (Sweller et al., 1998). With automation, familiar tasks are performed accurately, whereas unfamiliar tasks can be learned with maximum efficiency. Without automation, a previously encountered task may be completed, but performance is likely to be slow (Sweller, Van Merrienboer, & Paas, 1998).

In summary, both schema construction and automation can free WM capacity. Knowledge organized in schemas allows learners to categorize multiple interacting elements of information as a single element, thus reducing the load on WM. After extensive practice schemas can become automated, allowing learners to further bypass WM capacity limitations (Paas et al., 2004). From an instructional design perspective, it follows that designs should not only encourage the construction of schemas, but also the automation of schemas (Paas et al., 2004; Van Merrienboer, 1997). Therefore, the ability to automate a schema is a critical condition for utilizing schemas and reducing cognitive load. It can be said that these two processes constitute the primary role of education and training systems.

2.1.3 Capacity of the Working Memory

As discussed previously, as described by the Miller (1956), 7±2 items can only be processed at one time in human brain. On the other hand, Cowan (2001) claimed that the capacity limit of WM is 4±2 items. He identified memory capacity as the maximum number of chunks that can be recalled in a particular situation (Cowan, 2001 as cited in Khateeb, 2008). There are other cognitive theorist discussed the capacity of the WM, such as Baddeley and Hincks (1974).

Some factors affect the capacity of the WM. There obviously are systematic differences among individuals in their WM capacity for specific tasks, and these differences influence performance when the person operates at the limit of his/her WM capacity (Kalyuga, 2009). Such differences could be strongly influenced by knowledge structures available in LTM. In other words, the prior knowledge or background knowledge is a very important factor (Slavin, 1991). Individuals also differ in their abilities to organize information including large, complex interactions and procedures in LTM can be taught to consciously use strategies for making more efficient use of their WM capacity (Slavin, 1991).

The instruction that require learners to engage in complex reasoning processes involving combinations of unfamiliar elements, thus, must consider how is this information stored and organized in LTM, hence, it is accessible when and where it is needed (Kirschner, 2002). In other words, the goal of the instructional program is to free limited WM from irrelevant mental effort required to integrate new knowledge and skills into the schemas in LTM (Clark et al., 2005).

2.2 Cognitive Architecture Principles and Cognitive Load Theory

As discussed above, *human cognitive architecture* refers the components that constitute human cognition such as WM and LTM are organized (J. Sweller, Ayres, & Kalyuga, 2011b). Human cognitive architecture provides a base for CLT (Khateeb, 2008). As described in the first section, the main assumption of the CLT is that for the effective instructional methods, instruction designers need to consider the features of the human cognitive architecture. CLT also emphasizes the necessity for instructional techniques to be designed in alignment with the basic operational principles of the human cognitive system (Chandler & Sweller, 1991; Paas et al., 2010; Sweller, 1988, 1994; Sweller, 2003, 2004; Sweller et al., 2011a). In this section, five principles of the human cognitive architecture that underlie the CLT are considered.

2.2.1 The Information Store Principle

As mentioned in above paragraphs, LTM is a part of the human cognitive architecture where unlimited information is kept for long periods of time. The information stored in LTM can be considered similar to the biological information stored in a genetic code (Sweller, 2004).

The immense size of LTM is necessary to enable people to function in complex natural environments. A natural information store must be sufficiently large to enable it to respond flexibly and appropriately to a very large range of conditions. In the case of human cognition, LTM store is sufficiently large to enable the variety of cognitive activities (Khateeb, 2008; Sweller et al., 2011a).

2.2.2 The Borrowing and Reorganizing Principle

The *borrowing and reorganizing principle* provides the major technique by which knowledge is stored in the information store, it is both central and essential to a natural information store. Without this principle, large amounts of knowledge could not be acquired to be stored (Khateeb, 2008; Sweller et al., 2011a). However, this principle does not explain the procedure of acquiring original knowledge (Khateeb, 2008).

2.2.3 The Randomness as Genesis Principle

While the borrowing and reorganizing principle explains how information is communicated in natural systems, *the randomness as genesis principle* provides the mechanism by which it is initially created. It provides the creativity engine for natural information processing systems by using a random generate and test procedure (Sweller, 2003; Sweller et al., 2011a).

During problem solving, random moves are generated when knowledge is unavailable. These random moves are subject to effectiveness tests with useful ones being retained while non-beneficial ones are ignored. Retained moves can be incorporated into LTM and this knowledge then may be transmitted to others via the borrowing principle (Sweller, 2004).

Designing and reorganizing and *randomness as genesis* principles work together. They explain how information is created, transmitted and then stored in the information store LTM in the human cognition (Sweller et al., 2011a).

2.2.4 The Narrow Limits of Change Principle

The narrow limit of change principle incorporates the limitations of WM flows directly from the randomness as genesis principle. Random generate and test is a necessary aspect of dealing with novelty. Mechanisms are required to ensure that any alterations to the store of information in LTM maximize the probability that a particular change will be effective and minimize the probability that a change will destroy the functionality of the store (Sweller, 2008).

Instructional designers need to take into account this factor of not overloading WM. As discussed before, human cognition is limited by seven items to be held in WM (Miller, 1956) and by four items to be processed (Cowan, 2001). In order to avoid these limits, schemas held in LTM need to be utilized. A schema can permit multiple elements to be treated as a single one in WM and less effort will be faced by WM (Khateeb, 2008). Therefore, experts in an area do not suffer these limitations; their schemas have already been acquired and automated. The problem of WM limits apply only to novices when dealing with novel information (Sweller, 2003, 2004).

2.2.5 The Environmental Organizing and Linking Principle

The environmental organizing and linking principle provides the final step in permitting a natural information processing system to function in a given environment. It also provides the primary justification for a natural information processing system (Sweller, 2008; Sweller et al., 2011a).

The previous principles only are necessary in order to permit the environmental organizing and linking principle to function appropriately in its environment (Sweller et al., 2011a). It is this principle that ultimately allows performing in environment. Without the environmental organizing and linking principle, there would be no purpose to creating novel information through the randomness as genesis and narrow limits of change principles, no purpose to storing that information in an information store or transferring that information to other stores via the borrowing and reorganizing principle. Table 2.1 summarizes cognitive architecture principles.

Table 2.1

Cognitive Architecture Principles

Principle	Function
Information store principle	Keep information for long periods of time
Borrowing and reorganizing principle	Allow the building of an information store
Randomness as genesis	Create novel information
Narrow limits of change	Input environmental information to the information store
Environmental organizing and linking principle	Use information in information store

These characteristics of human cognitive architecture have direct implications for instructional design (Sweller, 2008) and provides a context that can be used to explain why some instructional procedures do or do not work (Sweller et al., 2011a). Based on human cognitive architecture, categories of instruction that are likely to be effective can be determined. CLT uses the cognitive architecture described above to generate instructional design principles (Sweller, 2004).

2.3 Types of Cognitive Load

Cognitive load can be defined as a multidimensional construct representing the load that performing a particular task imposes on the learner's cognitive system (Paas et al., 2003; Paas & Van Merrienboer, 1994). This section covers the types of the cognitive load that instructional procedures that impose depending on its function (Paas et al., 2003; Sweller et al., 1998).

2.3.1 Intrinsic Cognitive Load (ICL)

Element interactivity level is an important concept which determines the level of the ICL (Sweller, 2010). An *element* is anything that needs to be understood and learned. Clark et al. (2005) defines it as ''a property of instructional content that reflects the extent to which multiple content components must be held and processed simultaneously in WM in order to be learned or to achieve a performance objective''(p.344).

Sweller (2010) considered the learning chemical symbols or some of the nouns of a foreign language as examples for the low element interactivity tasks because they do not impose a heavy WM load because individual elements can be learned independently of each other. On the other hand, composing a sentence in a foreign language is considered as high element interactivity task because all words must be considered in relationship to each other and to grammar rules.

Another example considered by the Sweller (2010) is about the solution of the equations. When dealing with equations, all of the elements associated with an equation must be considered simultaneously because all of the elements interact. For a novice, learning algebra and faced with the problem,

$$\frac{a+b}{c} = d$$

solve for a, each of the symbols in the equation may act as an element, and all must be processed simultaneously in WM for the equation to be understood. Learning how to solve this category of problems is a much higher element interactivity task than learning the chemical symbols of the periodic table (Sweller, 2010).

As described before, element interactivity levels are determined by estimating the number of interacting elements (Sweller, 2010; Sweller & Chandler, 1991; Tindall-Ford, Chandler, & Sweller, 1997). Such estimates must simultaneously take into account the nature of the information and the knowledge of learners. The level of interactivity between elements of information that are essential for learning determines ICL. If element interactivity is low, ICL also will be low because only a small number of elements and relations will need to be processed simultaneously in WM (Sweller et al., 2011a).

ICL cannot be altered because it is intrinsic to a particular task. If the learning task is unaltered and if the knowledge levels of the learners remain constant, ICL also will remain constant. Therefore, ICL can be altered by changing the nature of the learning task and the levels of the learners (learning) (Sweller, 2010; Sweller et al., 2011a).

Reducing ICL by altering the nature of what is learned may be an important instructional technique, but in most cases its utility is to be temporary.

Learning includes converting a group of interacting elements that are treated as multiple elements in WM into a smaller number (or a single) element. A major function of learning is to reduce element interactivity and ICL by incorporating interacting elements in schemas. The reduction in ICL frees WM resources for other activities. Thus, learning through schema acquisition eliminates the WM load imposed by high element interactivity information (Sweller et al., 2011a).

Element interactivity can be used to define the term *''understanding''* (Marcus, Cooper, & Sweller, 1996). The term *understanding* is applied only when dealing with high element interactivity material (Sweller et al., 1998). Information is fully understood when all of its interacting elements can be processed in WM. A failure to understand occurs when appropriate elements are not processed in WM. Information is difficult to understand when it consists of more interacting elements than can be processed in WM. Low element interactivity information is easy to understand because it can easily and appropriately be processed in WM (Sweller et al., 1998; Sweller et al., 2011a).

As described before, the concept of element interactivity is closely tied to the definitions of schemas. An element is anything that needs to be learned or processed; schemas are usually multiple, interacting elements (Sweller, 2006). Once a schema has been constructed, it becomes another, single, element that does not impose a heavy WM load and can be used to construct higher-order schemas (Sweller et al., 2011a).

2.3.2 Extraneous Cognitive Load (ECL)

WM load is not only imposed by the intrinsic complexity of the material that needs to be learned but also may be imposed by instructional procedures that are less than optimal. Non-optimal instructional procedures are referred to as imposing an ECL (Sweller et al., 2011a). CLT is primarily concerned with techniques designed to reduce ECL (Clark et al., 2005; Sweller, 2010).

Reducing ECL is critical when teaching in an area with high element interactivity. In other words, when ICL is high, ECL is a concern that must be handled. In contrast, when dealing the material low element interactivity (low ICL), reducing of the ECL is not crucial because total cognitive load do not exceed the capacity of the WM (Clark et al., 2005).

Element interactivity is used for describing only ICL. However, Sweller (2010) suggested that element interactivity is the major source of WM load underlying ICL as well as ECL. Beckmann (2010 as cited in Sweller, 2010) suggested that if element interactivity can be reduced without altering what is learned, the load is ECL; if element interactivity only can be altered by altering what is learned, the load is ICL. The same information may impose an ICL or an ECL depending on what needs to be learned. Thus, element interactivity not only underlies ICL but also ECL and indirectly GL (Sweller, 2010) which will be discussed in next section.

There is a clear distinction between ICL and ECL (Sweller et al., 2011a). Both are additive and together contribute to the total cognitive load imposed by a learning task. If this total cognitive load exceeds the capacity of limited WM resources, learning will be difficult and schema construction and automation inhibited. If learning is to be successful, total cognitive load may need to be reduced. To reduce cognitive load, instructional procedures may need to be modified (Leahy, Chandler, & Sweller, 2003). There are several effects of the CLT that modifies the instruction for controlling the ECL. In the following sections, these effects will be considered.

2.3.3 Germane Cognitive Load (GCL)

This type of cognitive load is that remaining free capacity in WM toward schema acquisition and rule automation (Schnotz & Kürschner, 2007; Sweller et al., 2011a). Clark et al. (2005) defines GCL as ‘‘work imposed on WM that uses mental capacity in ways that contribute to learning’’(p.346). Sweller, Merrienboer, and Paas (1998) stated that GCL is load that directly contributes to learning, that is, to the learner’s construction of cognitive structures and processes that improve the performance.

CLT considers the construction and subsequent automation of schemas as the main goal of learning (Sweller et al., 1998). The construction of adequate and rich schemata is especially important in complex learning tasks where it will require more effort GCL is required for the construction and storage of schemata into LTM (Kirschner, 2002). The construction of schemas involves processes such as interpreting, exemplifying, classifying, inferring, differentiating, and organizing. Instructional designs should try to stimulate and guide students to engage in schema construction and automation and in this way increase GCL (Jong, 2010).

As described before, ICL and ECL are additive, an increase in ECL reduces the WM resources available to deal with ICL and hence reduces GCL. Decreasing ECL frees resources to deal with ICL and thus increases GCL. When ICL is high, it is important to decrease ECL; otherwise, the combination of both might exceed the maximum cognitive capacity and thus prevent the GCL to occur. From an instructional design point of view, it is important to consider communication of ECL and GCL, because the reduction of ECL can free cognitive resources for an increase in GCL (Paas et al., 2003; Paas et al., 2010; Schnotz & Kürschner, 2007).

2.4 Factors Affecting Cognitive Load

Both causal and assessment factors affect the cognitive load (Kirschner, 2002; Paas & Van Merrienboer, 1993). Causal factors can be characteristics of the subject, the task, the environment, and their mutual relations. Assessment factors include *mental load*, *mental effort*, and *performance* as the three measurable dimensions of cognitive load. The Figure 2.2 developed by the Paas and Van Merrienboer (1993) shows the factors determining the level of the cognitive load.

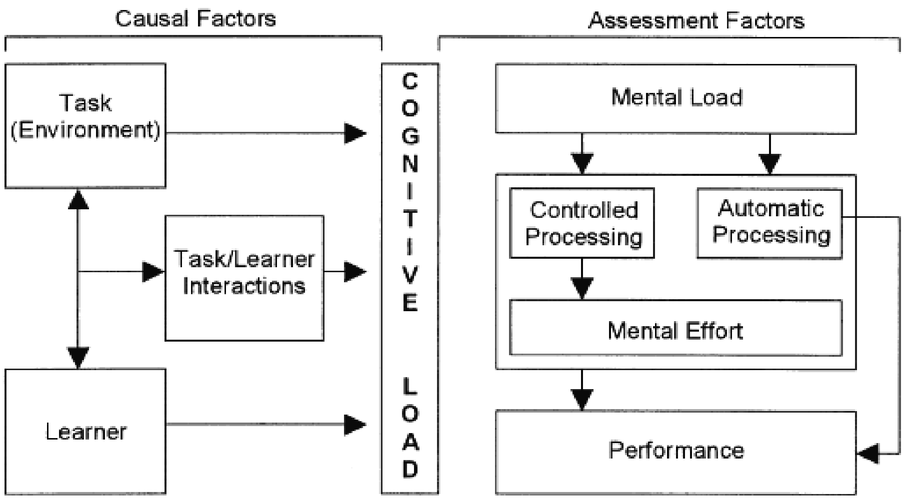


Figure 2.2. The factors determining the level of the cognitive load.

Source: (Paas & Van Merrienboer, 1993).

Mental load is the portion of cognitive load that is imposed exclusively by the task and environmental demands. In other words, it is the aspect of cognitive load that originates from the interaction between task and subject characteristics (Paas et al., 2003). According to the model, it provides an indication of the expected cognitive capacity demands and can be considered as a priori estimate of the cognitive load.

Mental effort refers to the cognitive capacity actually allocated to the task (Kirschner, 2002), thus, it can be considered to reflect the actual cognitive load (Paas et al., 2003).

As described before, c*ognitive load* is seen as a construct representing the WM resources required to learn a particular material or to perform a particular task. The amount of WM resources that is actually allocated by the learner to the process of learning or to task performance is called the *mental effort*. A learner's performance on a task depends on the cognitive load of the task and the learner's mental effort invested into the task. In this study, the term *cognitive load* is used instead of the term *mental load*; by referring the same meaning.

The *performance* is a reflection of mental load, mental effort, and the previously discussed causal factors. Performance can be defined in terms of learner's achievements, such as the number of correct test items, number of errors, and time on task. It can be determined while people are working on a task or later.

2.5 Measuring Cognitive Load

The question of how to measure the multidimensional construct of cognitive load has proven difficult for researchers. According to the Paas and Van Merrienboer (1993) model (Figure 2.2), cognitive load can be assessed by measuring mental load, mental effort, and the performance of learner (Paas et al., 2003).

The *analytical* and *empirical* methods to classify cognitive load measurement was used in the literature, but empirical techniques for measuring mental effort have received a lot of attention from CLT researchers (Paas et al., 2003). In particular, subjective rating scale, psycho-physiological, and task-performance-based techniques have been used to determine the cognitive load in cognitive load research. Each category incorporates a number of individual assessment techniques (Sweller et al., 1998).

Subjective rating scale techniques are based on the assumption that *people are able to introspect on their cognitive processes and to report the amount of mental effort expended* (Paas et al., 2003). This is also the main assumption of this study. Kalyuga (1999 as cited in Brunken, Plass, & Leutner, 2003) reported a high sensitivity of these scales in identifying differences in training strategies, but these differences could potentially also have been caused by task difficulty, individual competency levels of the learners, or different attention processes.

Physiological techniques are based on the assumption that changes in cognitive functioning are reflected in physiological measures. These techniques include measures of heart rate, heart rate variability, brain activity, and eye activity (Paas et al., 2003).

Task and performance-based techniques include two subclasses of techniques: *primary task measurement*, which is based on learner performance of the task of interest, and *secondary task methodology*, which is based on performance when a second task is performed concurrently with the primary task. These techniques use objective task characteristics and performance levels to obtain information on mental effort (Paas et al., 2003).

According Brünken, Plass, and Leutner (2003), the various methods of assessing cognitive load that are currently available can be classified along two dimensions, *objectivity (subjective or objective)* and *causal relation (direct or indirect)*. The *objectivity* dimension describes whether the method uses subjective, self-reported data or objective observations of behavior, physiological conditions, or performance. The *causal relation* dimension classifies methods based on the type of relation of the phenomenon observed by the measure and the actual attribute of interest.

Whereas the central claim of CLT is that any instructional design should incorporate efficient use of WM capacity, it is not common to measure cognitive load while conducting research on instruction. Until 1992, instructional research in the context of CLT was exclusively concerned with performance-task-based estimates of cognitive load (Paas et al., 2003). Recently, in addition to these estimates of cognitive load, subjective and physiological measurement techniques have been applied (Sweller et al., 2011a).

With respect to subjective techniques used in the context of CLT, Paas and Van Merrienboer (1994) have used a rating scale for measure perceived task difficulty. Using a 9-point Likert scale ranging from *very, very low mental effort* (1) to *very, very high mental effort* (9), learners were asked to rate their mental effort at various points in the learning and testing cycle. In comparing instructional procedures that were hypothesized to rise or lower cognitive load, Paas (1992) found a match between self-rated mental effort and test performance. Learners who were presented an instructional design hypothesized to impose a low cognitive load had superior learning outcomes and rated their mental effort lower than students who were presented a design hypothesized to be high in cognitive load (Sweller et al., 2011a).

Paas & Van Merrienboer (1993) reports on a calculation approach for combining measures of mental load and task performance that allows one to obtain information on the relative efficiency of instructional conditions. Efficiency is a property of instructional products that results in faster learning, better learning, or both (Clark et al., 2005). Paas & Van Merrienboer (1993) method is based on the standardization of raw scores for mental effort and task performance to *z* scores, which are displayed in a cross of Cartesian coordinate axes. Relative condition efficiency is calculated as the perpendicular distance to the line that is assumed to represent an efficiency of zero. The method for calculating and representing relative condition efficiency discussed in their study has a valuable addition to research on the training and performance of complex cognitive tasks.

The combination of measures of mental effort and performance can reveal important information about cognitive load, which is not necessarily reflected by performance and cognitive load measures alone (Paas et al., 2003).

2.6 Effects of the Cognitive Load Theory

CLT effects provide the instructional recommendations generated by CLT. Each effect has been studied as an experimental study using randomized, controlled experiments in which an instructional technique generated by CLT is compared to an alternative, usually more traditional technique (Sweller, 2008). Some of these effects are considered in the following.

2.6.1 Worked Example and Completion Example Effects

Early research into CLT found that instructional formats that required problem-solving search strategies imposed a heavy WM load that delayed learning (Sweller, 1988). To avoid this and enhance learning, instructional designers have successfully employed worked examples in a number of domains, such as mathematics (Clarke, Ayres, & Sweller, 2005).

A *worked example* provides a step-by-step solution to a problem (Sweller et al., 2011a). It is a technique that decreases ECL by replacing some practice exercises with a series of worked examples, each followed by similar practice exercise (Clark et al., 2005). Worked examples consist of modeling the process of problem solving in a well-structured domain such as physics or mathematics by presenting an example problem and demonstrating the solution steps and final answer to the problem (Renkl, Stark, Gruber, & Mandl, 1998). The worked example effect flows directly from the cognitive architecture (Sweller, 2008; Sweller et al., 2011a) discussed in the previous sections.

Worked examples can efficiently provide with the problem-solving schemas that need to be stored in LTM using *the information store principle*. Once stored in LTM, it can be used to solve related problems using *the environmental organizing and linking principle*. Those schemas are borrowed from the LTM of the provider of the worked example by way of *the borrowing and reorganizing principle* (Sweller, 2008; Sweller et al., 2011a).

Worked examples impose a relatively low WM load (*narrow limits of change principle*) compared to solving problems using means–ends search. While all intrinsic interacting elements are summarized in the information contained within a worked example, solving a problem by means–ends search adds the additional elements associated with *the randomness as genesis principle* (Sweller, 2008). That principle unnecessarily adds problem-solving search to the interacting elements, thus imposing an ECL (Cooper and Sweller, 1987 as cited in Paas & Van Merrienboer, 1994; Sweller, 2008). Together, these various mechanisms of CLT suggest that for novice learners, studying worked examples should be superior to solving the equivalent problems (Sweller et al., 2011a).

During the last few years, the educational advantages of worked examples have been provided in several fields such as Algebra, Engineering, and Statistics. Further, empirical evidence has shown that learning with worked examples is most important during initial skill acquisition stages for well-structured fields such as physics and mathematics (VanLehn, 1996). Some of these studies related to the mathematics field will be described in the following sections.

Sweller et al. (2011a) expressed the issue when worked examples are more beneficial by stated:

> Learners, particularly those in the initial stages of cognitive skill acquisition, benefit more from studying worked examples than an equivalent episode of problem solving. Unlike worked examples, conventional problems force learners to apply a capacity-demanding means-ends analysis, wherein the goal state of the problem can be attained only by subdividing it into a hierarchy of goals and sub-goals, which have to be achieved in a backward order by finding the appropriate operators. Once a problem is identified as belonging to a known problem type, the appropriate schema is retrieved from LTM, and the solution procedure that is associated with that problem type is activated in WM and used to produce a solution to the new problem (p.107).

As understood from the previous sentences of Sweller et al. (2011a), worked examples are very effective during the initial stages of cognitive skill acquisition. As learner gains expertise during the training, worked examples actually become detrimental and learners are better off with lessons in which they work all the problems (Clark et al., 2005; Sweller et al., 2011a). Once the learners has acquired a basic schema for the skill concept, they learn best by applying the schema to problems, rather than investigating redundant effort in studying more worked examples.

To accommodate learners as they build expertise is through a process called *backward fading* of worked examples (Clark et al., 2005). A completion problem is a partial worked example where the learner has to complete some key solution steps (Sweller et al., 2011a). It is a hybrid between practice assignment and a worked example. Clark et al (2005) defines completion examples as an ‘‘instructional technique in which step by step worked example is partially filled in by the instruction and fished by the learner’’(p.343). The *backward fading* is the process in which completion examples evolve into full problem assignments by a gradual increase in the number of steps that must be completed by the learner (Clark et al., 2005; Sweller et al., 2011a). For example, in this study, an Equation example demonstrated the first two steps and asks the learners to complete the last three steps. The Figure 2.3 illustrates this process.

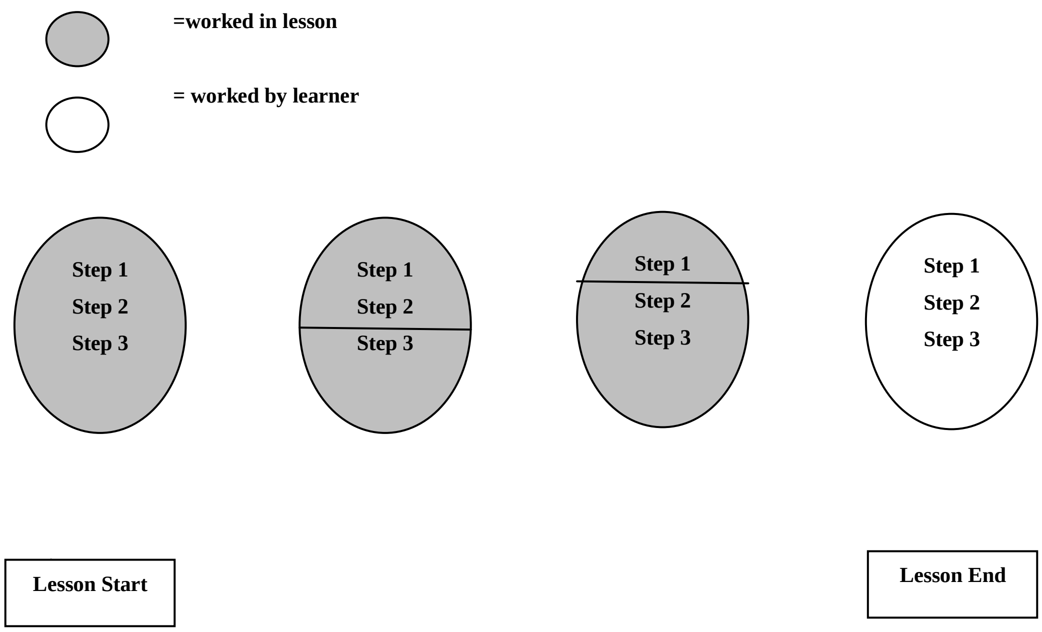


Figure 2.3. The backward fading.

Source: (Clark et al., 2005)

The process begins with a fully worked example that provides a model for the learner; the next few examples are the completion examples in which more and more of the work is done by the learner. End of the lessons, full problems are assigned (Clark et al., 2005).

According to Clark et al. (Clark et al., 2005), completion examples reduces cognitive load by incorporating some worked examples and it fosters deep processing requiring completion of the remaining elements.

As described early, the efficiency of a lesson can be increased by replacing some practice either with worked examples or completion examples. These effects manage cognitive load of novice learners by freeing up WM capacity to build new schemas by studying of examples (Clark et al., 2005). However, as learners gain expertise, eventually worked examples actually become detrimental and learners better off with lessons in work all the problems.

As a conclusion, worked example effect is the most important of the CLT effects which was also used as a main effect in this study. Further, it has given rise to many other cognitive load theory effects, some of them discussed subsequent sections.

2.6.2 The Split Attention Effect

Clark et al. (2005) defined split attention as a ‘‘source of ECL caused by separation of related instructional elements that must be processed together for understanding’’ (p.351). According to Sweller (2011a) split-attention occurs when learners are required to split their attention between at least two sources of information that have been separated either spatially or temporally. A geometric diagram and its associated statements provide an example for the split attention. Before the statements can be understood, the diagram and its associated statements must be mentally integrated (Leahy et al., 2003). Details of this research will be considered in subsequent sections.

From a CLT perspective, each source of information must be essential to an understanding of the overall content to be learned and must be unintelligible in isolation. For maximum learning to occur, all disparate sources of information must be mentally integrated (Sweller et al., 2011a). In other words, the individual sources of information cannot be understood in isolation and must be integrated in WM (Elliott, Kurz, Beddow, & Frey, 2009). However, by requiring learners to integrate several sources of information that are separated in space or time, ECL is created. Consequently, to prevent the learner experiencing split-attention, the different sources of information need to be physically integrated by the instructional designer (Sweller et al., 2011a).

Sweller (2011a) stressed the split-attention effect with human cognitive architecture by stating:

> Providing information to learners uses the *borrowing and reorganizing principle* to increase information in LTM. If that information is presented in split-source form, learners must search for referents. Search always involves *the randomness as genesis principle* and imposes a WM load due to *the narrow limits of change principle*. That search can be reduced by physically integrating multiple sources of information, reducing unnecessary interacting elements and so reducing ECL. The increased information stored in LTM then can be used to solve subsequent problems according to *the environmental organizing and linking* principle (p.112).

The split-attention effect has been obtained in a wide variety of situations using many different types of materials studied by many different categories of learners (Sweller et al., 2011a). Nevertheless, there is a set of requirements common to all situations in which split-attention occurs. The most important of these is that the multiple sources of information must be un-learnable in isolation. If, for example, a diagram provides all of the information needed to learn, integrating any additional text into the diagram will not be beneficial. Under these situations, for example, the text should be eliminated.

The split-attention effect only occurs when the two or more sources of information must be processed together in order to understand the information being presented. With that proviso, there are many different forms of the split-attention effect. These forms of split attention effect can be categorized as ‘‘worked examples and split attention’’, ‘‘diagrams and written explanations’’, ‘‘multiple sources of text’’, ‘‘more than two sources of information’’, and ‘‘split-attention while learning to use a computer’’. The research on these forms is considered in the following paragraphs by only taking the forms related to the mathematics education.

The split-attention effect is important for several reasons. First, it provides an important instructional design principle for information that needs to be considered simultaneously, in order to be understood needs to be presented in a manner that eliminates spatial or temporal separation (Sweller et al., 2011a). Secondly, the split-attention effect indicates why worked example effect sometimes fails. Simply presenting worked examples does not guarantee a reduction in ECL (Sweller & Chandler, 1991). Worked examples must be structured to ensure that they do not themselves impose a heavy ECL. Thirdly, the split attention effect flows directly from CLT. Holding information in WM, while searching for referents, imposes a heavy ECL that should be reduced (Sweller et al., 2011a).

Clark et al. (2005) developed guidelines to avoid split attention and focus on attention. When learners are faced with content and delivery systems that impose a relatively high cognitive load, instructional designers should use methods both to focus attention and to avoid split attention. To focus attention, use methods that direct cognitive resources toward relevant content in training materials. The ‘‘focus attention and avoid the split attention’’ guideline was implemented in this study. Some of the guidelines are ‘‘use cues and signals to focus attention to important visual and textual content’’ and ‘‘integrate explanatory text close to related visuals on pages’’.

Split attention caused by taking notes from a lecture may reduce the learning (Clark et al., 2005). The cognitive load required to notes reduces mental capacity that could be devoted to processing the content in ways that lead to learning. Clark et al. (2005) suggested that cognitive load can be minimized imposed by note-taking lectures by providing learners with content summaries and using class time for learning activities.

2.6.3 The Modality Effect

The modality effect is closely related to the split-attention effect (Sweller et al., 2011a). As discussed previously, the split-attention effect occurs when learners must process separate but related sources of information that cannot be understood without mental integration. The cognitive resources required to effect this integration are unavailable for learning and may exceed the available capacity of WM. An alternative way of dealing with split-attention conditions is the modality effect; doing so by engaging both auditory and visual channels of information in WM rather than just the visual channel (Sweller et al., 1998; Sweller et al., 2011a).

Sweller (1998) and Clark et al. (2005) stressed the fact that WM includes separate processing areas for visual and auditory information, using the auditory mode along with the visual makes most efficient use of limited WM resources. They define modality effect as ‘‘a CLT effect stating that complex visuals are understood more efficiently when explanatory words are presented in an audio modality than when presented in a written modality’’ (p.348).

Sweller (Sweller et al., 2011a) considered the modality effect with respect to cognitive architecture described earlier by stating:

> The cognitive architecture relies on *the borrowing and reorganizing principle* to facilitate the transfer of information to the LTM information store, that information needs to be structured to take into account the limitations of WM as indicated by *the narrow limits of change principle*, and once knowledge is stored in LTM, it can be used to govern activity as specified by *the environmental organizing and linking principle*. If dual-modality presentation taps into a biologically primary ability, it will automatically reduce WM load leading to an advantage (p.129).

The major instructional implication that flows from the modality effect can have considerable benefits to presenting information in a dual-mode, audio-visual form rather than in a visual-only form (Sweller et al., 1998; Sweller, et al., 2011a). Instruction designers must be ensuring that the conditions for the superiority of audio-visual instructions apply. The most important conditions, are that the audio and visual sources of information must rely on each other for intelligibility, element interactivity needs to be high and the audio component needs to be sufficiently short to be readily processed in WM.

2.6.4 The Redundancy Effect

Clark et al. (2005) stated that the redundancy effect is content or content expressions that are duplications either of each other or of knowledge already in memory impede learning. The redundancy effect occurs when unnecessary, additional information is presented to learners (Sweller, 2010). In other words, it occurs when multiple sources of information are contained and can be used without reference to each other. Sweller (2011a) suggested that the redundancy effect may also occur when the multiple sources of information can be understood separately without the need for mental integration.

Sweller (2011a) considered redundancy issue together with human cognitive architecture by stating:

> That ECL violates *the narrow limits of change principle* that requires WM load to be minimized. Less information will be transferred to the LTM information store resulting in less effective use of *the environmental organizing and linking principle*, the critical principle used to generate action. It follows that only essential information should be presented to learners in order to maximize use of *the borrowing and reorganizing principle* when acquiring information (p.154).

It is very important that levels of learner expertise could influence the redundancy effect, which may be affected by learner levels of expertise. Information that is essential and non-redundant for novices may become redundant for experts. The *expertise reversal effect* observed in such situations depends on the redundancy effect (Sweller et al., 2011a) and will be considered next.

2.6.5 The Expertise Reversal Effect

Expertise reversal effect is the negative effect of instructional methods that aid the learning of novices on the learning of experts (Clark et al., 2005). In other words, expertise reversal effect occurs when an instructional procedure “X” that is effective for novices in comparison to an alternative procedure “Y” becomes less effective as expertise increases (Kalyuga, Ayres, Chandler, & Sweller, 2003).

The expertise reversal effect is dependent on a change in status of interacting elements. Initially, for novices, a set of interacting elements reflect ICL because they are essential for understanding. With increases in expertise, the same interacting elements reflect ECL because they are no longer needed (Sweller, 2010).

The expertise reversal effect flows as a logical consequence of some fundamental features of human cognitive architecture as described by Sweller (2011a):

> The critical role of learner knowledge in LTM is central to human cognition. LTM provides an information store and information in that store can drive appropriate action via *the environmental organizing and linking principle*. It is therefore reasonable to expect that levels of learner knowledge (or levels of learner expertise) should influence the occurrence of all cognitive load effects. If learners already have acquired information, requiring them to process that information again via *the borrowing and reorganizing principle* may result in an ECL due to *the narrow limits of change principle*. Learners who already have acquired information will be unnecessarily processing excess interacting elements. In contrast, learners who do not have the required information will need to process those elements. Instructional procedures need to reflect these differing cognitive states. Instructional techniques and procedures that are optimal for novice learners may become suboptimal when learners acquire more expertise in the domain (p.155).

Feldon (2007 as cited in Khateeb, 2008) summarized the characteristics of experts in the following manner:

> Experts possess extensive conceptual and strategic knowledge. They use effective automated procedures that allow them to outperform non-experts; consuming less time and experiencing less effort. Experts' WM has more capacity than novices'. It allows them to successfully attempt more complex problems (p.61).

CLT provides evidence that learners' level of expertise plays a critical role in the extent to which they benefit from an instructional method. Thus, instructional designers need to be aware of learners' level of expertise to produce effective instructions (Chandler & Sweller, 1991; Kalyuga, Chandler, & Sweller, 2001; Khateeb, 2008).

2.6.6 Guidance Fading Effect

The worked example/problem-solving version of the expertise reversal effect leads directly to the guidance fading effect (Renkl & Atkinson, 2003). novices need to be presented many worked examples whereas more expert learners should be presented problems, it might be hypothesize that learners should first be presented worked examples, followed by completion problems and then full problems (Sweller, 2010).

Two types of fading procedures have been proposed. In backward fading as described before, the first learning task is presented as a completely worked example, the second task is presented with the solution to the last step omitted, the third task with the solutions to the last two steps omitted, etc. In a forward fading procedure, the first learning task is also presented as a completely worked example, followed by the second task with the solution to the first step omitted, the third task with the solutions to the first two steps omitted, etc (Sweller et al., 2011a). Table 2.2 illustrates the backward and forward backing procedures with an Algebra question.

Table 2.2

Backward and Forward Backing Procedures with an Algebra Question

Make *a* the subject of the equation $(a + b)/c = d$.	
Backward Fading	Forward Fading
$(a + b)/ c = d$	$(a + b)/ c = d$
$a + b = dc$	$a + b = ?$
$a = ?$	$a = dc - b$

Source: (Sweller et al., 2011a).

The element interactivity associated with the guidance fading effect is identical to the element interactivity associated with the expertise reversal effect. The interacting elements associated with worked examples are ICL to learning for novices. With increasing expertise, those ICL, interacting elements become

ECL to further learning because they are already part of LTM with learning being enhanced if the elements are eliminated (Sweller et al., 2011a).

2.7 Applying Cognitive Load Theory

The three types of cognitive load and CLT effects as discussed previously, imply that cognitive load depends on the interaction of the *learning goal and its content*, *the learners' prior knowledge*, and *the instructional environment*.

As discussed before, ICL can be high or low, depending on the required element interactivity. Clark et al. (2005) suggested that CLT effects reduced ECL efficiency in the learning of complex tasks only. Therefore, learning of low complex tasks is not impeded by ECL. The general guideline for achieving efficiency in learning is to ‘‘*minimize ECL in instructional materials when learning tasks are complex*’’ (Clark et al., 2005).

Experts have a large skill repertoire in their memory that allows them to perform tasks with less effort comparing to a novice. As a result, the general guideline given above paragraph can be extended as ‘‘*avoid ECL when lessons involve complex content and the learners are novices*’’ (Clark et al., 2005). Further, instructional designers need to change their instructional strategies *as learners develop expertise during training.*

2.8 Research Studies on Cognitive Load Theory

This section includes the research studies on CLT related to the mathematics education. Also some of the researches not directly related to the mathematics education were considered for discussing the concepts *efficiency* and *cognitive load measure*. Worked example, split attention, modality, expertise reversal, redundancy, and guidance faded effects of the CLT were considered together with the CLT principles in preparation of the Students' Booklets used in the implementation of this study. For this reason, research on these issues is considered in this section.

2.8.1 Research on Measuring Cognitive Load

In the section 2.5, the measuring techniques of the cognitive load, namely, subjective rating scales, psycho-physiological, and task-performance-based techniques were discussed; and concluded that subjective rating scale is the most widely used by the CLT researchers. This section represents some of the research studies together with the used measuring techniques of cognitive load (Table 2.3). The details of these studies will be considered in the subsequent sections.

Table 2.3

Research Studies and Used Cognitive Load Measure

Research	Cognitive Load Measure
F. G. Paas, 1992 *Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive-load approach.*	Subjective rating scale (9 scaled)
FGWC Paas and Van Merrienboer, 1993 *The efficiency of instructional conditions: An approach to combine mental effort and performance measures.*	
Yeung, Jin, and Sweller, 1998 *Cognitive load and learner expertise: Split-attention and redundancy effects in reading with explanatory notes.*	
Tuovinen and Sweller, 1999 *A comparison of cognitive load associated with discovery learning and worked examples.*	
Kalyuga, Chandler, Tuovinen, and Sweller, 2001 *When problem solving is superior to studying worked examples.*	
Khateeb, 2008 *Cognitive Load Theory and Mathematics Education.*	

Kalyuga, Chandler, & Sweller, 1998 *Level of expertise and instructional design*	Subjective rating scale (7 scaled)
Kalyuga, Chandler, & Sweller, 1999 *Managing Split-attention and Redundancy in Multimedia Instruction*	
Kalyuga, Chandler, & Sweller, 2000 *Incorporating learner experience into the design of multimedia instruction.*	
Kalyuga, Chandler, & Sweller, 2001 *Learner experience and efficiency of instructional guidance.*	
Paas & van Merrienboer, 1994b *Instructional control of cognitive load in the training of complex cognitive tasks.*	Heart rate variability

Source: (Paas et al., 2003).

As discussed in Section 2.5, the 9-point subjective rating scale originally developed and used in a research study conducted by Paas (1992). In his study, participants reported their invested mental effort on a symmetrical scale ranging from 1 *(very, very low mental effort)* to 9 *(very, very high mental effort)* after each problem during training and testing. The scale's reliability, sensitivity, its ease of use have made it the most widespread measure of WM load within CLT research (Paas et al., 2003).

2.8.2 Research on Efficiency

As described in Section 2.5, Paas and Van Merrienboer (1993) originally reports on a calculation approach for combining measures of mental load and performance that allows to obtain information on the efficiency of four instructional conditions: worked example and solving problems; with high and low variability in geometry lessons. They used the efficiency calculation method, standardization of performance and mental scores, by using the efficiency formula, discussed in the Section 2.5. Results of the study indicated that the learners who studied in the worked example lessons learned significantly faster and with lower mental effort than the learners in problem solving conditions. The Figure 2.4 shows the efficiency graph of these four lesson versions.

A number of experiments (Gerven, Paas, Merriënboer, Hendriks, & Schmidt, 2003; Kalyuga, Chandler, & Sweller, 2001; Van Gerven, et al., 2002; J. J. G. Van Merriënboer, Clark, & De Croock, 2002) demonstrated the calculation of the efficiency measure by using the efficiency formula. Some of them will be described in the subsequent section.

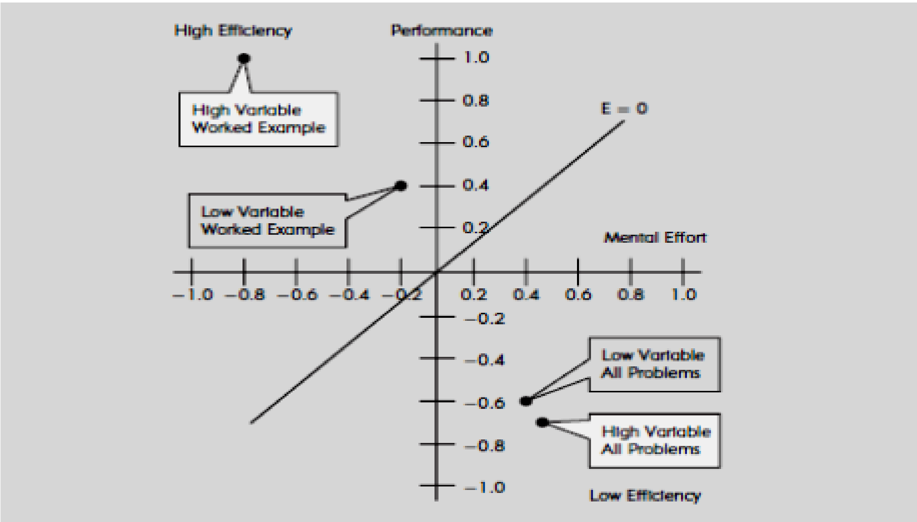


Figure 2.4. Efficiency of the four instructional conditions.

Source: (Clark et al., 2005).

2.8.3 Research on Cognitive Load Theory Effects

Research into worked examples has a long history. Atkinson et al. (Atkinson, Derry, Renkl, & Wortham, 2000) reported that from the 1950s, researchers used learning-by-example strategies to investigate the processes involved in concept formation. Whereas CLT researchers have also focused on concept or schema formation, many of their studies have explicitly compared worked example approaches to learning with a problem-solving approach (Sweller et al., 2011a). These comparisons direct to the identification of the worked example effect.

Sweller and Cooper (1985) conducted a study to show that replacing some practice problems with worked examples required less time and result in the same/even more learning as requiring learners to work all problems as practice problems (Clark et al., 2005). Results showed that while they found an improved test performance by the worked example group on problems similar to the acquisition problems, they failed to find evidence of transfer. The worked example group did not have an advantage over the conventional group on dissimilar problems (Sweller et al., 2011a). Cooper and Sweller (1987) investigated the conditions under which worked examples could facilitate transfer. They conducted a series of experiments using both algebra manipulation problems and word problems to test the hypothesis that in order for transfer to take place. Worked examples were found to accelerate this process compared with a problem-solving approach. (Sweller et al., 2011a). This experimental study direct all experimental studies conducted related to the worked example effect.

In a longitudinal study, Zhu and Simon (1987) showed that worked examples could be successfully substituted for lectures and other traditional mathematics classroom activities over a prolonged period. They found that a mathematics course that was traditionally taught in 3 years could be completed in 2 years with better performance using a comprehensive strategy based on worked examples (Clark et al., 2005; Sweller et al., 2011a).

Paas (1992) compared the efficiency and learning effectiveness of three lesson versions: all practice problems, worked examples and practice pairs, and completion examples and practice pairs. He performed this study in the field of statistics. He asked the participants to rate the amount of invested effort on 9-

point scaled subjective rating scale. Training with partly or completely worked examples leads to less effort demanding and better transfer performance. Moreover, time on training was shortest in the worked condition (Paas, 1992).

Carroll (1994) conducted two experiments with high school students; studied worked examples while learning how to translate English expressions into Algebraic equations. Results of these experiments indicated that students using worked examples outperformed the control group students on posttests after completing fewer practice problems; they also made fewer errors per problem and fewer types of errors during acquisition time, completed the work more rapidly, and required less assistance from the teacher.

Like other effects of the CLT, the initial research into split attention effect was conducted using learning materials from mathematics and the sciences (Sweller et al., 2011a). The initial research was conducted by Tarmizi and Sweller (1988), who originally aimed to extend the findings of the worked example effect to geometry materials. Initially, they found that neither worked examples nor guided solutions in geometry were any better than conventional problem solving strategies. They reasoned that the split-attention format conventionally used in geometry could explain the failure of geometry worked examples. The worked examples used had adopted the common presentation format found in mathematics textbooks with the written solution steps below the diagram. Tarmizi and Sweller (1988) then successfully tested an integrated approach similar to that depicted, demonstrating that studying worked examples was superior to conventional problem solving, provided diagrams and solution steps were physically integrated (Sweller et al., 2011a).

The split-attention effect was also found with coordinate geometry worked examples (Sweller, Chandler, Tierney, & Cooper, 1990). The study of Sweller et al. (1990) showed that worked examples had no advantage over conventional problem solving when they were constructed in a split-source presentation format, but had a significant advantage if they were structured according to an integrated approach.

The study to examine the effectiveness of explanatory notes within a split attention context was conducted by Sweller et al. (Sweller et al., 1990). They found that the most effective format used to provide explanations during initial instruction was to integrate explanatory notes into a diagram at the closest point of reference (Clark et al., 2005; Sweller et al., 2011a). Instead of writing explanatory notes below the diagram, the notes can be labeled and embedded into the diagram. They found that constructing worked examples that reduced or eliminated that search by physically integrating text into diagrams reinstated the worked example effect in geometry, in the process, demonstrated the split attention effect (Schnotz & Kürschner, 2007; Sweller et al., 1990).

There were many experiments (Chandler & Sweller, 1991; Chandler & Sweller, 1992, 1996; Tarmizi & Sweller, 1988) that demonstrated the split-attention effect in a diverse range of areas such as geometry, numerical control programming, computing, physics, electrical installation testing and human anatomy (Leahy et al., 2003). The results suggest that reducing or eliminating the split attention effect may have extensive applications (Sweller et al., 2011a).

Mousavi et al. (1995) first demonstrated the instructional modality effect by using geometry materials. They hypothesized that if WM has partially independent processors for handling visual and auditory material, effective WM may be increased by presenting material in a mixed rather than a unitary mode. Therefore, the negative consequences of split-attention in geometry might be avoided by presenting geometry statements in auditory form, rather than visual form. The results of experiments demonstrated that support of auditory solution statements regardless of whether problem information is presented in written or diagrammatic form (Mousavi et al., 1995).

Using novices, Kalyuga et al. (2001) obtained a conventional worked example effect with worked examples proving superior to solving the equivalent problems. With increasing expertise in the domain, that effect first disappeared and then reappeared as a reverse worked example effect. Solving problems was superior to studying worked examples for more expert learners. Studying worked examples was useful for novices in a domain. With increasing expertise, those worked examples merely demonstrated procedures that were already available to the learner from LTM, and so worked examples were redundant with further learning being facilitated by practicing solving problems (Schnotz & Kürschner, 2007; Sweller, 2010).

Brunstein, Betts, and Anderson (2009) investigated the effects of minimal guidance during instruction on learning using Algebra tuition. They found that with sufficient practice, minimal guidance was superior to explicit instruction but with less practice, minimal guidance was inferior to explicit instruction. These results were in accord with the expertise reversal effect (Sweller, et al., 2011a). Once students have learned enough during practice, they no longer require guidance and indeed, redundant guidance has negative effects.

Atkinson, Renkl and Merrill (2003) compared the learning effectiveness of worked example problem pairs with completion examples using progressive backwards fading. Progressive backward fading completion problems resulted in better learning and reduced cognitive load.

Kalyuga and Sweller (2004) obtained similar results by using coordinate geometry with high school students divided into two groups of relatively more and less knowledgeable learners based on pretest scores. Results of the posttest indicated a significant interaction between knowledge levels and instructional formats. Less knowledgeable students benefited more from worked examples providing guidance. For more knowledgeable learners, there was a clear indication of problem-solving benefits (Sweller et al., 2011a).

Kalyuga and Sweller (2004) tested a real time adaptive fading procedure when participants were learning to solve Algebraic Equations. To diagnose the learners' knowledge with respect to certain steps, researcher used the *rapid-assessment* technique. In this technique, learners receive a (partially solved) task and are asked to indicate rapidly their next solution step. Students' answers range from using a trial and error strategy to providing directly the final answer, indicating the availability of certain schemata in the domain. Researchers steered the provision of worked-out or faded steps right from the beginning on the basis of the individual learner's performance on rapid-assessment tests. The learners in the adaptive fading condition significantly outperformed with respect to knowledge gains (Plass et al., 2010).

Research into adaptive fading methods is still in its early stages and the number of studies is limited (Sweller et al., 2011a). However, the available research (Atkinson et al., 2003; Kalyuga, Chandler, & Sweller, 2001; Tindall-Ford et al., 1997) has already demonstrated that adaptive fading procedures can improve learning outcomes with significant impacts on the acquisition of basic knowledge and skills for novice learners as well as more strategic knowledge and transfer capabilities for more advanced learners (Sweller et al., 2011a).

Pawley et al. (2005) conducted a study investigating the augmentation of worked examples with a checking strategy. In this strategy, students learned how to generate and solve simple Algebraic equations together with how to check the accuracy of their answers. Experiments covered the three effects of the CLT: worked examples effect, redundancy effect, and expertise reversal effect. Results of the study indicated that checking technique was beneficial for students with low levels of general mathematical ability, but not for students with higher mathematics ability levels. The positive effect of checking for lower ability students and the negative effect for higher ability students was an example of the expertise reversal effect of the CLT.

2.8.4 Research Studies on Cognitive Load Theory in Turkey

Kılıç (2006) in her unpublished dissertation investigated the effects of parallel instructional design and task difficulty level on achievement and cognitive load in multimedia learning environment. This study includes the CLT principles adapted to multimedia learning. Statistical analyses revealed that the overall achievement scores of students in the experimental group that the CLT principle implemented were higher than the students in the control group that the regular instruction was implemented. Students' achievement scores in different task difficulty levels in the experimental group were higher than the control group. There were no significant differences between overall achievement scores of students in the experimental group according to the cognitive load level. However, there were significant differences between overall achievement scores of students in the control group according to the cognitive load level (Kılıç, 2006).

Kablan and Erden (2008) conducted an experimental study to check the effectiveness of an instruction prepared by the principles of the CLT adapted to multimedia learning, integrating text and animation, in computer-based science instruction. The efficiency of instruction was measured by mental effort and performance level of the learners. The results of the study indicated that processing integrated text and animation format in computer-based science instruction requires less mental effort than the separated format, and that the performance of the students in the group with integrated presentation format group was higher than that of students in the group with separated presentation format. Instructional efficiency of the integrated presentation group was found to be higher than that of the separated presentation group. In terms of the time performance, there was no difference between the two groups.

Sezgin (2009) in his unpublished dissertation conducted an experimental study to check the effectiveness of a software prepared by the CLT principles in multi-environment learning on students academic success, learning levels, retention in learning and cognitive load levels. Results indicated that the instruction via software prepared by CLT principles in multi-environment had significant effect on students' academic success, learning levels, retention in learning and their cognitive load levels. Further, interviews conducted with the experimental group students showed that the students had positive opinions about the instruction.

2.9 Summary

This chapter provides the review of related literature on CLT with underlined principles and effects.

Several definitions of the CLT stressed the importance of the human cognitive architecture system for designing efficient instruction. More specifically, according to the CLT, the success of an instruction heavily depends on the consideration of WM capabilities and limits.

Research on worked examples (Paas & Van Merrienboer, 1994; Paas, 1992; Sweller, 1988; Tarmizi & Sweller, 1988; Zhu & Simon, 1987) demonstrated that studying worked examples and completion examples which provide students with a solution to a problem is superior to solving the equivalent conventional problems. Studying worked examples reduces or eliminates the cognitive load associated with problem solving search.

On the other hand, the research studies on split attention effect together with worked example effect showed that worked examples had no advantage over conventional problem solving when they were constructed in a split-source presentation format, but had a significant advantage if they were structured according to an integrated approach.

Research on the modality effect (Mousavi et al., 1995; Tabbers, Martens, & Merriënboer, 2004) indicated that visual and auditory material, effective WM may be increased by presenting material in a mixed rather than a unitary mode.

Research on the expertise reversal effect indicated that solving problems was superior to studying worked examples for more expert learners; studying worked examples was useful for novices in a domain. With increasing expertise, worked examples only demonstrated procedures that were already available to the learner from LTM, and so worked examples were redundant with further learning being facilitated by practicing solving problems. It can be concluded that once students have learned enough during practice, they no longer require guidance and indeed, redundant guidance has negative effects.

Research into adaptive fading methods is still in its early stages and the number of studies is limited. Available research demonstrated that adaptive fading procedures can improve learning outcomes with significant impacts on the acquisition of basic knowledge and skills for novice learners as well as more strategic knowledge and transfer capabilities for more advanced learners.

Empirical research studies related to the CLT is restricted to only multimedia learning environment in Turkey. Available research indicated that instruction prepared by the principles of the CLT has significant effect on students learning and cognitive load.

Some of the implications of the literature discussed in this chapter were considered in the study. These can be summarized as: each lesson alternated worked examples with similar problems that is called worked example-problem pair lesson. For satisfaction smooth transition from examples to exercises, completion examples with backward fading were used; especially in the topics that were taught to be difficult. Split attention effect was used in this study to minimize cognitive load imposed by note taking during lectures by providing learners with Students' Booklets and using class time activities. The verbal explanations during the lessons were used instead of writing on the board and the lesson was conducted over the Students' Booklets. The information was presented in as few modes as needed to make it understandable. Further, researcher avoided to add related but unnecessary content or content to stimulate emotional interest. The minimalistic teaching approach was used. At the beginning of each lesson, directive lessons were provided for the novices by using steps, examples, and practice exercises. As learners gain expertise in a topic, classroom activities and group works were conducted in the lessons. In the study, experimental group included a mixture of novice and experienced learners. For this reason, in the Students' Booklets, guidance faded effect was considered by presenting worked examples, followed by completion example and then full problems.

CHAPTER III

METHOD

The purpose of this study was to investigate the effect of an instruction designed by the CLT principles on 7th grade students' achievement in Algebra topics and cognitive load. This chapter presents the methodology of the study. The chapter begins with a general description of the overall study design. It then introduces the research questions, the hypotheses that were tested, and the variables used. These are followed by the study context, the Teachers' and Students' Booklets, the instruction in experimental group, the sample, the data collection instruments and procedures, and the data analysis framework. Finally, the chapter concludes with a discussion of the limitations of the study and control of internal validity treats.

3.1 Overall Design of the Study

This study uses quasi-experimental research design in order to investigate the effect of an instruction designed by the CLT principles on 7th grade students' achievement in Algebra topics and cognitive load. The instruction designed by the CLT effects was defined as the independent variable; students' achievement in Algebra topics and cognitive load were defined as the dependent variables. The instruction designed by CLT effects was used in the experimental group, while the instruction recommended by the Ministry of Education (MONE) was used in the control group of the study.

The study was conducted from the first week of December 2010 to 3rd week of January 2011 (totally six weeks) in a public school in Kağıthane, İstanbul (the name of the school is not mentioned in order to protect the privacy of the participants). The study was implemented in a total of 19 class hours. Among the many public primary schools available in İstanbul, this particular school was chosen deliberately because the researcher could easily access it. Totally 80 students were included in the study. The students were assigned to classes randomly by the school administration at the beginning of the school semester. Therefore, random assignment of subjects to the experimental and control groups was not possible, and as a result, a quasi-experimental research design was utilized in the study. For the same reason, the classes were heterogeneous in terms of gender and academic achievement, and homogeneous in terms of socioeconomic status (SES), all being from low SES.

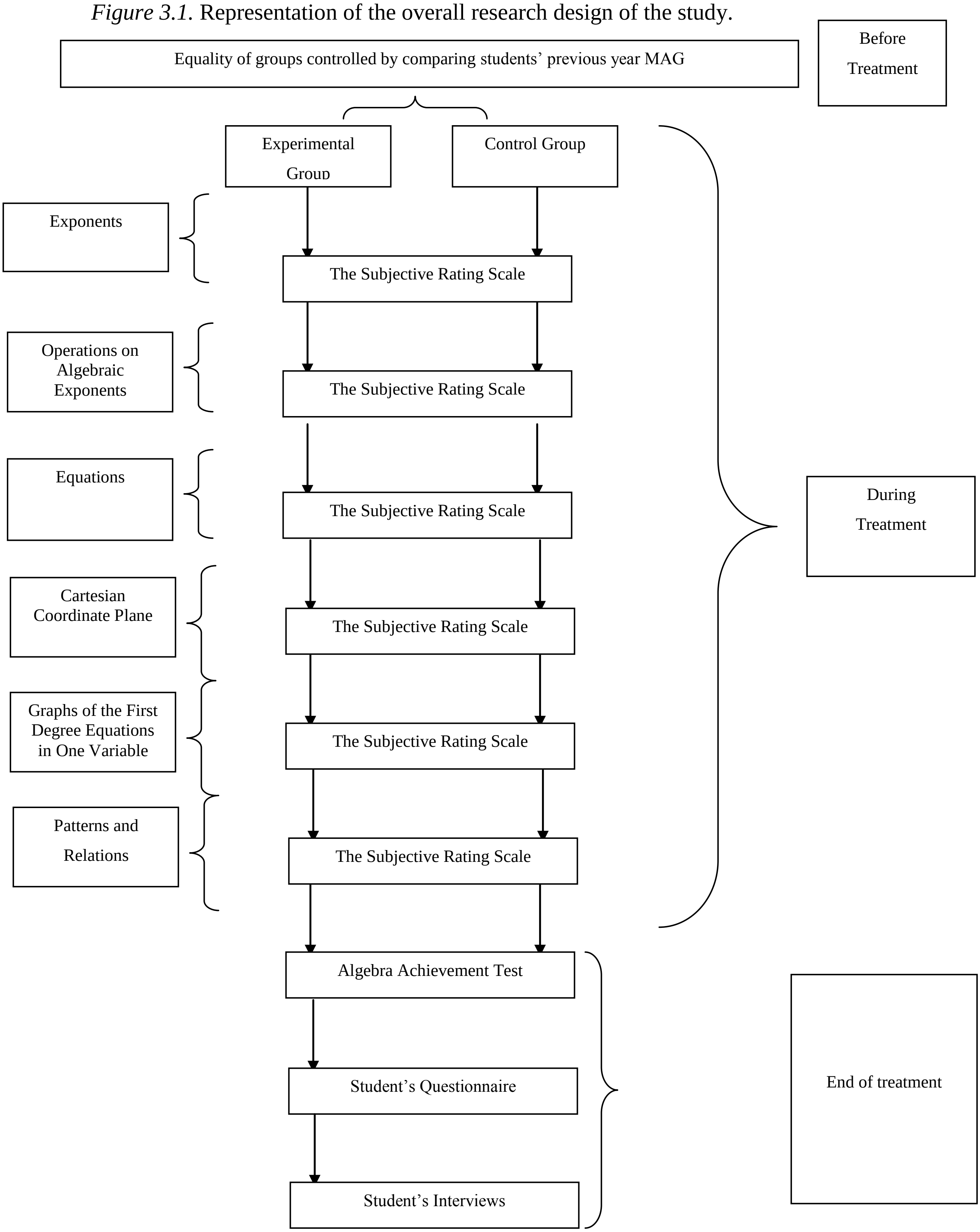
The equality of two groups defined above was controlled by comparing students' previous year mathematics achievement grades (MAG). The 6th grade mathematics achievement grades of the subjects were obtained from the grade report forms of the school records. An independent-samples t-test was conducted to control the equivalence of groups. The students' previous year mathematics grades were similar in both experimental and control groups. Both groups were taught the same mathematics content; but in experimental group, an instruction designed by the CLT principles was applied.

The study was carried out in six Algebra Units: (1) Exponents, (2) Operations on Algebraic Exponents, (3) Equations, (4) Cartesian Coordinate Plane, (5) Graphs of the First Degree Equations in One Unknown, and (6) Patterns and Relations. For each unit, the researcher developed ''Teacher Guidelines'' and ''Student's Booklets'' for using in experimental group. At the end of each unit, the Subjective Rating Scale (SRS) developed by Paas and Van Merrienboer (1993) was used to measure student's cognitive load for experimental and control groups. After the completion of the treatment, the ''Algebra Achievement Test (AAT)'' developed by the researcher was administrated to the experimental and control groups. The piloting of the AAT had been previously conducted in three public schools in İstanbul. The Students' Questionnaire (SQ) was administered to the experimental group for finding about student's views and opinions related to the treatment.

Students' interviews were conducted at the end of the treatment. For this purpose, an interview schedule including 12 structure questions were prepared in line with the SQ questions. Participants for interviews were selected purposefully according to their mathematics achievement. Four students from each of the high, medium and low achievers (*N=12*) were selected for the interviews.

Figure 3.1 shows the overall design of the study with the tools which were used in the study provided for the groups.

Figure 3.1. Representation of the overall research design of the study.



3.2 Research Questions

The purpose of this study was to investigate the effect of an instruction designed by the CLT principles on students' achievement in Algebra topics and cognitive load.

The study aimed to answer the following questions:

1. Does the instruction designed by CLT have significant effect on 7^{th} grade student's Algebra achievement and cognitive load?
2. Is there a significant difference between the efficiency scores of students who were exposed to instruction designed by CLT principles compared to instruction recommended by MONE?
3. What are the perceptions of students who were exposed to instruction designed by CLT principles about the treatment?

3.3 Hypotheses

The following hypotheses that are stated in null form tested the research questions given above.

Null Hypothesis 1.1: There is no significant mean difference between group of students who were exposed to instruction designed by CLT principles and to instruction recommended by MONE.

Null Hypothesis 2.1: There is no significant difference between the efficiency scores of students who were exposed to instruction designed by CLT principles and to instruction recommended by MONE.

3.4 Variables

Three variables were used in the study. One of them was independent and two of them were dependent variables. Descriptions of variables were given below:

Independent variable: Treatment (Instructional method with two levels): Instruction designed by CLT principles in experimental group and instruction recommended by MONE in control group.
Dependent Variables: Algebra Achievement and Cognitive Load of students.

3.5 Context

The school was built in 1999 with the help of a non-governmental organization (NGO) which no longer allocates any funds to the school. The school is located in a poor socioeconomic neighborhood and its physical conditions are quite poor.

Two mathematics teachers participated in the implementation of the study. Both teachers were female, graduated from four-year elementary school mathematics education programs. The teacher of the experimental group has 5 years of experience in teaching and the teacher of the control group has 4 years of experience in teaching. They are both attentive, eager to learn new teaching methods and very helpful. They personally defined their instructional approach or technique as teacher-centered because of the conditions of the school that they work.

7^{th} grade mathematics curriculum recommended by MONE is implemented in the school. It covers five learning areas: (1) Numbers, (2) Algebra, (3) Geometry, (4) Probability and Statistics, and (5) Measurement (MONE, 2005). 7^{th} grade mathematics course is offered for four hours per week. Identified teacher's and student's textbooks recommended by MONE are followed in the courses. This study was implemented in Algebra learning area. The Algebra topics and its objectives are provided in Table 3.1.

Table 3.1

The Topics and Objectives of 7th Grade Algebra Learning Area

Algebra Topics	Objectives: Learners are expected to
Exponents	Use exponential notation for n^{th} exponents.
Operations on Algebraic Expressions	Add and subtract Algebraic expressions. Multiply two Algebraic expressions.
First Degree Equations in One Variable	Solve the first degree equation in one variable. Solve problems that can be expressed as a first-degree equation.
Cartesian Coordinate Plane	Explain the Cartesian Coordinate Plane. Use Cartesian Coordinate Plane.
Graph of the First Degree Linear Equations	Explain linear equations.
Patterns and Relations	Represent number patterns with symbols and describe a rule for it.

3.6 Students' Booklets and Teachers' Guidelines

Students' Booklets (Appendix A) were developed as classroom materials which covered all Algebraic units of the 7th grade Mathematics curriculum. For developing each unit, the objectives of the 7th grade mathematics curriculum and CLT effects were considered. The literature on CLT was reviewed at the beginning of the development of the student's booklets (Chandler & Sweller, 1991; Clark et al., 2005; Kalyuga, Chandler, & Sweller, 2000, 2001; Kalyuga, Chandler, Tuovinen et al., 2001; Kirschner, 2002; Paas, 1992; Paas, et al., 2004; Paas et al., 2003; Paas & Van Merrienboer, 1993; Paas & Van Merrienboer, 1994; Paas & Van Merriënboer, 1994; Sweller et al., 1998; Sweller, 1988, 1994; Sweller & Chandler, 1991; Sweller & Cooper, 1985; Van Gog, et al., 2004; Van Merrienboer & Ayres, 2005; Van Merriënboer & Kirschner, 2001; Van Merrienboer, Kirschner, & Kester, 2003; Van

Merriënboer, Schuurman, De Croock, & Paas, 2002; Van Merriënboer & Sweller, 2005). The CLT effects used in the Student's Booklets are as follows: (a) worked example effect, (b) completion example effect, (c) split-half effect, (d) modality effect, (e) redundancy effect, and (f) guidance fading effect. Six Students' Booklets were developed together with Teachers' Guidelines.

Student's Booklets were developed by the researcher. Four mathematics teachers, one of whom has Ph.D degree in primary school mathematics education, two of whom are 25 years experienced teachers in a private school, and one of whom is a 3 years experienced teacher in a public school checked the booklets in terms of their content, appropriateness of the language used, the grade level of students, and the CLT effects. They filled out the Expert Opinion Form (Appendix C) which contained one explanation page that contains evaluation criteria and 3-point likert scale named as ‘‘not appropriate’’, ‘‘appropriate but some minor changes necessary’’, and ‘‘appropriate’’ for each booklet. This expert opinion form also included a statement about the CLT principles and its effect. Some modifications such as wording and ordering exercises according to CLT were made according to their criticisms and suggestions. After establishing the final form of the Students' Booklets, an expert in department of Secondary School Science and Mathematics Education, controlled them and made some suggestions about the general view of the booklets, their content and writing form for some of the exercises. In the Table 3.2, student's booklet name, duration, and used CLT effects are presented.

Table 3.2

Students' Booklets, Duration, and CLT Effects

Name of the Booklet	Duration	CLT Effects
Exponents	**3x40 min**	Worked examples, split attention, redundancy, modality
Operations on Algebraic Expressions	**6x40 min**	Worked examples, completion examples, split attention, redundancy, modality, guidance fading
First Degree Equations in One Variable	**4x40 min**	Worked examples, completion examples, split attention, guidance fading, redundancy, modality
Cartesian Coordinate Plane	**2x40 min**	Split attention, redundancy, and modality
Graph of the First Degree Linear Equations	**3x40 min**	Worked examples, split attention, redundancy, modality
Patterns and Relations	**1x40 min**	Worked examples, split attention, redundancy, modality

‘‘Teacher’s Guidelines’’ (Appendix B) were developed for teachers in order to help them manage the instruction. Teacher’s Guidelines were prepared by the researcher and covered the titles ‘‘explanations, duration of lesson, prerequisites of the lesson, objectives of lesson, classroom materials, and implementation of the lessons’’. In the ‘‘explanation’’ part, which effects of the CLT were used and how they were implemented were clarified for the teachers. In the ‘‘implementation of the lesson part’’, the implementation of the unit was explained from beginning to end by considering CLT effects and principles.

3.7 Instruction in Experimental Group

All the activities in the experimental group were prepared by using the CLT principles and effects. According to the CLT, the first step of in instruction is the determination of the students’ prior knowledge. The classroom was heterogeneous in terms of achievement, increasing the importance of the prior knowledge of students. This issue was related with the *expertise reversal effect* of the CLT. At the beginning of each lesson, the teacher asked some questions or made revisions about the topic in order to refresh the students' memory and activate their prior knowledge.

After the repetition of some prerequisite learning, for each Algebra topic, the teacher distributed Students' Booklets and carried out the lesson by following the content of the booklets. The worked examples included in booklets were the starting point of each lesson. The teacher explained each topic on the worked examples verbally (*modality effect*) and then assigned a similar practice exercise to the students for satisfying schema construction. The teacher gave the students enough time to complete practice exercises and always observed the classroom in order to help the students. For some Algebra topics such as Equations, the worked examples were not directly followed by the practice exercise; instead, completion examples were used. By using the completion examples, smooth transition from the worked examples to practice exercises were satisfied. Similarly, in the beginning of each lesson, the teacher explained worked examples verbally; then the teacher gave students time to complete the missing steps of the completion examples; and finally, practice exercises were assigned. The use of worked examples, completion examples, and practice exercises was related to *backward fading effect* of the CLT, which allowed accommodating a gradual learning process. By considering this effect, the WM overload was diminished.

In all Algebra topics, for satisfying the *split-attention effect* of the CLT, the teacher did not write anything on the board. Further, Students' Booklets were considered as content summaries and prevented note-taking for satisfying *split attention effect* of the CLT. Redundancy in training refers to proving more expressions of content than needed for understanding. At the beginning of each Algebra topic, any picture, extra explanation or classroom activity were not considered to satisfy the *redundancy effect* of the CLT. For this effect, information was presented to students through one mode; in other words, the teacher explained the content either virtually or in audio format. According to the CLT, after the students gain experience related with a topic, worked examples and completion examples become detrimental rather than beneficial for learning. For this reason, after the students gained some experience related with Algebra topics, full exercises or classroom activities/group works were assigned for the students. The same procedure was followed for all topics covered.

For example, for the Exponents, the teacher started the lesson by asking the students about basic definitions such as exponent and value of an exponent, then distributed to the Students' Booklet and repeated the definitions of these terms verbally from the booklet. When the examples were considered, she explained each example verbally and did not write worked example or its solution on the board. After the completion of each worked example, similar practice exercises were assigned to students. At the end of the Exponents topic, full exercises were assigned to students by considering as they gained some experience related with the topic.

3.8 Subjects of the Study

The subjects of the study were 80 7^{th} grade students in Kağıthane, İstanbul. 40 of the students were in classroom called 7A and the other 40 were in 7B. Groups were assigned as experimental and control randomly. The equivalency of the groups was controlled by using independent sample t-test by comparing the previous year (6^{th} grade) mathematics achievement grades. General distribution of the subjects of the study was shown in Table 3.2.

Table 3.3

Subjects of the Study

Gender Group	Experimental Group	Control Group	Total
Male	19	20	39
Female	21	20	41

Students for structured interviews were selected purposefully by looking at their mathematics achievement. From the highest achievers (four students), medium achievers (four students) and the low achievers (four students), totally 12 students were selected for the interviews.

3.9 Data Collection Instruments

The following instruments were used to find answers to the research questions and to test the hypotheses:

- Algebra Achievement Test (AAT): Posttest, used in both experimental and control groups after the implementation process.
- Subjective Rating Scale (SRS): Used in both experimental and control groups after the completion of each Algebra topic.
- Student Questionnaire (SQ): Used in experimental group after the implementation.
- Interview Schedule (IS): Used in experimental group after the implementation.

3.9.1 Algebra Achievement Test (AAT)

Algebra Achievement Test (AAT) (Appendix D) was developed by the researcher for determining the 7^{th} grade students Algebra achievement and consist of 20 open ended questions related to the Algebra topics. All questions in the test were developed by considering the objectives and content of the 7^{th}

grade Mathematics Curriculum related to the Algebra topics. To specify questions in the text, the researcher consulted many 7^{th} grade textbook materials and teacher's handbook (Işıklı, 2010; Mirasyedioğlu & Akpınar, 2004; MONE, 2005). The possible scores of the test range from 0 to 80. A rubric (Appendix E) was created for scoring the test by the researcher. For each question, a five-score level (0-4) was assigned. The highest score of 4 was awarded for responses that the researchers regard as being entirely correct and satisfactory answer, while the lowest score of 0 was reserved for no answer or completely wrong answer.

Four mathematics teachers, one of whom has Ph.D. degree in primary school mathematics education, two of whom are 25 years experienced teachers in a private school, and one of whom is a 3-years experienced teacher in a public school, checked the test and rubric for content validity evidence by comparing the items with the objectives. ''Expert Opinion Form (EOF)'' (Appendix F) was developed for determining the test according to the units, objectives, and class level, and its clarity and general outlook. It included one explanation page that contains evaluation criteria and 3-point likert scale named as ''not appropriate'', ''appropriate but some minor changes necessary'', and ''appropriate'' for each question. Also, there was an explanation part for each question for the teacher's recommendations. Moreover, the EOF was sent to the two mathematics education faculty staff to check the appropriateness, relevance, and consistency of the questions with the nature of CLT. Some revisions were made on the wording of the questions, taking into account of the experts, in order to make them clearer and more suitable for the learning outcome being measured.

The AAT was piloted with 229, 8^{th} grade students from three public schools in the first semester of 2009-2010 academic year. The purpose of the piloting was to check the clarity of the questions, to make sure the adequacy of the test duration, and to check reliability (internal consistency of the test). After the implementation, the researcher graded the test by taking the rubric into consideration. Upon the completion of grading by the researcher, another mathematics teacher scored randomly selected 80 tests. The inter rater reliability analyses were conducted by using Statistical Package for Social Sciences (SPSS) 15.0 for Windows. Inter-rater reliability coefficient by means of intra-class correlation (ICC) was computed in order to establish the extent of consensus on the use of the scoring rubric for the test. The ICC value of the test was 0.90, which indicated high reliability and internal consistency of scoring rubric as used by two raters.

The test covers the questions (1) finding value of an expression, (2) simplifying expressions, (3) writing the algebraic expression of a pattern, (4) solving equations, (5) solving problems by using equations, (6) constructing problems, (7) determining a point on Cartesian Coordinate plane, and (8) sketching graphs.

3.9.2 The Subjective Rating Scale of Cognitive Load

The one item Subjective Rating Scale (SRS) (Appendix G) developed by Paas and Van Merrienboer (1993) was used to measure students' cognitive load for both experimental and control groups of students. It was implemented at the end of each Algebra unit. The SRS was a 9-point symmetrical rating scale, ranging from 1 (very, very low mental effort) to 9 (very, very high mental effort). The reliability coefficient of the scale was found .82 by Paas and Van Merrienboer (1993). The Turkish adaptation of the scale (Appendix H) was developed by Kılıç and Karadeniz (2004). For the translation of the test to Turkish and its clarity, Kılıç and Karadeniz took expert opinion and prepared a form for piloting (Sezgin, 2009). For the internal consistency of the test (reliability), they conducted a study and found .90 Cronbach Alpha reliability coefficient which was indicated as high reliability. Sezgin (2009) also conducted a study to find the internal consistency of the SRS and found .78 Cronbach Alpha reliability coefficient which was indicated as moderate reliability.

CLT is about efficiency (Clark et al., 2005). Particularly, the combination of performance and cognitive load measures has been identified to constitute a reliable estimate of the cognitive efficiency of instructional methods (Paas et al., 2003). Higher learning outcomes with less cognitive effort are more efficient than environments that lead to lower outcomes with greater mental effort (Clark et al., 2005).

To quantify the efficiency, instructional scientists Paas and van Merriënboer's (1993) use efficiency metric. Their approach provides a tool to relate cognitive effort to performance measures. In this approach, high-task performance associated with low effort is called *high-instructional efficiency*, whereas low-task performance with high effort is called *low-instructional efficiency*. This metric is calculated by subtracting cognitive load from the performance outcomes. It can be expressed mathematically as E=P-CL. According to formula, when performance is greater than cognitive load, the efficiency value is positive; on the other hand, when performance is lower than cognitive load, the efficiency value is negative (Clark et al., 2005).

Performance is measured by a test taken at the end of the lesson. Cognitive load is most commonly measured by learner estimates of lesson difficulty. The difficulty (cognitive load) of lesson is assessed by using a 1 to 7 or 1 to 9 scales. In this study, performance was measured by a test taken at the end of the implementation (AAT) and cognitive load was measured by learner estimates of lesson difficulty (SRS).

To visually represent the efficiency metric, the student scores for cognitive effort and performance are standardized, yielding a *z* score for cognitive load and a *z* score for performance. Then, an instructional condition efficiency score (*E*) is computed for each student as the perpendicular distance between a dot and the diagonal, *E* = 0, where mental effort and performance are in balance using the formula $E = \frac{z_{performance} - z_{mental\ effort}}{\sqrt{2}}$.

The graphics are used to display the information on a Cartesian Axis, performance (vertical) and cognitive load (horizontal), helping to visualize the combined effects of the two measures. In Figure 3.2, the efficiency value represented by point A is high on performance line and low on the mental effort line. The upper left quadrant of the graph is considered the high efficiency area of the graph. In contrast, the point B represents an efficiency value that is low on the performance scale and high on the mental effort scale. The lower right quadrant of the graph is called the low efficiency area of the graph. When the efficiency is zero, mental effort and performance is equal, the line is labeled E=0.

To quantify the efficiency of the instruction in this study, the AAT and SRS scores of each subject in experimental and control group were converted to z-score and efficiency graph was sketched to represent the efficiency visually.

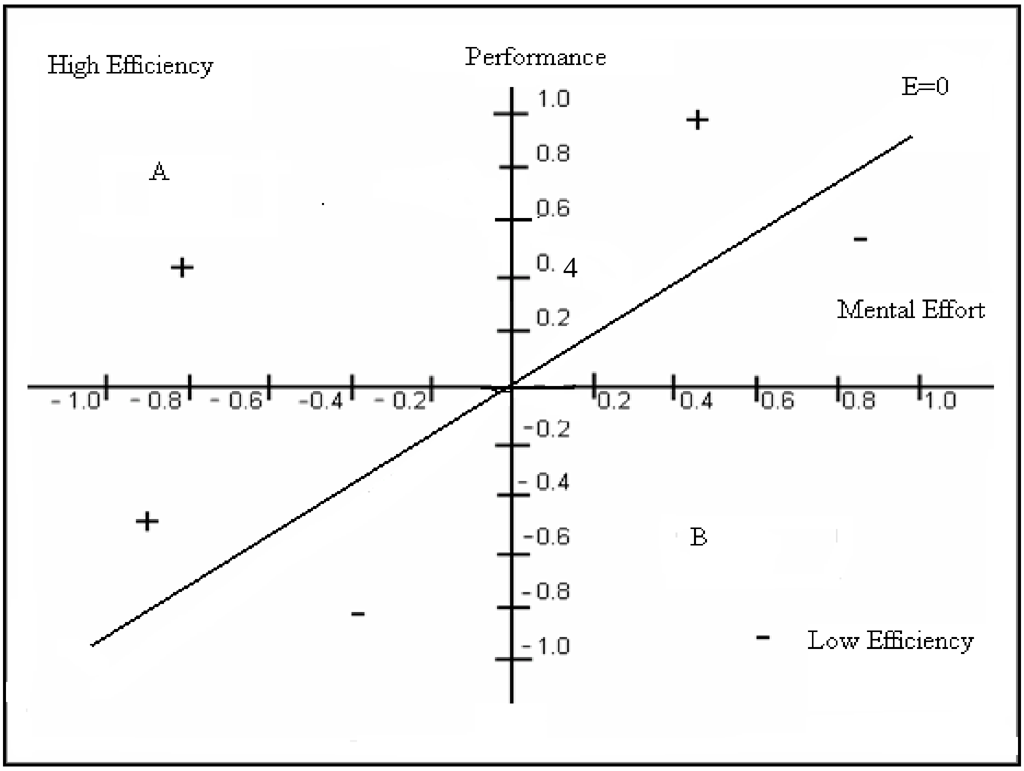


Figure 3.2. The efficiency graph.

Source: (Kılıç, 2006).

3.9.3 Students' Questionnaire

For determining student's views and opinions in the experimental group about the treatment, a Students' Questionnaire (SQ) (Appendix I) was developed by the researcher. The SQ included 19-items that were scored using a 5-point Likert type scale, named as strongly agree, agree, not certain, disagree, and strongly disagree. It also included five open-ended questions. Items of the SQ included questions about the form of the teaching, materials, classroom activities, and group works. Moreover, it included some items on the effects of the CLT such as worked example effect, completion example effect, and modality effect. The Cronbach' Alpha reliability coefficient of the SQ was .91. Descriptive statistics methods were used to analyze the data obtained from the SQ.

3.9.4 Students' Interview Schedules

The purpose of the interviewing process was to gain some insight into views and opinions of the students about the process of the lessons, classroom materials, classroom activities, and group works. For this purpose, 12 structured interview questions (Appendix J) were prepared parallel to the SQ questions.

All the interviewees were asked the same questions in the same order. Questions were worded completely in an open-ended format. The researcher believed that this type of questions help to increase the comprehensiveness of the data and make the data collection process more systematic. In case, the interviews were remained fairly conversational and situational.

All the data were written on a computer and coded. Codes were generated after reading the data line by line (inductive coding). The codes were determined from the data, the literature on CLT, and the researcher herself. All types of codes were considered: situation, acts, activities, process, and strategies.

3.10 Data Collection Procedures

The purpose of this study was to investigate the effect of an instruction designed by the CLT principles on students' achievement in Algebra topics and cognitive load. For this purpose, as explained earlier, a quasi-experimental research design was utilized. From the beginning to the end of the process, an instruction designed by CLT principles was used in the experimental group.

The researcher prepared Students' Booklets and Teachers' Guidelines which covered of all Algebraic units of the 7^{th} grade Mathematics curriculum. After the preparation of the booklets and guidelines, expert opinion was taken to ensure the convenience of the test according to the units, objectives, and class level, and its clarity and general outlook.

At the very beginning of the data collection process, the researcher informed the teacher of the experimental group about the CLT, its principles and effects. It took nearly 5-6 hours. Some extra handouts and internet sources were provided for the teacher to satisfy a deep understanding of CLT.

Before the implementation of the study, the equivalency of the groups was controlled by using the previous grade/year mathematics achievement scores of subjects (MAG). The 6^{th} grade mathematics achievement scores of the subjects were obtained from the grade report forms of the school records. An independent-samples t-test was conducted to control the equivalence of the groups. The t-test indicated that the students' previous year mathematics grades were similar in experimental and control groups.

The treatment lasted 6 weeks. On the 7^{th} and 8^{th} week, the AAT and the SQ were administered and interviews were conducted.

During the intervention period, two groups were taught the same Algebra units included in 7^{th} grade mathematics curriculum. In the experimental group, all the Algebra units were taught by the principles and effects of the CLT. On the other hand, in the control group, the subjects received the 7th grade mathematics content through regular mathematics instruction as suggested by the MONE. Subjects in the experimental group used the Student's Booklets prepared by the researcher as classroom materials. In addition to Students' Booklets, Algebra Tiles were used as classroom materials in some units of Algebra.

The one item SRS was administrated to students at the end of each Algebra topic. The time allocated for conducting the SRS was approximately 3 to 5 minutes each time. For each student, six SRS scores were obtained.

Teachers and experts in Mathematics education field checked the test and rubric for content validity evidence. To check the clarity of the questions, to make sure the adequacy of the test duration, and to check internal consistency of the test, the pilot study of AAT was conducted on 229 8^{th} grade students in three public schools in İstanbul, 2010-2011 fall semester. The inter rater reliability analyses were conducted by using Statistical Package for Social Sciences (SPSS) 15.0 for Windows.

Final form of AAT was administered to both the experimental and control groups to assess the effects of the instruction on Algebra achievement. The time allocated for the administration of the AAT was one lesson hour.

For determining the student's views and opinions in the experimental group about the treatment, a SQ was developed by the researcher. The SQ included 19 items that were scored using a 5-point Likert-type scale. The time allocated for the administration of the AAT was 15 to 20 minutes.

An interview schedule (IS) included 12 structured questions that were prepared in line with the SQ questions by the researcher. Interviews were conducted totally with 12 students selected purposefully according to their mathematics achievement. AAT scores and suggestion of experimental group teacher were taken into consideration for selection of students for interviews. Each interview was conducted individually in an empty classroom during the break times of students and audio-taped. The interviewees were informed that they were not graded for their answers and their names and other personal information would be kept confidential. The interview tone was friendly and non-threatening, and efforts were made to provide honest responses comfortably. Although interviews were primarily structured, some flexibility was provided by reacting spontaneously to student's explanations to make them clearer. Duration of the interviews varied from 10 to 20 minutes. Data collection procedures are tabulated in the Table 3.4.

Table 3.4

Data Collection Procedures

Duties	Dates	Groups	
		Experimental	Control
Control of Equivalency of Groups	30 November 2010 - 5 December 2010	6^{th} grade mathematics achievement grades	6^{th} grade mathematics achievement grades
Unit 1: Exponents	6 December 2010 - 12 December 2010	SRS	SRS
Unit 2: Operations on Algebraic Expressions	13 December 2010 – 26 December 2010	SRS	SRS
Unit 3: First Degree Equations in One Variable	13 December 2010 – 26 December 2010	SRS	SRS
Unit 4: Cartesian Coordinate Plane	27 December 2010 - 2 January 2011	SRS	SRS
Unit 5: Graph of the Linear Equations	3 January 2011 – 6 January 2011	SRS	SRS
Unit 6: Patterns and Relations	7 January 2011 – 13 January 2011	SRS	SRS
Comparison of the groups in terms of achievement, Student Questionnaire, Student Interviews	14 January 2011 – 25 January 2011	AAT, SQ, SI	AAT

3.11 Data Analysis

Multiple data analysis techniques were used for the data collected from various sources based on the research questions. Data collected from AAT, SRS, and SQ were analyzed by using descriptive and inferential statistical analysis techniques. For the analysis of the data, the SPSS 15.0 (Statistical Package for Social Sciences) was used. At the beginning of the study, an independent sample t-test at the level of significance 0.05 was conducted to control the equivalency of the groups. Then, the reliability analysis was conducted to test the reliability of the AAT.

MANOVA was used as the preferred inferential statistic technique to answer the research questions. MANOVA was chosen over other statistical methods because it adequate to the design of the study (one independent, two dependent variables). The data from the SQ were analyzed by using descriptive statistic techniques such as mean and percentages.

To quantify the efficiency of the instruction, the AAT and SRS scores of each subject in experimental and control group were converted to z-score and efficiency graph was sketched to represent the efficiency visually. In efficiency graph, the x-axis represents the range of cognitive load ratings (SRS scores) in z-scores and the y-axis represents the performance outcomes (AAT scores) in z-scores. The origin represents the average of all test scores and SRS ratings, which when converted to z-scores equal to 0. Therefore, a performance z-score greater than 0 falls above the axes, and a cognitive load score greater than 0 falls the right of the axes. To check the hypothesis that experimental group's efficiency scores of students was significantly different from the control group's efficiency scores of students; an Independent Samples t-test was conducted.

The data obtained from the open ended questions of SQ and interviews, were collected together into meaningful patterns by using both the literature and the structure of the questions. Different codes were collected together into themes and categories. In order to strengthen the reliability of the qualitative analysis results, the data were coded by a different researcher. Probable themes related to the questions of the questionnaire and the interviews were given in Appendix K. Categories of the qualitative analysis were described in the results part of the study.

3.12 Limitations of the Study

1. This study is limited the data obtained from 80 7^{th} grade students attending a public primary school in İstanbul, in the fall semester of the 2010-2011 academic year. The findings from this study were limited to the student profile and the environment of selected public school. Since the sample size was limited to 80 students, it might not reflect the general population so the results of the study cannot be generalized to other contexts.

2. The study is limited only to Algebra units.

3. The random selection and assignment of students was not used because of the administrative problems. Two classes of the school were used.

4. A pilot study of the classroom materials was not conducted in the previous year. Although no problems were encountered during the implementation of the study, it would be more desirable to conduct a pilot study in order to check the duration of the courses, or to detect any potential problems before the implementation of the study.

5. The CLT is a newly developed instructional method. The experimental group teacher was trained about the CLT and she constantly communicated with the researcher if she faced any problems or needed clarifications. Yet it would be a problem if the teacher did not understand the theory deeply.

6. SRS is a one item test. At the end of the each Algebra topic, it was distributed to students to collect data about their cognitive load. Sometimes students needed more clarification about the instrument. Because it is 9-point scale and some points overlapped.

7. All interviews were conducted by the researcher. Students might feel uncomfortable to answer interview questions.

3.13 Internal Validity

Possible threats to internal validity of the results and conclusions and how they would be controlled were explained in this section.

The possible threats for the design of this study would be subject characteristics, history, location, mortality, data collector characteristics, data collector bias, expectancy effects, and implementation.

The selection of people for a study may result in the individuals differing from one another in unintended ways that are related to the variables to be studied. This is referred as subject characteristics threat (Fraenkel & Wallen, 2002). Student's mathematics achievement was identified as a subject characteristics treat. Previous year mathematics scores of students was compared by independent sample t-test and it was found that there was no statistically significant mean difference of the experimental and control group's subject characteristics.

History and location threats were controlled completely because all of the data collection tools were administered to groups at the same time. Also, both the experimental and the control groups had the treatment and tests at the same school. Because of no missing participants after the treatment, mortality threat was controlled successfully in this research.

Data collector characteristics and data collector bias were controlled in this study by observing data collection conditions and procedures by the researcher for both of the experimental and the control groups.

To control the expectancy effect, upon the completion of grading by the researcher, one mathematics teacher scored the AAT of the experimental and control groups. The inter rater reliability analyses were conducted and high reliability was found between the scoring of researcher and other rater.

The implementation treat can occur when different individuals are assigned to implement different methods and these individuals differ in ways related to the outcome (Fraenkel & Wallen, 2002). In this research study, two different teachers were assigned to experimental and control groups. Thorough training of teachers reduced the implementation problems. Researcher maintained contact during the study and was aware of what was occurring at all times, this also reduced the implementation threats.

Confidentiality was provided in this research study because the names or the characteristics of the students were not written in any form. The numbers or letters were used instead of their names for the statistical analyses.

CHAPTER IV

RESULTS

The purpose of this study was to investigate the effect of an instruction designed by the CLT principles on 7th grade students' achievement in Algebra topics and cognitive load. This chapter covers the findings related to the problems of study; the results obtained by the implementation of the Algebra Achievement Test, Subjective Rating Scale, Student Questionnaire and Interview Schedule. The chapter is divided into two sections. The first section presents quantitative results; the second section includes the qualitative results. Summary of the findings are given at the end of the chapter.

4.1 Quantitative Results

4.1.1 The Results Concerning the Equality of Groups before the Treatment

The equality of the experimental and control groups before the process was controlled in terms of previous year mathematics achievement grades (MAG). The result of the Independent Samples t-test is presented in Table 4.1.

Table 4.1

Results of the Independent Samples t-test for Determining Equivalency of Groups (n=80)

Group	*M*	*SD*	*t*	*df*
Control	2.98	1,368		
Experimental	2.55	1,154	1,502	78

*p<.05

The results of the Levene's test evaluate one of the assumptions of the t-test, which is whether the population variances for the two groups are equal or not. Referring to the Levene's test of equality of variances, it can be concluded that the homogeneity of variances were not violated ($p=.261>.05$) in the current study. The t-test results presented in Table 4.1 showed that there was no significant mean difference on student's previous year mathematics scores between the control ($M =2.98$, $SD = 1.37$) and the experimental group ($M= 2.55$, $SD = 1.15$), $t(78)=1.50$, $p=.137$. This finding indicated that the students' previous year mathematics grades were similar in both experimental and control groups.

4.1.2 The Descriptive Results of the Algebra Achievement Test (AAT) and Cognitive Load Scores (SRS)

The descriptive statistics related to the student's AAT and SRS for each of the experimental and control groups are given in Table 4.2.

Table 4.2

Mean and Standard Deviation of AAT and SRS Scores

Groups	AAT*		SRS**	
	M	*SD*	*M*	*SD*
Experimental	41.18	12.86	3.58	1.55
Control	14.88	8.28	5.05	1.39

* Total score of the AAT is 80.
**9-point scale.

Descriptive statistics revealed that in terms of the AAT scores, the students in the experimental group (*M=41.18, SD=12.86*) had higher scores than the students in the control group (*M=14.88, SD=8.28*). In terms of the SRS scores, the experimental group students (*M=3.58, SD=1.55*) had lower scores than the control group students (*M=5.05, SD=1.39*).

The student's average cognitive load scores, gathered from the SRS and cognitive load conditions for experimental and control groups, are given in Appendix L. The cognitive load conditions defined according to students' average cognitive load scores. The mean scores of cognitive load was calculated by taking the mean of collected cognitive load data by using SRS at the end of the each six Algebra topics. Cognitive load score ranging between 1-4 denotes *low cognitive load* and those ranging between 5-9 denotes *high cognitive load* conditions (Paas & Van Merrienboer, 1993).

According to the cognitive load ranges (Appendix L), there were 7 students in high cognitive load condition in the experimental group, while there were 23 students in high cognitive load condition in the control group. In contrast, there were 33 students in low cognitive load condition in the experimental group, while 17 students were in low cognitive load condition in the control group. Hence, the number of students with a high cognitive load was greater in control group than in the experimental group.

4.1.3 Multivariate Analysis of the Variance (MANOVA): Investigation of the Effects of an Instruction Designed by CLT principles on Students' Algebra Achievement and Cognitive Load

Multivariate Analysis of the Variance (MANOVA) is a statistical technique used for assessing group differences across multiple metric dependent variables simultaneously, based on a set of categorical variables acting as independent variable (Green, Salkind, & Jones, 1996). The MANOVA technique was used in this study to examine the effects of an instruction designed by CLT principles on students' Algebra achievement and cognitive load.

The research question of the study is ''does the instruction designed by CLT have significant effect on 7th grade student's Algebra achievement and cognitive load?''

Prior to conducting MANOVA, the assumptions underlying this technique, namely the independence of observations, multivariate normality, homogeneity of variance-covariance, interval/ratio scale on dependent variables, and outliers (Tabachnick & Fidell, 2001) were checked in order to explore the appropriateness of the data for running MANOVA.

The independence of observations assumption was met since different groups did not affect each other when answering the items in the tests used for this study.

Multivariate normality requires that the sampling distributions of the means of the dependent variables in each cell and all combinations of them are normally distributed (Tabachnick & Fidell, 2001). In order to check univariate normality assumption, skewness-kurtosis values, Q-Q plots and Kolmogorov-Smirnov and Shapiro-Wilk's tests were examined (Field, 2009). Skewness-Kurtosis values were not quite away from 0 for each group implied the normal distribution. The points on Q-Q plots for the cases fall along the diagonal running from lower left to upper right, with some minor deviations due to random processes implies the normality of the distribution (Tabachnick & Fidell, 2001). The Q-Q plots of the variables indicated the normal distribution. Further, the results of the Kolmogorov-Smirnov and Shapiro-Wilk's tests also indicated the normal distribution. Mardia's test was used to examine multivariate normality. The test revealed a non-significant result indicating normal multivariate distribution (Appendix M).

The outliers are observations with a unique combination of characteristics identifiable as distinctly different from the other observations (Hair Jr, Anderson, Tatham, & Black, 1995). Because MANOVA is a multivariate analysis, multivariate outliers are of special importance (Stevens, 1996). In order to examine the data for multivariate outliers, Mahalanobis Distance (D^2) was used. D^2 is a measure of distance in multidimensional space of each observation from the mean center of multidimensional centrality (Hair Jr, et al., 1995). The analysis revealed that the data has no cases with D^2values greater than the critical values of 13.60 (2.77) for the alpha set as .05 (Appendix M). Therefore, there were no multivariate outliers.

The assumptions of homogeneity of variance and covariance is that the variance and covariance matrices within each cell of the design are sampled from the same population variance-covariance matrix and can be reasonably pooled to create a single estimate of error (Tabachnick & Fidell, 2001).

The equality of variance assumption was satisfied by the result of the Levene's test of equality of error variances (Field, 2009). Levene's test was found to be non-significant for both Algebra achievement and cognitive load scores (Table 4.3).

Table 4.3

Levene's Test of Equality of Error Variances

	F	*df1*	*df2*
AchScores	2.663	1	78
LoadScores	1.530	1	78

*p<.05

The homogeneity of covariance matrices was checked by using Box M test (Field, 2009). Results of the Box M Test showed that homogeneity of covariance assumption was violated for the analysis, $F(3,1095120)=2.70$, $p<.05$ (Table 4.4). Considering the result of Box M and the equality of the sample cells the robustness cannot be guaranteed (Tabachnick & Fidell, 2001). Hence, Pillai's Trace test was used instead of Wilks' Lambda to evaluate multivariate significance.

The dependent variables (AAT and SRS scores) were measured on a continuous scale, so the interval/ratio scale on dependent variables assumption was met.

The results of the MANOVA test, Pillai's Trace, was significant, $F(2,77)= 72.687$, $p<.05$, indicating that the population means on the Algebra achievement and cognitive load scores were different for the two groups. The multivariate eta squared .65 indicated that 65 percent of multivariate variance of the AAT and SRS scores were associated with the group factor.

Since a significant result was obtained on the multivariate test (Table 4.5), it was required to check univariate analysis ANOVA in order to understand the effect of instruction on AAT and SRS scores. The results of the univariate ANOVAs are shown in Table 4.4. The univariate ANOVAs for AAT and SRS scores were both significant, $F(1,78)=118.26$, $p<.05$ and $F(1,78)=19.86$, $p<.05$, respectively. In terms of the variance explained, groups explained 60 percent of the variance in AAT scores whereas the groups explained 20 percent of the variance in SRS.

Table 4.4

Multivariate and Univariate Analysis of Variance

	MANOVA	ANOVA	
Variable	*F*(2,77)	DV1 *F*(1,78)	DV2 *F*(1,78)
Group	72.687*	118.262*	19.863*

Note. F ratios are Pillai's Trace approximation, DV1= Achievement Scores, DV2= Cognitive Load Scores, *p<.05

4.1.4 The Results of the Efficiency of Instruction

The second research question of the study is ''is there a significant difference between the efficiency scores of students who were exposed to instruction designed by CLT principles and to instruction recommended by MONE?''.

In order to quantify the effects of instruction designed by CLT principles and by MONE on students', the following efficiency formula was used (Clark, et al., 2005; F Paas, et al., 2003).

$$E = \frac{\text{Average } z_{\text{performance}} - \text{Average } z_{\text{mental effort}}}{\sqrt{2}}$$

Algebra achievement and cognitive load, the AAT and SRS scores of each subject in experimental and control group were standardized by converting z-scores (Clark et al., 2005; Paas et al., 2003).

The data given in Table 4.5 shows the mean of AAT z-scores, SRS z-scores, and the efficiency values for both experimental and control groups calculated by the above formula (Kablan & Erden, 2008; Paas et al., 2003; Sezgin, 2009).

Table 4.5

The Mean of AAT z-scores and SRS z-scores

Groups	SRS z-score (x-axis)	AAT z-score (y-axis)	Efficiency Value
Experimental	-0.45	0.77	0.86
Control Group	0.45	-0.77	-0.86

Figure 4.1 shows SRS z-score, AAT z-score and efficiency values plotted on the efficiency graph for experimental and control groups.

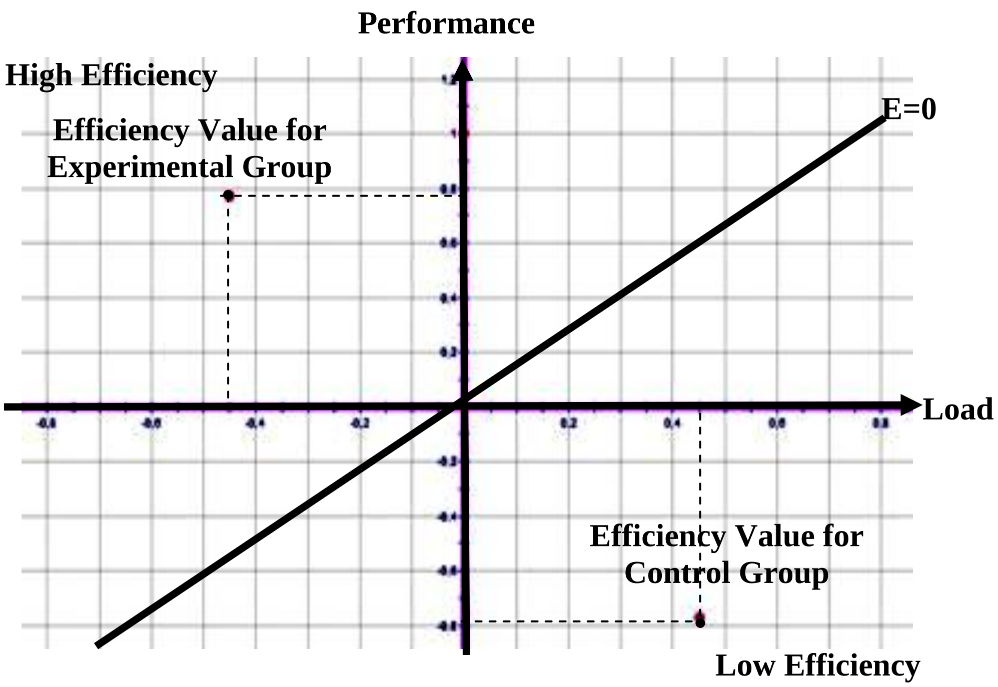


Figure 4.1. Efficiency values of experimental and control groups on efficiency metric.

To check the hypothesis that experimental group's efficiency scores of students was significantly different from the control group's efficiency scores of students; an Independent Samples t-test was conducted. The efficiency value of each student was calculated by using the above formula and putting SRS z-score and AAT z-score of each individual student on the efficiency formula. The result of the Independent Samples t-test is presented in Table 4.6.

The results of the Levene's test evaluate one of the assumptions of the t-test, which is whether the population variances for the two groups are equal or not. Based on the Levene's test of equality of variances, it can be assumed that the homogeneity of variances were not violated (p=.081>.05) in the study.

Table 4.6

Results of the Independent Samples t-test for Efficiency Values of Groups (n=80)

Group	*M*	*SD*	*t*	*df*
Control	-0.86	0.64		
Experimental	0.86	0.84	10.339	78

*p<.05

Table 4.6 shows that the t-test results indicated that significant mean difference on efficiency values between the control (*M*=-0.86, *SD = 0.64*) and the experimental group (*M=0.86, SD = 0.84*), t(78)=10.339, p<0.05. This finding implies that there was significant difference between the efficiency values of the students in the experimental and the control group.

4.1.5 The Descriptive Results of the Students' Questionnaire (SQ)

The third research question was ''what are the perceptions of the students who were exposed to instruction designed by CLT principles?''.

A questionnaire (SQ) with both open and close ended questions was applied to the experimental group participants to identify participant's perceptions after the treatment process. The likert scaled SQ questions deal with the form of the teaching, materials, classroom activities, and group works. Moreover, the questionnaire also included some items on the effects of the CLT such as modality, worked example, and completion example effects.

Table 4.9 shows the frequencies and percentages of the students' responses for each item. The categories on a discrete scale of 1-5 represents (1) strongly disagree, (2) disagree, (3) neither disagree nor agree, (4) agree, and (5) strongly agree.

Table 4.7

The Frequencies (f) and Percentages (%) of the Students' Responses for Each Item

Item	*Categories*	*f*	*%*
Q1. The teaching method helped me to learn the subject well.	1	2	5.0
	2	5	12.5
	3	8	20.0
	4	10	25.0
	5	15	37.5
Q2. I did not have difficulty to learn the topics with the teaching method.	1	2	5.0
	2	3	7.50
	3	8	20.0
	4	13	32.5
	5	14	35.0
Q3. I enjoyed the way of teaching.	1	3	7.5
	2	5	12.5
	3	4	10.0
	4	5	12.5
	5	23	57.5
Q4. Materials of the subject helped me to learn the topics well.	2	4	10.0
	3	5	12.5
	4	15	37.5
	5	16	40
Q5. I did not have any difficulties in using the class materials.	1	3	7.5
	2	2	5.0
	3	10	25.0
	4	9	22.5
	5	16	40

Q6. I enjoyed using the classroom materials.	1 2 3 4 5	2 4 6 10 18	5.0 10.0 15.0 25.0 45.0
Q7. Classroom activities conducted at the end of each lesson helped me to learn the topics well.	2 3 4 5	4 11 9 16	10 27.5 22.5 40
Q8. I did not have any difficulties in doing the classroom activities.	1 2 3 4 5	3 3 7 11 16	7.5 7.5 17.5 27.5 40.0
Q9. I enjoyed doing the classroom activities.	1 2 3 4 5	3 1 5 10 21	7.5 2.5 12.5 25.0 52.5
Q10. Group works helped me to learn the topics well.	1 2 3 4 5	4 6 7 9 14	10.0 15,0 17,5 22,5 35,0
Q11. I did not have any difficulties to do group works.	1 2 3 4 5	7 4 12 10 7	17.5 10.0 30.0 25.0 15.5
Q12. I enjoyed doing group works.	1 2 3 4 5	4 7 10 5 14	10.0 17.5 25.0 12.5 35.0
Q13. Revisions and questions asked in the beginning of each lesson helped me to learn the topics.	2 3 4 5	5 9 8 18	12.5 22.5 20.0 45.0

Q14. Verbal explanations during the lessons helped me to learn the topics.	1 2 3 4 5	2 2 6 8 22	5.0 5.0 15.0 20.0 55.0
Q15. Worked examples helped me to learn the topics.	1 2 3 4 5	4 3 13 5 15	10.0 7.5 32.5 12.5 37.5
Q16. Completion examples helped me to learn the topics.	2 3 4 5	1 14 8 17	2.5 35.0 20.0 42.5
Q17. Teaching method of the subject helped me to learn the topics in a shorter period.	2 3 4 5	5 6 14 15	12.5 15.0 35.0 37.5
Q18. I would like to see this teaching method used in other Mathematics topics.	1 2 3 4 5	2 2 7 9 20	5.0 5.0 17.5 22.5 50.0
Q19. I would like to see this teaching method used in other courses.	1 2 3 4 5	1 3 10 5 21	2.5 7.5 25.0 12.5 52.5

The analysis of the data obtained from SQ indicated that the majority of the students enjoyed the way of teaching (70%), materials (77.5%), and classroom activities (77.5%). Further, they thought that materials of the subject help them learn the topics well (77.5%). The data showed that the students agree about the helpfulness of the modality principle of the CLT (75%). Indicating efficiency of the treatment in terms of duration, students agree that they learned in a shorter time (72.5%). Finally, the majority of the students wanted to see the use of the teaching method in other mathematics topics (72.5%).

4.2 Results of Interviews

In order to capture students' perceptions about the treatment more deeply, in other words, to satisfy the deep understanding about the treatment, open-ended interviews were conducted at the end of the implementation process. The interviewees were selected purposefully based on their mathematics achievement. A total of 12 students were selected for the interviews from the highest achievers (four students), medium achievers (four students) and low achievers (four students). According to interviews, the codes were collected under the themes which are provided in Appendix K.

4.2.1 Revisions about Prerequisite Learning at the Beginning of Each Lesson

In the interview process, the first question was about the revisions and the questions asked at the beginning of each lesson to refresh the students' memory about the prerequisite learning. All of the participants had positive opinions about the revisions made and the questions asked at the beginning of each lesson. Some of the responses related to the revisions and the refreshing question include:

HSt-1 (High Achiever): *''At the beginning, a revision took place. It was better to cover new topics after the revisions. I think it was useful. It enabled us to remember the topics we had learned before; it made me remember [the previous subjects].''*

MSt-5 (Medium Achiever): *''It was useful that the teacher reminded us about the old subjects. I think it is much better this way. Reviewing the old subjects surely helped us to learn the new ones.''*

LSt-11 (Low Achiever): *‘‘For me it was a general review. Because I forgot the subjects that I had learned last year, it helped me to review and it refreshes my memory.’’*

4.2.2 Worked Example Effect

The second interview question was about the worked example-problem pair lessons. During the treatment, each lesson, worked examples with a similar practice problem were used for teaching of the Algebra topics. Half of the students (50%) expressed in SQ that worked examples help them learn the topics. Participants that had high, medium, or low Mathematics achievement found worked examples superior to straight practice for learning Algebra topics. Some of the examples of their responses are as follows:

HSt-1 (High Achiever): *‘‘I look at the solution as I try to solve the problem. I complete anything that I missed or forgot during the solving process …’’*

MSt-8 (Medium Achiever): *‘‘Having worked examples were superb in terms of understanding the subject. Before, the solutions were erased after the solving process. But now, they are all before my eyes, I can see them all the time. It makes it better for me to follow.’’*

LSt-7 (Low Achiever): *‘‘It was good for us. Even if I do not understand [the question], I can still solve them by looking at the worked examples. This is very good for me. ’’*

4.2.3 Completion Example Effect

The third interview question was about the completion examples. In SQ, 62.5% of the students thought that completion examples helped them to learn the

Algebra topics. Participants of interview that had low Mathematics achievement found completion examples helpful for learning Algebra topics. In contrast, participants that had medium or high Mathematics achievement found completion examples redundant. This is because once a learner has acquired a basic schema for the skill or concepts, applying the schema to problems help them to learn best rather than investing redundant effort in studying more examples. According to their responses:

MSt-8 (Medium Achiever): *''I think the half solved problems were not that necessary. I wish they were fully solved or not solved at all. Because I think the exercises following the examples were enough. These [half solved] examples did not need to be there.''*

HSt-10 (High Achiever): *''The half solved problems were not useful for me because they were presented step by step. I did not apply [the step by step solutions] so much. I solved the questions practically. I passed immediately to the exercises after looking at the examples. I completed the half ones with the methods that I know.''*

Interviewees MSt-8 and HSt-10 stressed the expertise reversal principle of the CLT. According to this principle, once the learners have performed their own schemas for performing a task, they are better off solving problems based on those schemas. Having to study completion examples of a task they already know adds an unnecessary and sometimes conflicting repetition.

4.2.4 Classroom Materials (Students' Booklets and Algebra Tiles)

The fourth question in the interview schedule was ''what is your opinion about the Students' Booklets and Algebra Tiles used as classroom materials? Have they been beneficial for you?''. In SQ, the majority of the students expressed the positive option about the materials in terms of the help to learn topics well (77.5%) and enjoy using them (70%). In interviews, all of the participants had positive opinions about the Students' Booklets and Algebra Tiles used as classroom materials. Some of the responses provided about the classroom materials include:

HSt-2 (High Achiever): *''The student booklets were very nice. They were very useful for us. It was better than writing in notebooks. The subjects are better explained in the booklets. Algebra tiles were good too. I learned the iterations better by modeling.''*

MSt-6 (Medium Achiever): *''I used the algebra tiles. I like them actually, but some groups answer while we are still working on the problem. We were a little bit behind. The student booklets were very nice. The examples in the booklets were very nice too. I liked it and I learned better. In fact, I never liked mathematics before. Now I show my correct solutions to my friends.''*

Interviewee MSt-6 stressed the effect of the materials for developing positive opinion toward mathematics course.

LSt-4 (Low Achiever): *''Algebra tiles were fun. We did it together with my friend. The student booklets were very good in terms of following the lessons.''*

Interviewees focused on the fact that their attention is normally decremented because of taking notes in a lecture. Hence, the Students' Booklet helped them to decrease the note taking and concentrate on the lesson.

4.2.5 Focus on Attention and Avoid Split Attention and Modality Effect

The fifth question of the interview schedule was ‘‘while teaching the lessons, your teacher did not write anything on the board not to split your attention and conducted the lesson over the Students’ Booklets. Was this practice beneficial to understand the topics better? What were the some of the benefits? Can you give an example?’’. The question ‘‘verbal explanations during the lessons helped me to learn the topics’’ asked in SQ stressed the modality principle of the CLT. This principle states that complex topics can be understood more efficiently when explanatory words presented in an audio modality (Clark, et al., 2005). The majority of the students (75%) found verbal explanations helpful for learning Algebra topics. In the interview process, researcher focused on the modality effect of the CLT together with the split attention effect. Split attention effect refers to the ECL imposed when the learners need to integrate two or more dependent sources of information that are physically separated (Clark, et al., 2005). High achiever interviewees stressed that they were easily able to follow the lessons from the Students’ Booklets and using the board during the lessons was not necessary. Some of the responses of high achievers provided insights about the modality and split attention effect of CLT are as follows:

HSt-1 (High Achiever): *‘‘It was good because it saved me from writing. It is already written on the booklets. To write on the blackboard is unnecessary.’’*

HSt-10 (High Achiever): *‘‘For me, rewriting the questions that are already solved [in the booklets] on the blackboard is a waste of time.’’*

Further, medium and low achiever interviewees stressed that they were able to follow the lesson more easily when the teacher did not use the board. Some of the answers provided as follows:

MSt-5 (Medium Achiever): *‘‘It is difficult to both write down and follow the blackboard at the same time.…’’*

LSt-4 (Low Achiever): *‘‘I think it was good that the teacher stopped writing on the blackboard. I cannot write on the notebook and listen to the lecture at the same time.’’*

Interviewees MSt-5 and LSt-4 focused on the split attention effect from the note taking perspective. The cognitive effort required to take notes reduces mental capacity that could be devoted to processing the content and leading to learning.

4.2.6 Classroom Activities

The sixth question in the interview schedule was ‘‘classroom activities took place when you had gained experience in courses on the subject. What do you think about the effect of the activities implemented at the end of the lessons on your Algebra learning? Would the effect of classroom activities be different had they been conducted at the beginning of the lesson? Please explain.’’ This question was about content organization and the design of the learning environment. In the implementation of the treatment, the directive architecture of the instruction was used by the number of lessons that start with basic prerequisite knowledge and skills and build hieratically to more complex skills. Classroom activities sequenced after the explanation of skills. In other words, classroom activities were not the starting point of the lesson. In the SQ, there were three questions about the classroom activities. It can be concluded from the data gathered from SQ, The students had positive opinion about the classroom activities (Table 4.9). Some of the responses of high achievers of interviewees about the classroom activities include:

HSt-1 (High Achiever): ''I could not have done anything if she did it at the beginning. Not knowing beforehand also lowers one's morale. Learning first and then solving the problems is better for us. I was trying to do something about the subjects which I did not learn. So it was difficult.''

HSt-2 (High Achiever): *''Learning first and then doing it by yourself is much better. Explaining the subject first was good. If I tried the exercise first, I would not have understood the subject. I mean, I could not have learned it. I could not have done the exercises and I would have been upset.''*

HSt-3 (High Achiever): *''It was very good. If the exercise was done first, I would not have learned anything. Of course it affects my learning. It was very useful for me. I would not have learned if the activity was done before.''*

Interviewees HSt-1, HSt-2, and HSt-3 stressed the effect of classroom activities on motivation and morale, and mentioned the importance of gaining some skills about the topic before doing the classroom activities.

Medium and low achievers also stressed the importance of conducting classroom activities at the end after the explanations or demonstration of skills. Some of the responses of medium and low achievers about the classroom activities are as follows:

MSt-5 (Medium Achiever): *''Activities were very suitable. How can I say… It would have been bad before learning and understanding the subject. I am very happy with the timing.''*

MSt-6 (Medium Achiever): *''The teacher should teach the subject first and the activities come later. It is very good like that. It would be bad to have the* *activity first and then teach. I should learn the subject first and I should do the activities later on in order to improve my skills.''*

LSt-7 (Low Achiever): *''Doing the activities first is better. I think it would be worse if the activity comes first. I cannot do the activity if I don't know the subject. Teaching the subject first was good.''*

4.2.7 Group Works

The seventh question of the interview schedule was ''at the end of the Algebraic Operations and Equations topics, group works were conducted. Were the group works useful for you? How?''.

In SQ, there were three questions about the group works. The percentage of students for each question did not describe positive opinion about the group works (see Table 4.9). Interviewees mentioned that there were many students in their classroom and for this reason they did not feel comfortable when they study in group works. They stressed that their classroom did not provide an ideal environment for group works. Only one interviewee found group works beneficial. Some of the responses of interviewees about the group works are:

HSt-10 (High Achiever): *''I did not like the group studies. I already know the subject. I bring my exercise book and solve the problems in it.''*

MSt-5 (Medium Achiever): *''It is good to work in pairs. But working with four or five people is hard. Two people can be useful to each other. I did not like the crowded group study.''*

LSt-11 (Low Achiever): *''It was very noisy. Sometimes we talked about other things. It was not so good. It was exhausting.''*

The interviewee HSt-10 stressed the redundancy of the group works, which depended on the level of the learner expertise. Information, classroom activities, or group works that is necessary for novices may be redundant for the experts. This is related to the expertise reversal effect of the CLT. Further, interviewees MSt-5 and LSt-11 found the group works exhausting. On the contrary, one of the interviewees (MSt-9) who had medium mathematics achievement found the group works beneficial:

MSt-9 (Medium Achiever): *‘‘For example I did not know some subjects so well. My friend taught me. We shared our knowledge by working together. I offered a method, he did too, and it was useful. There was sharing.’’*

4.2.8 Efficiency of the Course designed by the Effects of CLT

The CLT is about efficiency (Clark, et al., 2005). Efficient instructional environments lead to faster learning, better learning, or both. Efficiency can also be measured by the time required for satisfying learning. The eighth question of the interview schedule deals with the efficiency of the treatment, considering its ability to facilitate easier, better, or faster (shorter-time) learning. The question was ‘‘when you consider all the issues, do you think that you learned the topics easier, better, or in a shorter time? Please explain’’. In SQ, the efficiency was considered in terms of the duration and the majority of the students (72.5%) thought that the teaching method helped them to learn topics in a shorter time. All participants of interviews thought that they learned the topics easier, better, or in a short time. Some of the responses of interviewees provided about the group works:

HSt-2 (High Achiever): *‘‘I put in a lot of effort last year because it was not [taught] like this. I actually still learned well, but it required a lot of effort.’’*

MSt-8 (Medium Achiever): *‘‘I learned better by this teaching method. I absolutely learned in a shorter time. For example, I would learned the equations in more than one hour, but now it is much shorter.’’*

LSt-7 (Low Achiever): *‘‘In this way, it was superb. It took me less time. I learned more easily.’’*

4.2.9 Disliked/Useless Implementations during the Treatment

The ninth question was ‘‘When you consider all the teaching method, was there any teaching practices that you dislike or useless? Please explain why did you find these practices useless or dislike?’’ In interview process, all students except one reported that they were satisfied with all of the treatment process. Only one of the participants (HSt-10) stressed that there were many worked examples in the Students’ Booklets and instead of these worked examples it would have been better to solve some practice problems. In the SQ, the responses of the participants were the same with the interview.

4.2.10 Evaluation of the Teaching Method

The tenth question was about the evaluation of the treatment which also asked in the SQ. The question was ‘‘when you compare the teaching techniques/methods that your teacher used previously with this teaching method, which was aspects of the used teaching method was better?’’. Interviewees found this teaching method better because some reasons. For example, they taught that use of worked examples for teaching each lesson and less notes-taking during the lesson hours helped them follow the lessons easily. Some of the responses provided for evaluation of the teaching method:

MSt-5 (Medium Achiever): *''Last year [in Mathematics topics] and in other courses, this teaching method was not used. It was a little bit difficult to understand and learn the topics. I kept moving on comfortably in this topic. I wish it continued like this. I understand more easily and move on [to other topics].''*

MSt-9 (Medium Achiever): *''For example, it is really good to be given exercises in the beginning. Let's say I missed something, I look it up in the booklet. Then I say, "oh that's how it is done." I mean, it is really good to teach the subjects by using examples and exercises.''*

LSt-4 (Low Achiever): *''When you take too many notes, it becomes difficult to understand the lesson. In the beginning of the semester, I used to write a lot. I could not understand the lessons well. Now, it is very nice to have to write less now.''*

4.2.11 Use of the Teaching Method Designed by CLT Principles in Other Mathematics Topics and Courses

The final question of the interview schedule was about the use of the teaching method in other mathematics topics and in other courses. This question was also asked in the SQ. The students had positive opinions toward the use of this teaching method in other mathematics topics (72.5%). Interviews implied that the reason to want to see this teaching method in other mathematics topics and courses, students could easily follow the lessons. Accordingly, their responses stressed the issue of cognitive overload. Some of the responses include:

HSt-1 (High Achiever): *''It is possible to [apply it] in other courses, such as science and technology. I think it would be useful in computational courses. It* *is not that necessary in verbal courses because they are not that difficult, you just read the material.''*

MSt-6 (Medium Achiever): *''It would be really nice to apply it in other mathematics topics, namely Natural Numbers and Geometry. Well, actually, we have already covered the Natural Numbers. For the other courses, it would be nice to have it, for example, in Science and Technology. I prefer this method in the hard courses.''*

Interviewees HSt-1 and MSt-6 stressed that for the courses which they think are difficult. Such as Science and Technology and English, the implementation of this teaching method would be helpful.

MSt-5 (Medium Achiever): *''It would be better to learn other mathematics topics by this method. I would also prefer it especially in the Turkish Language course. Because I get bored from taking notes, I find it difficult.''*

LSt-11 (Low Achiever): *''I also prefer it in Turkish Language course. Because we always take notes in that course I cannot follow the lesson.''*

Interviewees HSt-1 and MSt-6 stressed that note taking leads to cognitive overload. They mentioned that in courses like Turkish, taking notes is tedious and therefore, they would prefer this method.

4.3 Summary of the Results

The results obtained from the statistical analyses could be summarized as follows:

The independent t-test results showed that there was no significant mean difference on student's previous year mathematics scores between the control and the experimental group. This finding indicated that the students' previous year mathematics grades were similar in both experimental and control groups.

The descriptive statistics related to the student's AAT and SRS for each of the experimental and control groups revealed that in terms of the AAT scores, the students in the experimental group had higher scores than the students in the control group. In terms of the SRS scores, the experimental group students had lower scores than the control group students. This result indicating the efficiency of the instructional method used in experimental group: higher achievement with less cognitive load.

MANOVA result indicated that instructional method affected the 7^{th} grade students' achievement on AAT test and cognitive load. It was found that there was a significant difference in the means of experimental and control groups when they were compared simultaneously on two dependent variables, Algebra achievement and cognitive load.

In terms of the efficiency of the courses, the efficiency value of the experimental group was in the second quadrant of the Cartesian Coordinate Plane above the line E=0. On the other hand, the efficiency value of the control group was in the fourth quadrant of the Cartesian Coordinate Plane below the line E=0. The results of the Independent samples t-test indicated that there was a significant difference between the efficiency scores of students who were exposed to instruction designed by CLT principles and to instruction recommended by MONE.

The findings related to the questionnaire and structured interviews could be summarized as follows:

Interview results indicated that all of the participants had positive opinions about the revisions made and the questions asked at the beginning of each lesson.

During the treatment, each lesson, worked examples with a similar practice problem were used for teaching of the Algebra topics. Half of the students (50%) expressed in SQ that worked examples help them to learn the topics. Interview participants that had high, medium, or low Mathematics achievement found worked examples superior to straight practice for learning Algebra topics.

In SQ, 62.5% of the students thought that completion examples helped them learn the Algebra topics. Participants of the interviews that had low Mathematics achievement found completion examples helpful for learning Algebra topics. In contrast, participants that had medium or high Mathematics achievement found worked examples redundant.

In SQ, the majority of the students expressed positive option about the materials in terms of help to learn topics well (77.5%) and enjoy using them (70%). In interviews, all of the participants had positive opinions about the Students' Booklets and Algebra Tiles used as classroom materials.

The question ‘‘verbal explanations during the lessons helped me to learn the topics’’ asked in SQ stressed the modality principle of the CLT. The majority of the students (75%) found verbal explanations helpful for learning Algebra topics. In the interview process, researcher focused on the modality effect of the CLT together with the split attention effect. Interviewees stressed that they were easily able to follow the lessons from the Students' Booklets and using the board during the lessons was not necessary.

The data gathered from SQ indicated that students had positive opinion about the classroom activities (Table 4.9). This result was supported by the interviews. However, the percentages of students for group work questions were not described positive opinion in the SQ (see Table 4.9). Interviewees mentioned that there were many students in their classroom and for this reason they did not feel comfortable when they study in groups. They stressed that their classroom did not provide an ideal environment for group works.

In SQ, the majority of the students (72.5%) thought that the teaching method helped them to learn topics in a shorter period. All interview participants thought that they learned the topics easier, better, or in a short time. In interview process, all students except one reported that they were satisfied with all of the treatment process. Only one of the participants (HSt-10) stressed that there were many worked examples in the Students' Booklets and instead of these worked examples it would have been better to solve some practice problems. Interviewees found this teaching method better because, they taught that the use of worked examples for teaching each lesson and less notes-taking during the lesson hours helped them follow the lessons easily.

The students had positive opinions toward the use of this teaching method in other mathematics topics (72.5%). Interviews implied that the reason to want to see this teaching method in other mathematics topics and courses is that they thought that they could easily follow the lessons. Hence, results of quantitative data analysis were supported by the results of the qualitative data analysis.

CHAPTER V

DISCUSSIONS

This chapter consists of discussions of the findings obtained from data analysis and recommendations for practice and future research. The results are restated and discussed in some detail in the first part; recommendations for practice and future research are given in the second part.

5.1 Discussions

The purpose of the study was to investigate the effect of an instruction designed by the CLT principles on 7^{th} grade students' achievement in Algebra topics and cognitive load.

More specifically, the study had three objectives. The first objective was to determine whether the treatment had an effect on students' Algebra achievement and cognitive load. The second one was to find out the efficiency of the instruction in terms of the students' achievement and cognitive load measures. Finally, the third objective was to reveal the perceptions of the students who were exposed to the instruction designed by the CLT principles about the treatment.

In the following sections, the conclusions drawn from the experiment results are discussed in conjunction with the related literature.

5.1.1 Students' Performance on Tests

The results presented in the previous chapter indicate that the students in experimental group performed relatively well in AAT (Algebra Achievement Test) compared to the control group. The mean score of the experimental group was 41.18 and the mean score of the control group was 14.88 (out of 80). The results of the SRS (Subjective Rating Scale) indicated that the students in the experimental group had lower SRS scores than those in the control group. The mean SRS scores of the experimental and the control groups were 3.58 and 5.05 (out of 9), respectively.

These results are consistent with the studies which claim that an instruction is efficient if the learning results in such a way as to maximize learning and minimize the amount of cognitive load required (Paas & Van Merrienboer, 1994; Paas, 1992; Tuovinen & Sweller, 1999).

Although the mean AAT score of the experimental group was much higher than the control group, the mean scores of AAT for both groups were actually low. One of the reasons for these low achievement scores may be the deficiencies of the students' prior knowledge. The results presented in Table 4.1 in the previous chapter indicated that the means of student's previous year mathematics scores for the experimental group (M=2.55) and control groups (M=2.98) were not very high. According to the NCTM (2000) Principles and Standards, the importance of the prior knowledge was stressed as ‘‘students learn mathematics by connecting new ideas to prior knowledge... Teachers should reveal students' prior knowledge and design experiences and lessons that respond to, and build on, prior knowledge’’ (p.18). Tatar and Dikici (2008) reported that one of the reasons of students' disabilities in the mathematics is the deficiencies of their prior knowledge. Therefore, it can be concluded that students' prior knowledge both in experimental and control groups effected their achievement in the AAT.

Another reason would be the socio-economic background of the students. As described in the Method section, the school that the study conducted was located in a poor socioeconomic neighborhood. Research has consistently shown that socioeconomic status have a negative influence on students' achievement (Coleman, 1966; Engin-Demir, 2009; Heyneman & Loxley, 1983; Savaş, Selma, & Adem, 2010; Tansel & Bircan, 2004). More specifically, TIMMS 98-99 data (Yayan, 2003) indicated that socioeconomic status is positively related to mathematics achievement in Turkey. Ersoy and Erbaş (1998) conducted a study to assess the Algebra achievement level of the 7th grade students in Turkey. They found that Algebra teaching was very problematic in the poor socio-economic neighborhood. In other words, students in poor socio-economic neighborhood had lower achievement scores in Algebra topics compared to the medium or high socio-economic neighborhood.

The other reason would be the school characteristics. The physical conditions of the school that the study was conducted were quite poor in terms of school facilities and class size. Previous research indicated that school characteristics in terms of school facilities and class size had significant effect on the academic achievement of students (Engin-Demir, 2009; Fuchs & Woessmann, 2007).

As discussed previously, the mean AAT score of the experimental group was much higher than the control group. This result indicates the success of the CLT in poor socioeconomic neighborhood. Therefore, it can be concluded that the instruction designed by the principles and effects of the CLT is successful for teaching Algebra topics in poor socio-economic neighborhood. Further, SRS scores of the students in experimental group was much lower than the SRS scores of the students in control group indicating the efficiency of the instruction designed by the principles and effects of the CLT in poor socio-economic neighborhood.

5.1.2 The Effect of the Instruction Designed by the CLT Principles on Students' Algebra Achievement and Cognitive Load

One of the research questions of this study was to find out if there was a significant impact of the instruction designed by the CLT principles on 7^{th} grade students' Algebra achievement and cognitive load.

The results of the MANOVA showed that there was a significant effect. The effect size (.65) claims the practical significance of this result. It was indicated that scores of students on AAT and SRS significantly differ according to the instruction and 65 percent of multivariate variance of the AAT and SRS scores were associated with the group factor. In other words, 65 percentages of the variation of the AAT and SRS scores was explained by the instruction developed by CLT principles.

Similar results concerning the significant effect of the CLT principles had been found in several studies before (Atkinson et al., 2003; Brunstein et al., 2009; P. Chandler & Sweller, 1992; Kalyuga, Chandler, & Sweller, 2001; Kalyuga & Sweller, 2004; Mousavi et al., 1995; Paas, 1992; Paas & Van Merrienboer, 1994; Sweller & Cooper, 1985; Tarmizi & Sweller, 1988; Zhu & Simon, 1987).

The results of the MANOVA suggested that the instruction developed by the CLT principles can be used in Algebra courses to increase achievement and decrease the cognitive load.

5.1.3 Efficiency Scores of Experimental and Control Groups

The other research question of this study was to find out if there was a significant difference between the efficiency scores of students who were exposed to instruction designed by CLT principles and to instruction recommended by MONE.

To answer this research question, the mean of the AAT z-scores, SRS z-scores, and the efficiency values for both the experimental and the control groups were calculated and put in the efficiency formula. The mean of AAT z-scores (-0.45), SRS z-scores (0.77), and efficiency value (0.86) indicate that the efficiency value of the experimental group was in the second quadrant of the Cartesian Coordinate Plane, above the line E=0. As discussed before, the sign of the efficiency scores determines the efficiency; as low or high, therefore, the efficiency score of the experimental group indicated high efficiency. On the other hand, the mean of AAT z-scores (0.45), SRS z-scores (-0.77), and efficiency value (-0.86) indicate that the efficiency value of the control group was in the fourth quadrant of the Cartesian Coordinate Plane, below the line E=0. The efficiency score of the control group indicated low efficiency.

The results of the Independent samples t-test, $t(78)=10.339$, $p<0.05$, indicated that there was a significant difference between the efficiency scores of students who were exposed to the instruction designed by the CLT principles and those expose to the instruction recommended by MONE.

This result is consistent with the previous results that claimed that an instruction designed by the CLT are more efficient than the instructions designed by other instructional techniques (Gerven et al., 2003; Kalyuga, Chandler, & Sweller, 2001; Van Gerven, et al., 2002; Van Merriënboer, et al., 2002).

As discussed in Chapter 2, previous studies include the CLT principles were adapted to multimedia learning in Turkey, although, the results are still being considered for their calculation of efficiency. The results of these studies conducted by Kılıç (2006), Kablan and Erden (2008), and Sezgin (2009) indicated that the instructions prepared by the CLT principles had significantly high efficiency.

5.1.4 Results of the Students' Perceptions about the Treatment

5.1.4.1 Revisions about Prerequisite Learning at the Beginning of Each Lesson

All of the students in the experimental group had positive opinions about the revisions made and the questions asked at the beginning of each lesson. Majority of the students expressed that these revisions and questions refreshed their memory and helped to understand the topics better.

According to the CLT, the first step in instructional design is to research and define the backgrounds of the learners (Clark et al., 2005). The classrooms usually include a mixture of novice and experienced learners. Clark at al. (2005) suggested that for mixed classrooms a pre-work is to be assigned to equilibrate prior knowledge of the class at beginning. Another suggestion is, along with prerequisites, for instructional designers to organize the lesson into introductory or advanced sections. These methods increase the efficiency of the instructional environments (Clark et al., 2005) and can lead to schema automation (Sweller et al., 2011a). The answers of the students interviewed for this study are therefore consistent with the literature.

5.1.4.2 Worked Example Effect

The participants that had high, medium, or low Mathematics achievement found worked examples superior to straight practice for learning Algebra topics. Worked examples have proven effectiveness: examples to replace practice and get equivalent learning results in less time and less learner effort (Paas, 1992; Paas & Van Merrienboer, 1994; Sweller & Cooper, 1985).

As described by Clark et al. (2005), when studying worked examples, limited WM capacity can be devoted to building a schema of how to perform the task. Having a worked example to study just prior to solving a similar problem provides the learner with an analogy to be used while solving the problem. When solving a problem without the benefit of an analogous example, most WM capacity is used up in figuring out the best solution approach with, little memory remaining for building a schema.

5.1.4.3 Completion Examples Effect

According to the results of SQ and the interviews, the students thought that completion examples helped them to learn the Algebra topics. The interviewees that had low Mathematics achievement found completion examples helpful for learning Algebra topics. Like worked examples, completion examples also reduce cognitive load because schemas can be acquired by studying the worked portions. As described before, a completion example offers a psychological balance. It reduces cognitive load by incorporating some worked examples and it fosters deep processing requiring completion of the remaining elements (Clark et al., 2005).

In contrast, participants that had medium or high Mathematics achievement found completion examples redundant. As describe by Clark et al. (2005) this is because once a learner has acquired a basic schema for the skill or concepts, applying the schema to problems help them to learn best rather than investing redundant effort in studying more examples.

Kalyuga and her colleagues (2001) demonstrated that worked examples and completion examples resulted more efficient learning during initial stages of learning. As the learners gain experience, all problem lessons become more efficient. Therefore, differing levels of learner experience should be taken into account when designing instruction using worked examples, completion examples, and problems.

5.1.4.4 Classroom Materials (Students' Booklets and Algebra Tiles)

In the SQ, the majority of the students expressed positive opinion about the materials helping them to learn topics well (77.5%) and enjoying to using them (70%). In the individual interviews, all of the participants had positive opinions about the Students' Booklets and Algebra Tiles that were used as classroom materials.

Interviewees focused on the fact that their attention is normally decremented because of taking notes in a lecture. During the treatment process, the ''Students' Booklet'' helped the students reduce the note-taking and concentrate on the lesson. As considered previously, Clark et al. (Clark et al., 2005) described that split attention caused by taking notes might reduce learning. The cognitive effort required to take notes reduces cognitive capacity that could be devoted to processing the content in ways that lead to learning. They recommended that the limited WM resources be utilized in more productive ways, such as written content summaries and small booklets, than taking notes from a lecture (Sweller et al., 1990).

5.1.4.5 Focus on Attention and Avoid Split Attention and Modality Effect

The question ‘‘verbal explanations during the lessons helped me to learn the topics’’ asked in the SQ stressed the modality principle of the CLT. Further, the researcher focused on the modality effect of the CLT together with the split attention effect in the interviews. The interviewees stressed that they were able to follow the lessons from the Students’ Booklets easily and hence using the board during the lessons was not necessary.

Similarly, previous research suggests that reducing or eliminating the split attention effect may have extensive applications (P Chandler & Sweller, 1991; P. Chandler & Sweller, 1992, 1996; Tarmizi & Sweller, 1988) and the negative consequences of split-attention might be avoided by presenting statements in an auditory form, rather than in a visual form (Mousavi, et al., 1995).

5.1.4.6 Classroom Activities

As discussed before, in the implementation process of the treatment, the directive architecture of the instruction was used by the number of lessons that start with basic prerequisite knowledge and skills; and they were building hieratically to more complex skills. The classroom activities were sequenced after the explanation of the skills. In other words, classroom activities were not the starting point of the lesson. The students stressed the positive role of classroom activities on motivation and morale, and mentioned the importance of gaining some skills about the topic before doing the classroom activities, a finding that is consistent with the literature.

The related literature suggests that for most novice learners the result of a whole task course will be cognitive overload. The whole task course designs are suited only for learners with considerable relevant prior experience, because these learners are likely to have already learned many of the required components (Van Merrienboer et al., 2003; Van Merriënboer, 1997).

5.1.4.7 Group Works

The interviewees mentioned that there were many students in their classroom and they did not feel comfortable studying in group works. They stressed that their classroom did not provide an ideal environment for group works. Further, interviews stressed the redundancy of the group works, which depended on the level of the learner expertise.

As previous research shows, information, classroom activities, or group works that is necessary for novices may be redundant for the experts (Brunstein et al., 2009; Kalyuga, Chandler, & Sweller, 2001).

5.1.4.8 Efficiency of the Course designed by the Effects of CLT

The quantitative analysis of the data indicated that the instruction designed by the CLT principles has an effect on students' Algebra achievement and cognitive load. Further, the instruction was efficient (efficiency score was 0.86) in terms of performance and cognitive load. These results were supported by the qualitative results. All of the participants during the interviews stressed that they learned the topics easier, better, or in a shorter time.

5.1.4.9 Disliked/Useless Implementations during the Treatment

All but one student reported that they were satisfied with all of the treatment process. Only one of the participants indicated that there were many worked examples in the Students' Booklets and instead of these worked examples it would have been better to solve some practice problems.

As discussed previously, once a learner has acquired a basic schema for the skill or concepts, applying the schema to problems help them to learn best rather than investing redundant effort in studying more examples (Clark et al., 2005; Kalyuga, Chandler, & Sweller, 2001).

5.1.4.10 Evaluation of Teaching Method

The interviewees found the experimented method better due to several reasons. For example, they taught that the use of worked examples in lesson and the need for less note-taking helped them follow the lessons more easily. Similarly, these results are supported by the related literature (Atkinson et al., 2003; Paas, 1992; Paas & Van Merrienboer, 1994; Sweller & Cooper, 1985).

5.1.4.11 Use of the Teaching Method Designed by CLT Principles in Other Mathematics Topics and Courses

The students in the experimental group want to see this teaching method in other mathematics topics and courses. The reason for this preference was because they could easily follow the lessons. Accordingly, their responses stressed the issue of cognitive overload. According to Clark et al. (2005) the goal of the training is to minimize wasteful forms of cognitive load and maximize the useful forms.

5.2 Recommendations

In this section, recommendations for practice and further research are considered based on the results of the study.

5.2.1 Recommendations for Practice

The results of this study show that there was an effect of the instruction designed by CLT principles on students’ achievement in Algebra topics and cognitive load. Further, the efficiency value of the instruction indicates high efficiency. Therefore, the principles and CLT effects that were used in this study can be recommended to practitioners to design effective instructional environments. Recommendations for practice are as follows:

1. The first and most important implication of an instruction designed by the CLT principles is that effective instructional environments depend on the human cognitive architecture system. Therefore, the characteristics and the principles of this system should be known well by the designers for effective instructional environments.

2. How the knowledge is presented to the learners and in which activities they engage depends on the characteristics of the WM, because the WM first processes information before it can be stored in the LTM. The major characteristic of the WM is its limitation, both in terms of duration and capacity. The aim of an instruction should be to ensure that the learners’ WM is not overloaded. Therefore, the limitations of the WM should be well known and the instruction should be designed according to these limitations.

3. The ICL is dependent on element interactivity; the number of elements that need to be processed simultaneously by the learner. If element interactivity is high, learning becomes more difficult and WM-resource intensive, whereas for low element interactivity material, learning is easier and, requires fewer WM resources. Hence, the content with a high complexity level, one should reduce the ICL by using worked examples, completion examples, and other recommended CLT effects depending on the specific learning objectives.

4. To manage the WM load and to facilitate LTM, the ECL (caused by poorly designed instructional procedures that interfere with schema acquisition) should be eliminated. The CLT effects, such as worked example effect, split attention effect, and modality, should be understood well in order to manage this load.

5. Studying worked examples has been identified by the CLT as an effective method of reducing the ECL. The learner can devote all the available WM capacity to studying a worked-out solution and constructing a schema to solve similar problems in LTM.

6. Worked example-problem pair instruction used in this study help to decrease the ECL of the learners. This type of lessons alternated worked examples with a similar practice problem can be used in different instructional contexts.

7. The guidance fading effect of the CLT can be used especially for the novice learners who are most susceptible to cognitive overload.

8. Instructional designers can use guidelines for instructional methods that work best with low knowledge learners and with high knowledge learners.

Instructional designers should avoid ECL when the learners are novice. As the learners develop expertise, the instructional techniques should be adjusted accordingly.

9. The cognitive effort required to take notes reduces cognitive capacity. Therefore, small content summaries or other supplementary materials can be provided for the learners.

10. The teachers can be trained or educated about the basic principles of the CLT in order to utilize the limited capabilities of the learners' WM.

11. The curricula developed by MONE can be updated by considering the principles of the CLT principles to promote learning while reducing cognitive load.

5.2.2 Recommendations for Further Research

Based on the findings of this study, recommendations for future research are the following:

1. This study was conducted with 7^{th} grade students (*N=80*) attending a public primary school in Kağıthane, İstanbul. Further studies can use the tools developed by this research to replicate a similar experiment by using a larger sample for generalization purposes.

2. Whether the findings of this study hold in other grade levels, other mathematics topics or other courses is an open question, which needs to be answered by further research in this area.

3. Since a random assignment was not possible for the sampling procedure; quasi experimental research design was used for this study. The groups can be assigned randomly in the future research studies.

4. Whereas this study was conducted in a public school with students from poor socio-economic backgrounds, it can be replicated in other socio-economic background setting to determine its efficiency.

5. Further research studies can consider additional variables such as attitude and retention.

6. The 9-scaled Subjective Rating Scale (SRS) was used to measure student's cognitive load. Further research can use physiological measures such as heart rate, heart rate variability, brain activity, and eye activity.

7. In this study, the different effects of the CLT were considered collectively in the research design. Further research can construct experimental designs that consider these effects separately.

8. To calculate the efficiency, the performance and cognitive load measures were used in this study. Further research may include the time as an indicator of efficiency together with performance or cognitive load.

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APPENDIX A

SAMPLE STUDENTS' BOOKLET

Üslü Nicelikler
Öğrenci Kitapçığı

Sevgili Öğrenciler;

Bu kitapçıkta Üslü Nicelikler ile ilgili olarak gerekli olan ön öğrenmelere, örneklere ve alıştırmalara yer verilmiştir.

Kitapçığın sonunda verilecek olan *Bilişsel Yük Anketini,* lütfen cevaplandırınız. ☺

<u>**Üslü Nicelikler-1**</u>

Dersin Ön Öğrenmeleri

Üslü Nicelik

Bir sayının kendisi ile tekrarlı çarpımına denir.

$$a^n = \underbrace{a \cdot a \cdot a \dots\dots \cdot a}_{n \text{ tane}} = b$$

Bu tekrarlı çarpımın sonucunu bulmaya ‘kuvvet alma’ denir.

Örneğin;

$3^3 = 3 \cdot 3 \cdot 3 = 27$

Üs/Kuvvet

↑

$a^n = b$

↓ ↓

Taban Değer

Önemli Bilgiler

1. $a^0 = 1$ Bir sayının sıfırıncı kuvveti birdir (0 hariç).

Örnek: $2^0 = 1$

2. Bir sayının birinci kuvvetti kendisidir.

Örnek: $4^1 = 4$

3. Birin tüm kuvvetleri kendisine eşittir.

1. $(1)^2 = 1.1 = 1$

Alıştırma:

$(1)^{1000} =?$

2. $(10)^2 = 10.10 = 100$

Alıştırma:

$(10)^3 =?$

3. $(2)^2 = 2.2 = 4$

Alıştırma:

$(2)^4 =?$

4. $(-3)^2 = -3.-3 = 9$

Alıştırma:

$(-5)^2 =?$

5. $-(7)^2 = -(7.7) = -49$

Alıştırma:

$-(4)^3 = ?$

6. Aşağıda verilen çarpımları üslü nicelik olarak yazalım.

a. $5.5.5 = 5^3$

Alıştırma: $3.3.3.3 = ?$

b. $\underbrace{10.10 \ldots\ldots.10}_{11 \text{ tane}} = 10^{11}$

Alıştırma: $\underbrace{12.12 \ldots\ldots.12}_{8 \text{ tane}} =$

c. ***Alıştırma:*** $(-3).(-3).(-3) = ?$

d. $(-2).(-2).5.5.5 = (-2)^2.5^3$

Alıştırma: $3.3.3.(-6).(-6) = ?$

Üslü Nicelikler-2

1. Aşağıda verilen çarpımları üslü nicelik olarak yazalım.

a. $a.a.b.b.b = a^2.b^3$

Alıştırma:

$\mathbf{n.n.n.k.k.k.k} = ?$

b. $(-k).(-k).m.(-n).(-n) = (-[k)]^2.m^1.([-n)]^2$

Alıştırma:

$-a.-a.-a.b.b.c.c.c.c = ?$

2. Aşağıda verilen üslü sayıları çarpım şeklinde yazalım.

a. $(-[9)]^2 = -9.-9$

Alıştırma: $-([5)]^3 = ?$

$([-2)]^2 = (-2^2)$ eşitliğinin doğruluğunu tartışınız.

$$([-2)]^2 = (-2).(-2) = 4$$
$$(-2^2) = -2.2 = -4$$

Bu eşitlik doğru değildir. $([-2)]^2$; (-2)'nin karesi alınıyor. Çift bir kuvvet alındığı için (-), (+)'ya dönüşüyor. (-2^2) de ise sadece 2'nin karesi alınıyor.

Örnek:

$([-2)]^3 = (-2^3)$ eşitliğinin doğruluğunu tartışınız.

$$([-2)]^3 = -2.-2.-2 = -8$$
$$(-2^3) = -2.2.2 = -8$$

$([-2)]^3$ **ve** (-2^3) eşittir. Çünkü

………………………………………………………………………………

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Alıştırma:

$([-3))^4 = (-3^4)$ eşitliğinin doğruluğunu tartışınız.

……………………………………………………………………………………

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3. $([-4))^4$, $\mathbf{10^2}$, $([-3))^{11}$ sayılarını büyükten küçüğe doğru sıralayınız.

$([-4))^4 = -4.-4.-4.-4$

$\mathbf{10^2 = 10.10}$

$([-3))^{11} = \underbrace{-3.-3.-3 \ldots\ldots.-3}_{11 \text{ tane}}$

$([-4))^4 > 10^2 > ([-3))^{11}$

Alıştırma:

$(\llbracket -7)\rrbracket^{9}$, $(5)^{3}$, $(\llbracket 10)\rrbracket^{3}$ sayılarını küçükten büyüğe doğru sıralayınız.

4. $(\llbracket -3)\rrbracket^{2} + (\llbracket 2)\rrbracket^{4} = ?$

Çözüm:

$(\llbracket -3)\rrbracket^{2} = -3.-3 = 9$

$(\llbracket 2)\rrbracket^{4} = 2.2.2.2 = 16$

$9 + 16 = 25$

Alıştırma:

$2^{3} + (-2^{3}) = ?$

Alıştırma:

$-10^{2} + (\llbracket -7)\rrbracket^{2} + 3.100^{0} = ?$

Alıştırma:

$m = -2$ için $m^3 - 2m^2 + m = ?$

Alıştırma:

$a = -3$ ve $b = -5$ için $a^3 - b^2 = ?$

Üslü Nicelikler-3

1. Aşağıda verilen üslü ifadelerin değerlerini bulunuz.

a. $4^3 =$
b. $-2^5 =$
c. $(-[3)]^3 =$
d. $[-(-10]^3) =$

2. Aşağıda verilen çarpımları üslü olarak yazınız.

a. $-2.-2.-2 =$
b. $-3.3.3.3 =$
c. $-6.-6.3.3.3 =$
d. $-5.-5.4.4.4.-2.-2.-2.-2 =$

3. a. $n = -1$ için $n^3 - 2n^2 + n =?$

b. $k = 2$ için $2k^3 - 3k^2 + 5 =?$

c. $x = -2$ ve $y = 3$ için $x^3 - 2y^2 - x.y =?$

4. Aşağıdaki işlemleri yaparak ifadelerin sonuçlarını bulunuz.

a. $10^2 - 2.3^3 + 5^2 = ?$

b. $-(-4)^3 - 3.2^3 - (-8)^2 = ?$

5. $1000^0, 12^2, 10^2, 11^1$ sayılarını küçükten büyüğe doğru sıralayınız.

BİLİŞSEL YÜK ANKETİ

Üslü Nicelikler ile ilgili olarak

Verilen alıştırmaları tamamlarken ne kadar çaba saffettiniz?								
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 B

SAMPLE TEACHERS' BOOKLET

Üslü Nicelikler
Öğretmen Kılavuz Kitapçığı

Bu kitapçık, *Üslü Niceliklerle* ile ilgili olarak

- *Açıklamalar*
- *Süre*
- *Ön Öğrenmeler*
- *Kazanımlar*
- *Materyal*
- *Dersin İşlenişi Bölümlerinden* oluşmaktadır.

Üslü Nicelikler Öğrenci Kitapçığı da ekte verilmiştir.

Açıklamalar:

Aşağıda, Bilişsel Yük Kuramının, 'çalışılmış örnekler', 'bölünmüş dikkat', 'gereksizlik' ve 'biçem' etkilerine göre hazırlanmış bir öğrenci kitapçığı bulunmaktadır. Bu etkilerin açıklamaları, 'Bilişsel Yük Kuramı İlkeleri ve Etkileri' adlı kitapçıkta bulunmaktadır. Bilişsel Yük Kuramına göre, bilgiyi mümkün olduğunca basit parçalara ayırma, öğrenciden mümkün olduğunca birden fazla şeyi aynı anda anlamasını beklememe, küçük parçalar veya işlem dizeleri halinde konuyu sunma ve işlemi çözme beklenmektedir. Konunun bütününde bu ilkeler dikkate alınmalıdır.

Kitapçık, Üslü Nicelikler konusunu içermektedir. Kitapçık, toplam üç ders saatinde işlenecektir. Dersler, Üslü Nicelikler-1, Üslü Nicelikler-2 ve Üslü Nicelikler-3 şeklinde ayrılmıştır.

Süre: 3 ders saati

Ön Öğrenmeler:

1. Tamsayılar
2. Tamsayılarda İşlemler

Kazanım:

Tam sayıların kendileri ile tekrarlı çarpımını üslü nicelik olarak ifade eder.

Materyal: Üslü Nicelikler Öğrenci Kitapçığı

Dersin İşlenişi:

Dersin başında öğrencilere 6. Sınıfta öğrendikleri Üslü Nicelikler konusunda hatırladıkları sorulur. Öğrencilerden tanımlama yapma, örnekle gösterme gibi beceriler beklenebilir. Öğretmen, öğrencilere 6.sınıfta öğrendikleri Üslü İfadeleri 7.sınıfta Tamsayılar için kullanacaklarını söyleyebilir. Bu kısa girişin ardından *Üslü Nicelikler Öğrenci Kitapçığı* dağıtılır. Derse kitapçığın *Üslü Nicelikler-1* bölümünün girişinde anlatılan üslü nicelik, üs, kuvvet ve değer gibi kavramların tekrarı ile başlanır ve dersin başında öğrencilerin belirttiği tanımlarla örtüştürülür. Önemli bilgiler bölümünde bir sayının sıfırıncı kuvveti ve birinci kuvveti ile ilgili bilgiler bulunmaktadır. Dersin ilk bölümü bu ön öğrenmelere ayrılır. Daha sonra bu bölümdeki örnekler incelenir. Dikkati bölmemek için tahtaya herhangi bir şey yazılmaz (bölünmüş dikkat). Ders tamamen çalışılmış örnekler üzerinden işlenip; hemen ardından bir benzeri alıştırma olarak öğrencilere çözdürülür. Bu şekilde öğrencilerin şema oluşumuna katkı sağlayacağı düşünülmüştür. Alıştırmalar çözülürken öğrencilerin çözme süresi ve yanıtlarının doğruluğuna dikkat edilir.

İkinci dersin başında öğrencilerden kitapçığın *Üslü Nicelikler-2* bölümünü açmaları istenir. Dersin başında bir önceki derste yapılanlar hakkında sözel olarak hatırlatma yapılıp; bu derste ilk olarak harflerle verilen çarpımların üslü nicelik olarak yazılacağı söylenir. Bu bölümde ilk örneklerde harfler kullanılarak daha kavramsal öğrenmeler oluşturulmaya çalışılmıştır. Üslü Niceliklerin sıralanması ile ilgili örneklerde hesaplama yapmadan sıralama yapıldığı vurgulanmalıdır. Örneklerde bulunan sayıların kuvvetlerine göre oluşabilecek durumlar çok iyi açıklanmalıdır. Alıştırmada da aynı şey beklenmelidir. Ayrıca tamsayıların özelliklerinin kullanılması ile ilgili örnekler ve alıştırmalara yer verilmiştir. Üslü nicelikler içeren işlem örnek ve alıştırmalara da yer verilmiştir.

Bilişsel Yük Kuramına göre öğrenciler konu hakkında deneyim kazandıklarında; örneklere devam etmek öğrenciler üzerinde gereksiz yüke sebep olmakta ve öğrenmeyi olumsuz yönde etkilemektedir. Bu sebeple üçüncü ders öğrencilerin deneyim kazandıkları düşünülerek tamamen alıştırmalara ayrılmıştır. *Üslü Nicelikler-3'*de alıştırmalar öğrenciler tarafından çözülür. Bunun için öğrencilere gerekli zaman tanınır. Daha sonra yanıtların doğruluğu kontrol edilir. Gözlem yapılarak destek isteyen öğrencilere yardımcı olunur.

Kitapçığın bitiminde dağıtılacak olan Bilişsel Yük Anketi, öğrenciler tarafından doldurulacaktır.

Öğrencilere dağıtılacak olan kitapçık ekte verilmiştir.

APPENDIX C

EXPERT OPINION FORM-1

Uzman Değerlendirme Formu

Sayın …

‘Bilişsel Yük Teoremi Etkilerine Göre Hazırlanmış Bir Dersin Öğrencilerin Cebir Başarısına ve Bilişsel Yüklenmelerine Etkisi’ adlı doktora tezimde 7. Sınıf düzeyinde Cebir Öğrenme Alanında kullanılmak üzere

- Öğretmen Kılavuz Kitapçıkları ve
- Öğrenci Kitapçıkları geliştirilmiştir.

Sizden, bu materyalleri

- Bilişsel Yük Kuramı (İlke ve Etkileri),
- Materyallerin açıklığı
- Anlaşılırlığı ve
- Sınıf düzeyine uygunluğu

bakımından incelemenizi ve değerlendirmelerinizi beklemekteyim.

Sınıf içi materyaller hakkında verilen ifadeler için aşağıdaki yönergeyi kullanınız.

Uygunluk	Açıklama
1	Hiç uygun olmadığını ve tamamen değiştirilmesi gerektiğini düşünüyorsanız bu seçeneği işaretleyiniz. Belirtmek istediğiniz düşüncenizi ve önerinizi ‘Açıklama’ sütununa yazınız.
2	Genel olarak uygun olduğunu ancak bazı değişiklikler yapılarak daha uygun hale geleceğini düşünüyorsanız bu seçeneği işaretleyiniz. Önerdiğiniz düzeltmeleri lütfen ‘Açıklama’ sütununa yazınız.
3	Tamamen uygun olduğunu düşünüyorsanız bu seçeneği işaretleyiniz.

Bilişsel Yük Kuramı, İlkeleri ve Etkileri hakkında bir açıklama metni, öğretmen ve öğrenci kitapçıkları ve uzman değerlendirme ölçeği ekte verilmiştir.

Değerli vaktinizi ayırdığınız ve katkıda bulunduğunuz için teşekkürlerimi ve saygılarımı sunarım.

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Program Geliştirme ve Öğrettim Anabilim Dalı
Doktora Öğrencisi

EK-1: Bilişsel Yük Kuramı ve Etkileri
EK-2: Öğretmen ve Öğrenci Kitapçıkları
EK-3: Uzman Değerlendirme Ölçeği

Bilişsel Yük Kuramı, İlkeleri ve Etkileri

Bilgi işleme süreçlerinde, insanların sınırlı çalışma belleği ve sınırlı olmayan uzun süreli belleklerinin olduğu varsayılır. Miller'e (1956) göre sınırsız uzun süreli belleğe karşın, çalışan bellek organize etme, yapılandırma, karşılaştırma ya da kayıt etme işlemleri esnasında bilgiyi hafızada tutma açısından bir anda en fazla yedi parça ya da öğeyle ilgilenebilmektedir. Miller'in (1956) bu prensibi, sayısız deneysel çalışmalar ile genişletilmiş ve Bilişsel Yük Kuramı (BYK) olarak yeniden tanımlanmıştır (Clark, et al., 2005).

BYK'nın merkezinde, öğretimi tasarlarken çalışan belleğin yapısının ve sınırlılıklarının göz önünde bulundurulması ve çalışan bellek kapasitesinin en verimli şekilde kullanılması görüşü yer almaktadır (F Paas, et al., 2003). BYK, görsel ve işitsel bilgilerin kısmen bağımsız olduğu kısa süreli bellek ile uzun süreli belleğin etkileşimine bağlı olan bir bilişsel mimariye dayanır (Kirschner, 2002).

BYK, konu dışı yükün azaltılarak mevcut bilişsel kaynakların etkili olarak kullanımını sağlayan öğretim yöntemlerinin üzerinde durmaktadır (P Chandler & Sweller, 1991; J. van Merriënboer & Sweller, 2005). Temelde, ortaya çıkan karmaşık bilişsel görevlerin öğrenilmesi ile ilgilenmekte ve bilişsel süreçler üzerinde durmaktadır (Paas, et al., 2004).

BYK, öğrenenin bilişsel süreçlerinin bir sonucu olarak verimliliği kanıtlanmış öğretim ortamlarını oluşturan evrensel öğrenme ilkeleridir (Clark, et al., 2005).

1. BYK, tüm öğretim tasarlayıcılarının kullanabileceği oldukça detaylı ilkeler içerir.
2. Yapılmış olan deneysel çalışmaların ürünüdür. Kanıta dayanır.
3. Etkin öğrenme ortamları sağlar. Etkin öğrenme ortamları, daha iyi öğrenme, daha hızlı öğrenme veya daha iyi ve hızlı öğrenme ortamları anlamına gelmektedir.

4. BYK'na göre hazırlanmış öğrenme ortamları, bilişsel çabaları en aza indirerek bu bilişsel çabaları öğrenmeyi üst düzeye çıkaracak şekilde düzenlemektedir.

Özetlersek, BYK, çalışan belleğin sınırlı kapasiteye sahip olduğu ve aşırı yüklenilirse öğrenmenin olumsuz yönde etkileneceğini savunmaktadır.

Bilişsel Yük Kavramı

Bilişsel yük kavramı, belirli bir öğrenme işinin öğrencinin bilişsel sistemi üzerinde oluşturduğu baskı şeklinde çok boyutlu bir yapı olarak tanımlanabilir (Sweller, et al., 1998). Ayrıca, belli bir zaman diliminde çalışma belleği tarafından kullanılan kaynakları ifade etmektedir.

Bilişsel yük kuramında, öğretim materyallerinin öğreneni üç bağımsız bilişsel yük kaynağıyla etkilediği öne sürülmektedir ((Paas, et al., 2004; F Paas, et al., 2003; Sweller, et al., 1998): asıl yük (intrinsic load), konu dışı yük (extraneous load/ineffective load) ve etkili yük (germane load/effective load).

Asıl yük, konu dışı yük ve etki yük, öğreneni etkileyen toplam çalışan bellek kapasitesini etkilemektedir. Bu nedenle bu üç bilişsel yükün toplamı çalışan bellek kapasitesini aşmamalıdır (F Paas, et al., 2003).

Asıl yük, öğrenilmesi gereken içerikle ilgilidir. Öğrenilmesi zor olan içeriğe bağlı olarak çalışma belleğinde yüklenmenin olmasıdır. Bu yük öğretim tasarımcısının kontrolü dışındadır.

Asıl yük, eş zamanlı olarak çalışan bellekte işlenen öğelerin sayısına ve bunların birbirleriyle olan etkileşimlerine bağlı olarak değişmektedir (element interactivity). Örneğin, matematik dersinde problem çözmesi gereken bir öğrenci problemin öğelerini birlikte ve eş zamanlı işe koşmalıdır. Başka bir deyişle problemle ilgili öğeleri anlayabilmek için tüm öğeleri eş zamanlı bellekte tutmalıdır.

Konu dışı bilişsel yük, iyi tasarlanmamış öğretim materyalleri ve iyi olmayan öğretim tasarımı sonucunda çalışma belleğinin yüklenmesidir (J. van

Merriënboer & Sweller, 2005). Konu dışı bilişsel yük her zaman öğretimi tasarlayan kişinin kontrolündedir (Clark, et al., 2005). Yani tasarlanan öğrenme ortamı, uygun olmayan bilgileri ya da bilgi işleme sürecini olumsuz yönde etkileyen diğer materyalleri içeriyorsa konu dışı yük yüksek olacaktır (J. van Merriënboer & Sweller, 2005). Öğretimi taslarlarken amaç çalışan bellekteki yükün uygun düzeyde tutulmasıdır.

Etkili yük ise zihinsel yapıların oluşması ve düzenlenmesini sağlayan süreçlerde ortaya çıkar (Clark, et al., 2005). Etkili bilişsel yük, şema oluşumuna yardımcı olan ve öğrenme sürecini destekleyen yüktür. Öğrenene sunulan içeriğin türü ve öğrenme etkinlikleri etkili bilişsel yükün düzeyini belirlemede etkili faktörlerdir. Bununla konu dışı yük öğrenmeyi engelleyebilirken, etkili yük öğrenmeyi arttırabilmektedir.

Bilişsel Yükün Dengesi

Bilişsel yük üç ana bileşene bağlıdır. Bu bileşenler içerik, ön öğrenmeler ve öğrenme ortamlarıdır. Asıl yük, konu dışı yük ve etkili yükün toplamı çalışma belleğinin kapasitesini aşmamalıdır (Clark, et al., 2005; F Paas, et al., 2003). Bu üç tür yükün, çalışma belleğinin kapasitesini aşmaması için öğretim tasarımcıları, konu dışı yükü azaltmak gerektiğini vurgulamaktadır.

Konu dışı yük, asıl yük yüksek olduğunda bu iki tür yükün birbirinin üzerine eklenmesi oldukça önem taşımaktadır. Asıl yük düşük olduğunda konu dışı yükün düzeyi, bu iki yükün toplamı çalışma belleğinin kapasitesini aşmayacağından, daha az önem taşımaktadır (Lorch & Lorch, 1996; Marcus, et al., 1996). Dolayısıyla öğretim tasarımcıları, öğrenilecek olan içeriğin zor olması durumunda bilişsel yükü azaltmak için daha çok çaba harcamak durumundadırlar.

Konu dışı yükün azaltılması, etkili yük için daha fazla yer kalmasını ve zihinsel yapıların oluşturulabilmesi için daha fazla çaba harcanabilmesini sağlamaktadır. Zihinsel yapıların oluşması ise asıl yükün azalmasını sağlayacaktır. Asıl yük, konu dışı yük ve etkili yükün hepsi birbirinin üzerine eklendiğinde toplamın çalışma belleğinin kapasitesini aşmaması gerekir (Clark, et al., 2005; Kirschner, 2002).

Konu dışı yükün, öğretim tasarımının etkili şekilde yapılandırılması ile azaltılması, çalışma belleğindeki boşluğun etkili yüke ayrılmasını sağlar; böylece zihinsel yapılar daha rahatlıkla oluşabilir. Zihinsel yapıların oluşması ile bir sonraki aşamada asıl yük azalacaktır. Bu nedenle öğretim tasarımı sürecinde konu dışı yükün azaltılmasına yönelik öğretim teknikleri geliştirilmeye çalışılmaktadır (Ebru Kılıç, 2006).

Bilişsel Yük ve Öğretimin Verimliliği

BYK verimlilik ile ilgili bir kuramdır. Bu verimlilik iki değişkenle tanımlanmaktadır: *öğrenenin performansı* ve *bilişsel yükü* (Clark, et al., 2005). BYK'ya göre az zihinsel çaba ile yüksek öğrenme sağlayan ortamlar etkili öğrenme ortamları olarak tanımlanmaktadır. Performans, öğretimin sonunda uygulanan bir test ile ölçülürken; yük ölçümü farklı teknikler ile yapılabilmektedir. Görev-Performans Temelli Ölçümler bireyin kendi bilişsel süreçlerini dikkate alarak, bir öğrenme etkinliğini yürütürken ne kadar çaba harcadığını bildirmesiyle yapılmaktadır. Paas ve Van Merriënboer (1993) tarafından geliştirilmiş olan 9'lu derecelendirme ölçeği (Subjective Rating Scale) en sık kullanılan yük ölçme aracıdır.

Öğretimin verimliliği, performans testi ve bilişsel yük anketlerinde bulunan puanların iki boyutlu grafiğe aktarılması ile hesaplanır. Eğer performans testi sonuçları bilişsel yükten büyükse *öğretim etkindir* denir.

Bilişsel Yük Kuramının Uygulanmasında Kullanılan Etkiler

Konu dışı yükün azaltılması için yapılan araştırmalarda, bazı tasarım ilkeleri geliştirilmiştir. Bu ilkeler;

1. Çalışılmış örnekler (Worked Examples Effect),
2. Yarı Çözümlü Örnekler (Completion Example Effect),
3. Bölünmüş dikkat (Split Attention),
4. Gereksizlik (Redundancy Effect) ve
5. Biçem etkisi (Modality Effect) dir.

Asıl yükün sabit olduğu varsayılan durumlarda, konu dışı yükün azaltılmasında kullanılan bu ilkeler etkili yükün artması ile sonuçlanmaktadır (Paas, et al., 2004).

BYK'ya göre şema oluşumu ve otomasyon öğrenmenin en temel fonksiyonlarıdır. Bilgiler uzun süreli bellekte şemalar şeklinde saklanmaktadır. Şemalar bir bilgiyi organize etmek için kullanılan temel çerçeve niteliğindeki yapılardır (Sezgin, 2009). Şemaların görevlerinden biri, bilginin düzenlenmesi ve depolanması için bir işleyiş sağlamasıdır. Bir başka görevi ise çalışan belleğin yükünü azaltmaktır (Sweller, et al., 1998). Otomasyon şema oluşumunda önemli bir süreçtir. Bütün bilgiler hem bilinçli olarak hem de otomatik olarak işlenmektedirler. Bunun sonucu olarak da çalışan bellek yükü minimum olmaktadır.

$\frac{c(a+d)}{f} = g$ şeklinde verilen bir denklemin a için çözülmesi istendiğinde, öğrencinin konuyla ilgili şeması onun problemi otomatik olarak çözmesine ve böylece işlem için çalışan belleğin yükünün azalmasına neden olur. Ancak bu tür problemlerin çözümünü yeni öğrenen öğrenciler farklı biçimlerde çözmeye çalışabilirler. Çünkü şemaları henüz otomatikleşmemiştir. Öğrenciler problemi bilinçli olarak ve de daha fazla çalışan bellek kapasitesi kullanarak çözmeye çalışacaklardır (Cooper & Sweller, 1987).

Çalışılmış örnekler etkisi, çözülmüş örneklerin alıştırmaların yerine kullanılması ile ilgili bir etkidir. Öğrenenlerin dikkati soru çözmekten çok problemin kendisine ve çözüm aşamalarına yönlendirilmelidir. Sweller ve arkadaşlarına göre (1987), çok fazla alıştırmanın çözülmesi öğrenme için etkisiz bir yöntemdir. Matematik öğretiminde genellikle takip edilen yöntem gerekli olan bilginin öğrencilere sunulması, az sayıda örneğin çözülmesi ve çok sayıda alıştırmanın öğrenciler tarafından çözülmesidir. Sweller ve Cooper' a (1985) göre öğrencilerin konu hakkında bilgi düzeylerine göre örnekler kullanılmalı ve şema oluşumu tamamlandıktan sonra alıştırmalara geçilmelidir. Yarı çözümlü örneklerde de, BYK'ya göre öğrencilerin dikkatini problem cümlesine ve çözüm adımlarına vermesini sağlamaktadır. Yarı çözümlü örnekler, çalışılmış örneklerden alıştırmalara özellikle zor konularda yumuşak bir geçiş sağlamaktadır (Clark, et al., 2005).

Bölünmüş dikkat etkisi, öğrencilerin, aynı algı kanalına hitap eden farklı bilgilerin sunulması ile dikkatlerinin bölünmesine bağlı olarak, konu dışı yükün artacağını vurgulamakta ve bundan kaçınılması gerektiği üzerinde durmaktadır. Bölünmüş Dikkat etkisinde öğrenme için birbiri ile bütünleşmiş kaynağa ihtiyaç duyulurken, bu bilgiler birbirinden ayrı örneğin metin ve grafik şeklinde sunulduğunda öğrenme süreci etkili olmamaktadır. Bu şekilde bölünmüş kaynaklarla sunulan bilgi bilişsel yükün artmasına neden olmaktadır (P Chandler & Sweller, 1991).

Biçem etkisi, yazılı veya görsel kanala hitap eden bir takım şekillere dayanan bilginin aktarımında bilgi akışı yazılı anlatımdan sözlü anlatıma kaydırılması ile ilgilidir. Yapılan araştırmalara göre bilginin yazılı olarak değil de işitsel kanala hitap edilerek anlatılması öğrenmeyi artırmaktadır (Clark, et al., 2005).

Gereksizlik ilkesi, aynı bilgiyi hem yazılı hem de sözlü olarak sunmanın gereksiz olduğunu belirtmektedir. İlginç ancak öğrenmeye katkısı olmayan bir takım materyallerin öğretimden çıkartılması gerekliliği üzerinde durmaktadır (Clark, et al., 2005). BYK, öğretimde az çoktur minimalist yaklaşımını önermekte ve her zaman ilginç bilgi, resim veya şema gibi materyallerin öğrenmeye ve bilişsel motivasyona katkısı olmayacağını belirtmektedir.

Özetlersek, çalışılmış örnekler, yarı çözümlü örnekler ve bölünmüş dikkat etkisi, konu dışı yükü azaltarak zihinsel yapıların oluşmasını sağlayan ilkelerdir. Biçem etkisi ve gereksizlik etkisi bilginin işlenmesi için mevcut kapasiteyi en iyi şekilde kullanmayı sağlayan ilkelerdir.

Öğretmen ve Öğrenci Kitapçıkları Uzman Değerlendirmesi

Uygunluk Derecesi / Sınıf İçi Materyal	1	2	3	Açıklama
1. Üslü Sayılar konusunda hazırlanan öğretmen kılavuzu içeriği				
2. Üslü Sayılar konusunda hazırlanan ön öğrenmeler bölümü				
3. Üslü Sayılar konusunda hazırlanan örnekler				
4. Üslü Sayılar konusunda hazırlanan alıştırmalar				
5. Üslü Sayılar konusuna ayrılan ders saati süresi				
6. Cebirsel İfadelerle Toplama, Çıkarma ve Çarpma konusunda hazırlanan öğretmen kılavuzu içeriği				
7. Cebirsel İfadelerle Toplama, Çıkarma ve Çarpma konusunda hazırlanan örnekler				
8. Cebirsel İfadelerle Toplama, Çıkarma ve Çarpma konusunda hazırlanan alıştırmalar				
9. Cebirsel İfadelerle Toplama, Çıkarma ve Çarpma konusunda hazırlanan etkinlikler				
10. Cebirsel İfadelerle Toplama, Çıkarma ve Çarpma konusuna ayrılan ders saati süresi				
11. Sayı Örüntüleri konusunda hazırlanan öğretmen kılavuzu içeriği				
12. Sayı Örüntüleri konusunda hazırlanan örnekler				
13. Sayı Örüntüleri konusunda hazırlanan alıştırmalar				
14. Sayı Örüntüleri konusunda ayrılan ders saati süresi				
15. Denklemler konusunda hazırlanan öğretmen kılavuzu içeriği				
16. Denklemler konusunda				

hazırlanan örnekler				
17. Denklemler konusunda hazırlanan alıştırmalar				
18. Denklemler konusunda hazırlanan etkinlikler				
19. Denklemler konusunda ayrılan ders saati süresi				
20. Kartezyen Koordinat Sistemi konusunda hazırlanan öğretmen kılavuzu içeriği				
21. Kartezyen Koordinat Sistemi konusunda hazırlanan konu anlatımı				
22. Kartezyen Koordinat Sistemi konusunda hazırlanan örnekler				
23. Kartezyen Koordinat Sistemi konusunda hazırlanan alıştırmalar				
24. Kartezyen Koordinat Sistemi konusuna ayrılan ders saati süresi				
25. Denklemlerin Grafikleri konusunda hazırlanan öğretmen kılavuzu içeriği				
26. Denklemlerin Grafikleri konusunda hazırlanan konu anlatımı				
27. Denklemlerin Grafikleri konusunda hazırlanan örnekler				
28. Denklemlerin Grafikleri konusunda hazırlanan alıştırmalar				
29. Denklemlerin Grafikleri konusuna ayrılan ders saati süresi				

Eklemek istediğiniz başka görüş veya önerilerinizi varsa lütfen buraya yazınız.

APPENDIX D

SAMPLE ITEMS OF
ALGEBRA ACHIVEMENT TEST

Matematik Dersi

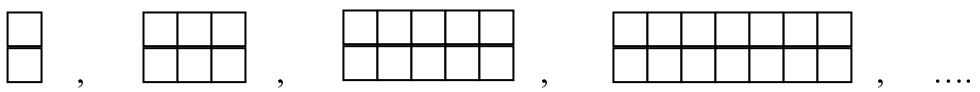
Cebir Öğrenme Alanı

Başarı Testi

1. Aşağıda verilen işleminin sonucunu her bir adımı göstererek bulunuz.

n= -1 ve k= -2 ise $2n^3 - 2k^2 + nk = ?$

2. Aşağıda küçük karelerle oluşturulmuş şekil örüntüsü için



a. Örüntüyü sayı örüntüsüne dönüştürüp genel terimini yazınız.

b. Örüntünün 40. adımdaki kare sayısını hesaplayıp, yazınız.

c. Yukarıdaki örüntünün, küçük kareleri oluşturan çubuklar ile oluşturulduğunu kabul ederek şekil örüntüsünü sayı örüntüsüne dönüştürüp genel terimini yazınız.

d. Örüntünün 40. adımdaki *çubuk sayısını* hesaplayıp, yazınız.

3. Aşağıda verilen denklemlerde $\mathbf{x}$ aynıdır. Buna göre Δ değerini, işlemlerinizi basamak basamak yazarak bulunuz.

$$-3x - 4 = 2 \quad \text{ve} \quad \mathbf{6x} + \Delta = \mathbf{1}$$

4. Aşağıda verilen eşitliğinin doğru olması için … yerine hangi <u>cebirsel ifade</u> gelmelidir? (İşlemlerinizi basamak basamak gösteriniz)

$$-2(x+1) = \blacktriangle \ldots + 4$$

5. Kartezyen Koordinat Sisteminde, (a,b) noktasında bulunan bir araç üç birim sağa, iki birim yukarı hareket ederek (-2a,3b) noktasına varmıştır. Buna göre <u>(a,b) noktasının koordinatlarını</u> bulunuz.

APPENDIX E

RUBRIC

Soru No	0	1	2	3	4
1	●Hiçbir şey yazmamıştır. ●Soruyu aynen yazıp, çözüm yapmamıştır. ●n ve k değerlerini verilen ifadede doğru yerleştirmemiştir.	●n ve k değerlerini verilen ifadede doğru yerleştirmiş ancak başka işlem yapmamıştır. ●n ve k değerlerini verilen ifadede doğru yerleştirip en az bir tanesinin kuvvetini doğru hesaplamıştır. ●Hiçbir işlem yapmadan sonuç bulmuştur.	●n ve k değerlerini denklemde yerleştirmiş ve kuvvetlerini doğru hesaplamış ancak katsayıları ile çarparken yanlışlıklar yapmıştır.	●n ve k değerlerini denklemde yerleştirip kuvvetlerini doğru hesaplamış; katsayılar ile çarpma işlemlerini bitirip toplama veya çıkarmada hata yapmıştır veya işlemi tamamlamamıştır.	●n ve k değerlerini denkleme yerleştirmiş; kuvvetlerini doğru bir şekilde hesaplamış; gereken işlemleri doğru bir şekilde yapmış ve doğru sonuca ulaşmıştır.
2	●Hiçbir şey yazmamıştır. ●Tüm ifadelere yanlış karar vermiştir.	● Bir veya iki maddenin doğru ve yanlış olduğuna doğru karar verip yanlış olan maddelerin en fazla birini açıklamıştır.	● Üç maddenin doğru veya yanlış olduğuna doğru karar verip yanlış olan maddelerin en fazla birini açıklamıştır.	● Hepsinin doğru veya yanlış olduğunu doğru bir şekilde belirtip yanlış olanların en fazla birini açıklamıştır.	●Tüm maddelerin doğru veya yanlış olduğuna doğru karar vermiş ve yanlış olanların ikisini de açıklamıştır.
3 (a) (b)	●Hiçbir şey yazmamıştır. ●Örüntünün kuralını ve 6.adımdaki sayıyı yanlış bulmuştur.	●a şıkkını cevaplamadan b şıkkının sonucunu yazmıştır (hiçbir işlem yapmadan veya yanlış kural yazarak 6.adımdaki sayıyı yazmıştır).	●a şıkkını doğru cevaplamış ancak b şıkkının sonucunu yanlış hesaplamıştır veya hiç hesaplamamıştır (örüntünün kuralını doğru bulup 6.adımdaki sayıyı hesaplamamıştır).	●a şıkkını doğru hesaplamış ancak b şıkkının cevabını bulurken hata yapmıştır (örüntünün kuralını doğru bulup, 6. adımdaki sayıyı hesaplarken hata yapmıştır).	●a ve b şıklarını doğru cevaplamıştır (örüntünün kuralını doğru bulup, 6. adımdaki sayıyı doğru hesaplamıştır).

4 (a) (b)	●Hiç bir şey yazmamıştır.	● a şıkkını cevaplamadan b şıkkının sonucunu yazmıştır (hiçbir işlem yapmadan 40.adımdaki kare sayısını yazmıştır). ●a şıkkında örüntüyü sayı örüntüsüne yanlış çevirmiş ve genel terimi yanlış bulmuştur.	●a şıkkında örüntüyü sayı örüntüsüne doğru çevirmiş ancak örüntünün genel terimini yanlış yazmış veya hiç yazmamış; b şıkkının sonucunu da yanlış bulmuştur veya istenilen yöntemle bulmamıştır.	● a şıkkını doğru bulmuş ancak b şıkkının cevabını bulurken hata yapmıştır (şekil örüntüsünü sayı örüntüsüne çevirip, örüntünün genel terimini doğru bulmuş ancak 40.adımdaki kare sayısını yanlış hesaplamıştır).	● a ve b şıklarını doğru cevaplamıştır (şekil örüntüsünü sayı örüntüsüne çevirip, örüntünün kuralını doğru bulup; 40.adımdaki kare sayısını doğru hesaplamıştır).
4 (c) (d)	●Hiç bir şey yazmamıştır.	●c şıkkını cevaplamadan d şıkkının cevabını yazmıştır (hiçbir işlem yapmadan 40.adımdaki çubuk sayısını yazmıştır). ●c şıkkında örüntüyü sayı örüntüsüne yanlış çevirmiş ve genel terimi yanlış bulmuştur.	●c şıkkında örüntüyü sayı örüntüsüne doğru çevirmiş ancak örüntünün genel terimini yanlış yazmış veya hiç yazmamış; d şıkkının sonucunu da yanlış bulmuştur veya istenilen yöntemle bulmamıştır.	●c şıkkını doğru bulmuş ancak d şıkkında hata yapmıştır (şekil örüntüsünü sayı örüntüsüne çevirip, örüntünün kuralını doğru bulmuş ancak 40.adımdaki çubuk sayısını yanlış hesaplamıştır).	●a şıkkındaki şekil örüntüsünü sayı örüntüsüne çevirip, örüntünün kuralını doğru bulup 40.adımdaki çubuk sayısını doğru hesaplamıştır.
5	●Hiçbir şey yazmamıştır. ●Soruyu aynen yazıp, çözüm yapmamıştır. ●Tamamen yanlış sonuç bulmuştur.	●Hiç işlem yapmadan sonuç bulmuştur. ●Parantezi yanlış açıp devamındaki işlemleri de yanlış yapmıştır.	●Parantezi doğru açıp devam etmemiştir.	●Parantezi doğru açıp benzer terimleri bir araya getirirken hata yapmıştır.	●Parantezi açıp benzer terimleri bir araya getirmiş ve sonucu doğru olarak bulmuştur.
6	●Hiçbir şey yazmamıştır. ●Soruyu aynen yazıp, çözüm yapmamıştır.	●Hiç işlem yapmadan sonuç bulmuştur. ●Parantezleri yanlış açıp devamındaki işlemleri de yanlış yapmıştır.	●Parantezleri doğru açıp devam etmemiştir veya yanlış devam etmiştir.	●Parantezleri doğru açıp benzer terimleri bir araya getirirken hata yapmıştır.	●Parantezleri açıp benzer terimleri bir araya getirmiş ve sonucu doğru olarak bulmuştur.
7	●Hiçbir şey yazmamıştır. ●Modeldeki işlemi tamamen yanlış yazmıştır.	●Modeldeki işlemin çarpma olduğunu fark etmiş ancak her iki çarpanı da yanlış	●Modeldeki işlemin çarpma olduğunu fark etmiş ancak işlemi iki çarpan şeklinde	●Modeldeki işlemin çarpma olduğunu fark etmiş ve çarpanlardan birinin	●Modeldeki işlemin çarpma olduğunu fark etmiş ve her iki çarpanın cebirsel

		yazmıştır.	değil modelden okuduğu şekilde yazmıştır.	cebirsel ifadesini doğru yazmıştır.	ifadesini doğru yazmıştır.
8	●Çözümü yazmamıştır. ●Soruyu aynen yazıp, çözüm yapmamıştır.	●Birinci denklemde x'i yanlış bulmuş; sonucu ikinci denklemde yerleştirip Δ 'i yanlış bulmuştur. ●Hiç işlem yapmadan Δ 'ni bulmuştur.	●Birinci denklemde x'i doğru bulup; ikinci denklemde yerine yerleştirmeyip Δ 'i bulamamıştır.	●Birinci denklemde x'i doğru bulup; ikinci denklemde yerine yerleştirmiş ancak Δ bulurken işlem hatası yapmıştır.	●Birinci denklemde x'i doğru bulup; ikinci denklemde yerine yerleştirip Δ doğru bulmuştur.
9	●Çözümü yazmamıştır. ●Tamamen yanlış bir çevre formülü yazmıştır.	●Hiç işlem yapmadan sonuç bulmuştur. ●Dikdörtgenin çevre formülüne göre cebirsel ifadeleri yazmış ancak daha sonraki hiçbir işlemi yapmamıştır.	●Dikdörtgenin çevre formülüne göre kenar uzunluklarının cebirsel ifade toplamlarını doğru yazıp denklemi çözerken hata yapmıştır.	●Dikdörtgenin çevre formülüne göre kenar uzunluklarının cebirsel ifade toplamlarını doğru yazıp, benzer terimleri bir araya getirirmiş, oluşan denklemi çözmüş ancak uzun kenarı bulmamıştır.	●Dikdörtgenin çevre formülüne göre kenar uzunluklarının cebirsel ifade toplamlarını doğru yazıp, benzer terimleri bir araya getirirmiş, oluşan denklemi çözmüş ve uzun kenarın uzunluğunu bulmuştur.
10	●Çözümü yapmamıştır. ●Soruyu aynen yazıp, çözüm yapmamıştır.	●Hiç işlem yapmadan sonuç bulmuştur. ●Her iki tarafı iki ile çarpmadan işlem yapmaya çalışmış ve yanlış çözmüştür.	●Her iki tarafı iki ile çapıp oluşan yeni denklemi doğru bir şekilde yazamamıştır.	●Her iki tarafı iki ile çapıp oluşan yeni denklemi doğru bir şekilde yazmış ancak devam etmemiş veya çözerken hata yapmıştır.	●Her iki tarafı iki ile çapıp oluşan yeni denklemi doğru bir şekilde yazmış ve çözmüştür.
11	●Çözümü yapmamıştır. ●Soruyu aynen yazıp, çözüm yapmamıştır. ●Yapılan işlemlerin hiçbiri doğru değildir.	●Hiç işlem yapmadan sonuç bulmuştur. ●Dağılma özelliğini kullanıp parantezi yanlış açmıştır.	●Dağılma özelliğini kullanıp parantezi doğru açmış daha sonra devam etmemiş veya cebirsel ifadeyi belirten … yalnız bırakmaya çalışmamıştır.	●Dağılma özelliğini kullanıp parantezi açıp oluşan yeni denklemde cebirsel ifadeyi belirten … yalnız bırakmaya çalışmış ancak sonucu hatalı bulmuştur.	●Dağılma özelliğini kullanıp parantezi açıp oluşan yeni denklemi çözüp cebirsel ifadeyi doğru bir şekilde bulmuştur.

12	●Hiç bir şey yazmamıştır. ●Tamamen yanlış sonuç bulmuştur.	●Gereken basamakları yazmadan denklemi yazmıştır.	●Denklemi yazma basamakları doğru ancak adımlarda hatalar yapmıştır.	●Denklemi yazma basamakları doğru ancak son halini hatalı yazmış veya yazmamıştır.	●Denklemi yazma basamaklarını ve son halini doğru bir şekilde yazmıştır.
13	●Hiç bir şey yazmamıştır.	●Bu denklem ile çözülemeyecek bir problem yazmıştır.	●Yazılan problemin bir kısmını verilen denkleme göre doğru yazmıştır.	●Problem temelde doğru ancak eksiklikler vardır.	●Yazılan problem verilen denklem ile çözülebilecek bir problemdir.
14	●Hiç bir şey yazmamıştır.	●Problemi çözmen için gereken denklemi yanlış yazmıştır.	●Denklemi doğru kurmuş ama çözümü için gereken ikinci adımı yanlış yazmıştır.	●Denklemi doğru kurmuş ancak tamamını çözmüş özellikle ikinci adımı belirtmemiştir.	●Denklemi doğru kurmuş ve çözümü için gerekli olan ikinci adımı yazmıştır.
15	●Hiç bir şey yazmamıştır.	●Üç birim sağa, iki birim yukarı hareket ederek gelinen yeni koordinatları yanlış yazmıştır.	● Üç birim sağa, iki birim yukarı hareket ederek gelinen yeni koordinatları doğru bulmuş ancak (-2a,3b) noktası ile eşitlememiştir.	●Üç birim sağa, iki birim yukarı hareket ederek gelinen yeni koordinatları doğru yazmış ancak (-2a,3b) noktası ile eşitleyip çözerken hata yapmıştır.	●Üç birim sağa, iki birim yukarı hareket ederek gelinen yeni koordinatları doğru yazmış (-2a,3b) noktası ile doğru bir şekilde eşitleyip çözmüştür.
16	●Hiç bir şey yazmamıştır. ●İlişkiyi doğru belirtmemiştir. ●İlişkiyi doğru belirtmemiş ve denklemini yanlış yazmıştır.	●İlişkiyi doğrusallık olarak değil başka ifadeler kullanarak ifade etmiş denklemini eksik yazmış veya hiç yazmamıştır.	●İlişkiyi doğru belirtmiş denklemini yazmamıştır. ●Denklemini yazmış ancak ilişkiyi belirtmemiştir.	●İlişkiyi doğru belirtmiş ancak denklemini yazarken hata yapmıştır.	●İlişkiyi doğru belirtip denklemini doğru yazmıştır.
17 (a)	●Hiç bir şey yazmamıştır. ●x'i kestiği noktayı bulmak için y yerine o yazması gerektiğini bilmiyor.	●x eksenini kestiği noktayı bulmak için denklemde y yerine 0 yazmış ancak denklemi çözüp x'i bulmamıştır.	● x eksenini kestiği noktayı bulmak için denklemde y yerine 0 yazmış ancak denklemi hatalı çözüp x'i farklı bulmuştur.	● x eksenini kestiği noktayı bulmak için denklemde y yerine 0 yazıp denklemi çözüp x'i bulmuş ancak noktayı yazmamış veya hatalı yazmıştır.	● x eksenini kestiği noktayı bulmak için denklemde y yerine 0 yazıp denklemi çözüp x'i bulmuş ve noktayı doğru bir şekilde yazmıştır.

17 (b)	●Hiç bir şey yazmamıştır. ●y'yi kestiği noktayı bulmak için x yerine o yazması gerektiğini bilmiyor.	●y eksenini kestiği noktayı bulmak için denklemde x yerine 0 yazmış ancak denklemi çözüp y'i bulmamıştır.	● y eksenini kestiği noktayı bulmak için denklemde x yerine 0 yazmış ancak denklemi hatalı çözüp y'yi farklı bulmuştur.	● y eksenini kestiği noktayı bulmak için denklemde x yerine 0 yazıp denklemi çözüp y'yi bulmuş ancak noktayı yazmamış veya hatalı yazmıştır.	● y eksenini kestiği noktayı bulmak için denklemde x yerine 0 yazıp denklemi çözüp y'yi bulmuş ve noktayı doğru bir şekilde yazmıştır.
17 (c)	●Hiç bir şey yazmamıştır.	●a veya b şıklarında noktaları yanlış bulduğu için grafiği yanlıştır.	●x ve y y eksenlerini kestiği noktaları grafik üzerinde yanlış yerleştirmiştir ve yanlış bir grafik çizmiştir.	●x ve y eksenlerini kestiği noktaları grafik üzerinde doğru yerleştirip grafik çiziminde hata yapmıştır.	●x ve y eksenlerini kestiği noktaları grafik üzerinde doğru yerleştirmiş ve grafiği doğru bir şekilde çizmiştir.

APPENDIX F

EXPERT OPINION FORM-2

Sayın …

'Bilişsel Yük Teoremi İlkelerine Göre Hazırlanmış Bir Dersin, Öğrencilerin Cebir Başarılarına ve Bilişsel Yüklenmelerine Etkisi' adlı doktora tezimde 7. Sınıf öğrencilerine, Cebir Öğrenme Alanının bitiminde verilmek üzere bir başarı testi hazırlanmıştır. Bu başarı testini ve değerlendirme ölçeğini

- Konulara uygunluğu;
- Kazanımlara uygunluğu;
- Sınıf Düzeyine Uygunluğu;
- Anlaşılırlığı ve
- Genel görünümü açısından incelemenizi ve değerlendirmelerinizi beklemekteyim.

Başarı testi ve dereceli değerlendirme ölçeği hakkında verilen ifadeler için aşağıdaki yönergeyi kullanınız.

Uygunluk	Açıklama
1	Hiç uygun olmadığını ve tamamen değiştirilmesi gerektiğini düşünüyorsanız bu seçeneği işaretleyiniz. Belirtmek istediğiniz düşüncenizi ve önerinizi 'Açıklama' sütununa yazınız.
2	Genel olarak uygun olduğunu ancak bazı değişiklikler yapılarak daha uygun hale geleceğini düşünüyorsanız bu seçeneği işaretleyiniz. Önerdiğiniz düzeltmeleri lütfen 'Açıklama' sütununa yazınız.
3	Tamamen uygun olduğunu düşünüyorsanız bu seçeneği işaretleyiniz.

Cebir Öğrenme Alanında bulunan konular, kazanımları ve programa göre süreleri (sınıf içi materyaller hazırlanırken bu sürelerde değişiklikler yapılmıştır) uygulama, başarı testi ve başarı testi uzman değerlendirme ölçeği, dereceli puanlama anahtarı ve dereceli puanlama anahtarı uzman değerlendirme ölçeği ekte verilmiştir.

Değerli vaktinizi ayırdığınız ve katkıda bulunduğunuz için teşekkürlerimi ve saygılarımı sunarım.

EK-1: Cebir Öğrenme Alanı Konuları, Kazanım Listesi ve Süreleri
EK-2: Başarı Testi ve Uzman Değerlendirme Formu
EK-3: Dereceli Puanlama Anahtarı ve Uzman Değerlendirme Formu

Aygil TAKIR
ODTU Eğitim Fakültesi
Eğitim Bilimleri Bölümü
Program Geliştirme ve Öğretim Anabilim Dalı
Doktora Öğrencisi

Başarı Testi Uzman Değerlendirme Formu

Soru Numarası	1	2	3	Açıklama
1				
2				
3				
4 a				
4 b				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17 a				
17 b				
17 c				

Başarı Testi Dereceli Puanlama Anahtarı Uzman Değerlendirilmesi

Soru Numarası	1	2	3	Açıklama
1				
2				
3				
4 a				
4 b				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17 a				
17 b				
17 c				

APPENDIX G

SUBJECTIVE RATING SCALE-ENGLISH

How easy or difficult did you find the…?

Extremely easy	Very easy	Easy	Rather easy	Neither easy nor difficult	Rather difficult	Difficult	Very difficult	Extremely difficult
1	2	3	4	5	6	7	8	9

APPENDIX H

SUBJECTIVE RATING SCALE-TURKISH

Verilen görevi tamamlarken ne kadar çaba sarfettiniz?								
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 I

STUDENT QUESTIONAIRE

Cebir Öğrenme Alanı
Öğrenci Görüş Anketi

Sevgili Öğrenciler;

Aşağıdaki anket, Cebir Öğrenme Alanındaki Üslü İfadeler, Cebirsel İfadelerle İşlemler, Denklemler, Kartezyen Koordinat Düzlemi, Denklemlerin Grafikleri ve Örüntü ve İlişkiler konularında uygulanan ders öğretimi, kullanılan materyaller ve yapılan etkinlikler ile ilgili olarak görüşlerinizi almak üzere hazırlanmıştır. Hiçbir cümlenin doğru veya yanlış cevabı yoktur.

Verilen ifadeleri dikkatlice okuduktan sonra;

1: Hiç katılmıyorum,

2: Katılmıyorum,

3: Ne Katılmıyorum Ne de Katılıyorum,

4: Katılıyorum,

5: Tamamen Katılıyorum

seçeneklerinden size uygun olanı (X) ile işaretleyiniz.

Sevgi ve saygılarımla ☺
Aygil TAKIR
ODTÜ Eğitim Fakültesi
Eğitim Bilimleri Bölümü
Doktora Öğrencisi

Görüşünüz / Cebir Öğrenme Alanındaki	1 *Hiç Katılmıyorum*	2 *Katılmıyorum*	*Ne Katılmıyorum Ne de*	4 *Kısmen Katılıyorum*	5 *Tamamen Katılıyorum*
1. Kullanılan öğretim şekli, konuyu iyi öğrenmeme yardımcı oldu.					
2. Konuların öğretim şekli ile öğrenirken zorlanmadım.					
3. Konuların öğretim şeklinden zevk aldım.					
4. Kullanılan materyaller (Öğrenci Kitapçıkları ve Cebir Karoları), konuyu iyi öğrenmeme yardımcı oldu.					
5. Materyalleri kullanırken zorlanmadım.					
6. Materyalleri kullanmaktan zevk aldım.					
7. Ders sonunda yapılan etkinlikler konuyu iyi öğrenmeme yardımcı oldu.					
8. Yapılan etkinliklerde zorlanmadım.					
9. Yapılan etkinliklerden zevk aldım.					
10. Grup çalışmaları konuyu iyi öğrenmeme yardımcı oldu.					
11. Grup çalışmalarında zorlanmadım.					
12. Grup çalışmalarından zevk aldım.					
13. Ders başında yapılan hatırlatmalar ve sorulan					

sorular konuyu öğrenmeme yardımcı oldu.					
14. Ders sırasında yapılan sözel açıklamalar konuyu öğrenmeme yardımcı oldu.					
15. Derste kullanılan ‘Çalışılmış Örnekler’ denilen çözümü tamamen verilmiş sorular konuyu öğrenmeme yardımcı oldu.					
16. Çözümü eksik bırakılmış ve benim tamamlamam istenen sorular konuyu öğrenmeme yardımcı oldu.					
17. Bu konuların öğretiminde kullanılan öğretim şekli ile daha kısa sürede öğrendim.					
18. Bu konuların öğretiminde kullanılan öğretim şeklinin diğer Matematik konularının öğretiminde de kullanılmasını isterim.					
19. Bu konuların öğretiminde kullanılan öğretim şeklinin diğer derslerin öğretiminde de kullanılmasını isterim.					

Aşağıda verilen her bir soru için görüşlerinizi belirtiniz.

1. Derslerin öğretimi ile ilgili olarak *en çok sevdiğiniz ya da yararlı buldunuz* uygulama hangisiydi? Neden?

2. Derslerin öğretimi ile ilgili olarak *hiç sevmediğiniz ya da yararsız bulduğunuz* uygulama hangisiydi? Neden?

3. Cebir konularının öğretiminde uygulanan konuların öğretim şeklini, daha önceki konuların öğretim şekli ile karşılaştırdığınızda bir farklılık sağladı mı? Lütfen açıklayınız.

4. Bu ders öğretim şeklini Matematik dersinin diğer konularında veya diğer derslerinizde de görmek ister misiniz? Yanıtınız evet ise birkaç örnek verir misiniz?

5. Eklemek istediğiniz görüş ve düşünceleriniz varsa lütfen yazınız.

APPENDIX J

INTERVIEW SCHEDULE

Öğrenci Görüşme Formu

Amaç:

Bilişsel Yük Kuramı Etkileri'ne göre hazırlanmış olan Cebir Öğrenme Alanı derslerinin işlenişi ile ilgili olarak öğrenci düşüncelerini ortaya koymak.

Tarih:…/…/… Saat (Başlangıç/Bitiş) :……………./……………

Giriş

Merhaba, ismim Aygil TAKIR. ODTÜ Eğitim Fakültesi, Eğitim Programları ve Öğretim Anabilim dalında doktora öğrencisiyim. Bilişsel Yük Kuramı ilkelerine göre hazırlanmış olan ve yakında tamamladığınız Cebir Öğrenme Alanındaki, Üslü Nicelikler, Cebirsel İfadelerle İşlemler, Denklemler, Kartezyen Koordinat Düzlemi, Denklemlerin Grafikleri ve Örüntü ve İlişkiler konuları hakkında, sizin görüşlerinizi almak üzere bir çalışma yapmaktayım. Katkılarınız için şimdiden teşekkür ederim.

Görüşmeye başlamadan önce görüşmenin gizli olduğunu ve konuşulanları sadece benim bileceğimi belirtmek isterim. Görüşme yapılan diğer öğrenciler ile öğretmeniniz konuşulanları duymayacak veya okumayacaktır. Araştırma raporunda isminiz kesinlikle kullanılmayacaktır.

Görüşmeye başlamadan önce sormak istediğiniz herhangi bir soru varsa yanıtlamak veya belirtmek istediğiniz düşünceniz varsa dinlemek isterim.

Konuşmalarımızı kaydedebilir miyim?

Görüşmenin yaklaşık 25-30 dakika süreceğini düşünüyorum. İzinizle başlamak istiyorum.

Görüşme Soruları

1. Öğretmeniniz her dersin başında sorular sormuş veya 6. Sınıfta öğrendiğiniz konulardan hatırlatmalar yapmıştır. Öğretmenizin derslere bu şekilde başlaması ile ilgili ne düşünüyorsunuz? Sizin için yararlı oldu mu? Ne gibi yararları oldu? Örnek verebilir misiniz?
2. Tüm konular, *çalışılmış örnekler* denilen çözümü tamamen verilmiş sorular üzerinden işlenmiş ve her bir örneğin ardından bir benzeri sizlere alıştırma olarak verilmiştir. Çalışılmış örnekler hakkındaki görüşleriniz nelerdir?
3. Derslerin öğretiminde çözümünü sizin yapacağınız alıştırmalara geçilmeden önce, çözümü eksik bırakılmış ve sizin tarafınızdan tamamlanması istenen sorular kullanılmıştır. Bu alıştırmaların kullanılması ile ilgili görüşleriniz nedir?
4. *Öğrenci Kitapçıkları'nın* ve *Cebir Karoları'nın* sınıf içi materyaller olarak kullanılması ile ilgili görüşleriniz nelerdir? Sizin için yaralı oldu mu?
5. Derslerin öğretiminde öğretmeniz dikkatinizi bölmemek için tahtaya herhangi bir şey yazmamış ve dersi Öğrenci Kitapçıkları üzerinden yürütmüştür. Bu uygulama, konuları daha iyi öğrenmeniz için yararlı oldu mu? Ne gibi yararları oldu? Örnek verebilir misiniz?
6. Derslerin öğretiminde konu hakkında deneyim kazandığınız düşünüldükten sonra etkinliklere yer verilmiştir. Etkinliklerin ders sonunda uygulanmasının Cebir konularını öğrenmenize etkisi konusunda ne düşünüyorsunuz? Başta olsa öğrenmenizi farklı olarak etkiler miydi? Lütfen açıklayınız.
7. Cebirsel İfadelerle İşlemler ve Denklemler konularının bitiminde grup çalışmalarına yer verilmiştir. Bu grup çalışmaları sizin için yararlı oldu mu? Neden?
8. Dersin tüm konularının öğretim şeklini bütünüyle dikkate aldığınızda bu şekilde *daha kolay, daha iyi ya da daha kısa sürede* öğrendiğinizi düşünüyor musunuz? Lütfen açıklayınız.
9. Dersin tüm konularının öğretim şeklini dikkate aldığınızda sevmediğiniz ya da yararsız bulduğunuz uygulamalar var mıydı? Bunları neden sevmediğinizi veya yararsız bulduğunuzu lütfen açıklayınız.

10. Öğretmeninizin daha önce kullandığı öğretim şekillerini/yöntemlerini, bu konuların öğretiminde kullandığı öğretim ile karşılaştırdığınızda, kullanılan bu ders öğretiminin daha iyi olduğunu düşündüğünüz yanları nelerdir?
11. Bu ders öğretim şeklini, Matematik dersinin diğer konularının öğretiminde veya diğer derslerinizin öğretiminde de kullanılmasını ister misiniz? Yanıtınız evet ise birkaç örnek verir misiniz?
12. Eklemek istediğiniz görüşleriniz var mı?

Zaman ayırdığınız için teşekkür ederim. İyi günler.

APPENDIX K

CATEGORIZATION OF INTERVIEW CODES UNDER THEMES

Revisions about Prerequisite Learning at the Beginning of Each Lesson	Worked Example Effect	Completion Example Effect
• Refresh memory • Spiral Curriculum	• Use for solving similar question • Complete knowledge • Superior to straight practice for learning • Better Learning • More easily solve the problems • Step by step solution • Increase cognitive motivation	• Better learn Algebra topics • Redundancy • Expertise reversal principle • Unnecessary repetition • Smooth transition to problems
Classroom Materials	Split Attention	Modality Effect
• Students’ Booklets • Algebra Tiles • Positive opinion • Decrease the note taking Concentrate on the lesson • Funny • Good examples in Students’ Booklets	• Easily able to follow the lessons • Focus attention • Avoid split attention • Less note taking	• Easily able to follow the lessons • Follow Students’ Booklets
Classroom Activities	Group Works	Efficiency of the Course
• Timing of classroom activities • Learners Gain Expertise • Cognitive Load • End of Lessons Motivation and morale • Gaining some skills about the topic before doing the classroom activities • Activities at the end after the explanations or demonstration of skills	• Number of the group members • Novice Learners • Interactions • Crowded Classroom • Expert novice distinction • Like working classmates • Redundancy • Exhausting	• Easier learning • Better learning • Learning in a short time • Learning mathematics easily
Disliked/Useless Implementations	Evaluation of the Teaching Method	Use of the Teaching Method Designed by CLT Principles in Other Mathematics Topics and Courses
• Problems instead of worked examples	• Worked examples • Less notes-taking • Less cognitive load	• Natural Numbers • Geometry • Equations • Exponential Numbers, Algebraic Expressions (Addition-Subtraction) • Computational courses Statistics • Science and Technology • English • Turkish

APPENDIX L

COGNITIVE LOAD SCORES AND COGNITIVE LOAD CONDITIONS OF EXPERIMENTAL AND CONTROL GROUP

Experimental Group	Mean of CLS	CL Condition	Control Group	Mean of CLS	CL Condition
St1	1,83	Low	St1	2,50	Low
St2	3,00	Low	St2	5,33	High
St3	2,17	Low	St3	5,00	High
St4	5,00	High	St4	4,83	Low
St5	2,33	Low	St5	6,33	High
St6	3,83	Low	St6	2,00	Low
St7	7,83	High	St7	7,33	High
St8	1,83	Low	St8	3,33	Low
St9	4,50	Low	St9	8,33	High
St10	4,67	Low	St10	6,33	High
St11	1,67	Low	St11	4,83	Low
St12	6,50	High	St12	5,00	High
St13	3,00	Low	St13	6,17	High
St14	3,83	Low	St14	5,83	High
St15	5,83	High	St15	5,17	High
St16	4,33	Low	St16	5,33	High
St17	3,50	Low	St17	5,33	High
St18	3,67	Low	St18	5,00	High
St19	5,00	High	St19	4,83	Low
St20	4,00	Low	St20	5,33	High
St21	2,33	Low	St21	4,83	Low
St22	4,83	Low	St22	6,00	High
St23	2,50	Low	St23	7,00	High
St24	4,83	Low	St24	4,67	Low
St25	1,00	Low	St25	4,67	Low
St26	2,33	Low	St26	2,83	Low
St27	4,33	Low	St27	5,33	High
St28	1,33	Low	St28	4,67	Low
St29	4,00	Low	St29	4,17	Low
St30	2,67	Low	St30	7,33	High
St31	2,67	Low	St31	5,00	High
St32	3,00	Low	St32	5,00	High
St33	5,00	High	St33	7,00	High
St34	3,67	Low	St34	5,17	High
St35	6,83	High	St35	3,83	Low
St36	2,50	Low	St36	5,33	High
St37	1,67	Low	St37	4,17	Low
St38	2,50	Low	St38	1,67	Low
St39	3,17	Low	St39	5,17	High
St40	3,67	Low	St40	3,83	Low

APPENDIX M

MULTIVARIATE NORMALITY TEST

Run MATRIX procedure:

Number of observations:
80

Number of variables:
2

Measures and tests of skew:

	g1	sqrt(b1)	z(b1)	p-value
AchScore	.6595	.6471	2.3763	.0175
LoadScor	.1014	.0995	.3907	.6960

Measures and tests of kurtosis:

	g2	b2-3	z(b2)	p-value
AchScore	.2604	.1703	.6710	.5022
LoadScor	-.4301	-.4778	-.8413	.4002

Omnibus tests of normality (both chisq. 2 df):

	D'Agostino & Pearson K sq		Jarque & Bera LM test	
	K sq	p-value	LM	p-value
AchScore	6.0970	.0474	5.6791	.0585
LoadScor	.8604	.6504	.8927	.6400

*************** Multivariate Statistics ***************

Tests of multivariate skew:

Small's test (chisq)

Q1	df	p-value
5.8553	2.0000	.0535

Srivastava's test

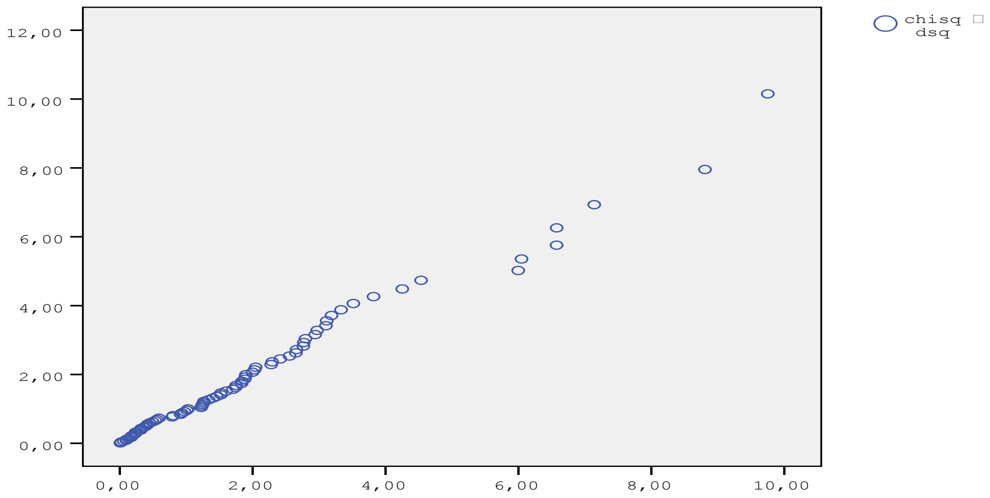
chi(b1p)	df	p-value
6.2675	2.0000	.0436

Tests of multivariate kurtosis:

A variant of Small's test (chisq)

```
     VQ2        df    p-value
   1.1676    2.0000      .5578

  Srivastava's test
     b2p     N(b2p)    p-value
   3.0143      .0370      .9704
Mardia's test
     b2p     N(b2p)    p-value
   8.1334      .1492      .8814

Omnibus test of multivariate normality:

  (based on Small's test. chisq)
     VQ3        df    p-value
   7.0229    4.0000      .1347

------ END MATRIX -----


Critical values (Bonferroni) for a single multivar. outlier:

  critical F(.05/n) =13.60  df =  2.  77
  critical F(.01/n) =16.24  df =  2.  77

5 observations with largest Mahalanobis distances:
  rank = 1  case# =  12  Mahal D sq =      9.75
  rank = 2  case# =  10  Mahal D sq =      8.81
  rank = 3  case# =  34  Mahal D sq =      7.14
  rank = 4  case# =  78  Mahal D sq =      6.58
  rank = 5  case# =   5  Mahal D sq =      6.57
```

Plot of ordered squared distances



APPENDIX N

OBJECTIVES AND QUESTION NUMBERS

Kazanım	Soru Numarası
Tam sayıların kendileri ile tekrarlı çarpımını üslü nicelik olarak ifade eder.	1 2
Sayı örüntülerini modelleyerek bu örüntülerdeki ilişkiyi harflerle ifade eder.	3 4 (a,b)
Cebirsel ifadelerle toplama ve çıkarma işlemleri yapar.	5 6
İki cebirsel ifadeyi çarpar.	7
Birinci dereceden bir bilinmeyenli denklemleri çözer.	8 9 10 11
Denklemi problem çözmede kullanır.	12 13 14
İki boyutlu Kartezyen koordinat sistemini açıklar ve kullanır.	15
Doğrusal denklemleri açıklar.	16
Doğrusal denklemlerin grafiğini çizer.	17 (a,b,c)

APPENDIX O

TURKISH SUMMARY

1. Giriş

Bilişsel Yük Kuramı (BYK) seksenli yıllarda John Sweller önderliğinde New South Wales üniversitesinde ortaya çıkmış; eğitim psikolojisi ve öğretim tasarımında etkili olan bir kuramdır.

BYK, öğrenenlerin bilişsel mimarisini temel almış kuramsal bir çerçevedir (Janssen, et al., 2010). Bu kuram çalışan belleğin bilgiyi saklama ve işleme yönünden sınırlı kapasiteye, uzun süreli belleğin ise sınırsız bir kapasiteye sahip olduğunu kabul eder. BYK bu yapıların sınırlılıklarını ve kapasitelerini göz önüne alan öğrenme ortamları önermektedir.

Tanımından da anlaşılacağı üzere BYK diğer öğretim yöntemlerinden farklı olarak bilişsel mimariye önem vermekte ve öğretim tasarlanırken bu mimariyi göz önünde bulundurmanın etkin öğretim tasarlamak için önemini vurgulamaktadır.

Bilişsel yük çok boyutlu bir yapı olarak ele alınmakta ve belirli bir öğrenme işinin öğrencinin bilişsel sistemi üzerinde oluşturduğu baskı olarak tanımlanmaktadır. Bilişsel mimarideki çalışan ve uzun süreli bellekler, bilişsel yükün üç şekilde ortaya çıkmasına yol açmaktadır. Bunlar asıl yük, konu dışı yük ve etkili yüktür. Eğer öğrenilmesi gereken içerikle ilgili bir yükten bahsediliyorsa bu asıl yüktür. Eğer tasarlanan öğretim veya öğrenme süreçleri ile ilgili bir yükten bahsediliyorsa bu yük konu dışı veya asıl yüktür. Tasarlanan öğrenme ortamı, uygun olmayan bilgileri ya da bilgi işleme sürecini olumsuz yönde etkileyen diğer materyalleri içeriyorsa konu dışı yükten; zihinsel yapıların oluşması ve düzenlenmesini sağlayan süreçler varsa etkili yükten bahsedilir. Bu üç yük arasındaki ilişki döngü şeklindedir. Konu dışı yük, öğretim tasarım sürecinin etkili şekilde yapılandırılması ile azalır, çalışan bellekteki boşluk etkili yüke ayrılır ve böylece zihinsel yapılar rahatlıkla oluşabilir. Zihinsel yapıların oluşması ile bir sonraki aşamada asıl yük azalır. Bu nedenle öğretim tasarımı sürecinde konu dışı yükün azaltılmasına yönelik öğretim teknikleri geliştirilmeye çalışılmaktadır.

Bilişsel yüklenmeyi ölçmek adına birçok teknikler kullanılmaktadır. Bu çalışmada, insanlar kendi bilişsel süreçlerinin farkındadır ve harcadıkları zihinsel çaba miktarını doğru şekilde rapor edebilirler sayıltısına dayanan öznel ölçme tekniği kullanılmıştır. Bu amaçla, Paas ve van Merrienboer (1994) tarafından geliştirilen ‘‘çok, çok düşük yük’’ten ‘‘çok, çok yüksek yük’e kadar derecelendirme içeren 9’lu likert tipi ölçek kullanılmıştır.

BYK araştırmalarında öne çıkan önemli bir konu öğretimin verimliliğini hesaplamadır. Verimli öğrenme ortamı, daha iyi öğrenmeyi, daha hızlı öğrenmeyi veya her ikisini de sağlayan öğrenme ortamlarına denir. Bu yaklaşımda, performans ve zihinsel çaba ölçüm sonuçları bir formüle dayalı olarak sayısal değere dönüştürülmekte ve verimlilik hesaplanmaktadır.

Öğretim tasarımı sürecinde konu dışı yükün azaltılmasına yönelik bir takım deneysel çalışmalar sonucunda öğretim teknikleri geliştirilmiştir. Bu teknikler *BYK etkileri* adını alıp bu tezde kullanılanlar, çalışılmış örnekler, tamamlama örnekleri, bölünmüş dikkat, biçem, gereksizlik, uzmanlık ve destek etkileridir. BYK deneysel çalışmalara dayanan bu öğretim teknikleri ile de diğer öğretim yöntemlerinden ayrılır.

Bu çalışmanın temel etkisi çalışılmış örnekler etkisidir. Bu etki tamamlama örnekleri ile birlikte kullanılarak çalışan bellekteki yük azaltılmaya çalışılmıştır. Biçem etkisi, yazılı veya görsel kanala hitap eden bir takım şekillere dayanan bilginin aktarımında, bilgi akışının yazılı anlatımdan sözlü anlatıma kaydırılması ile ilgilidir. Bu bağlamda, bu çalışmada sözlü anlatımlara önem verilmiştir. Gereksizlik ilkesi, aynı bilgiyi birkaç formda sunmanın gereksiz olduğunu savunmakta ve ilginç ancak öğrenmeye katkısı olmayan bir takım materyallerin öğretimden çıkartılması gerekliliği üzerinde durmaktadır. Gereksizlik etkisi, öğretim tasarımında oldukça önemli bir etkidir. Uzmanlık etkisi, destek etkisi ile birlikte öğrencilerin öğrenme düzeyleri ile ilgili olan etkilerdir. Özellikle bu çalışmadaki gibi karma başarı düzeyine sahip ortamlarda, çalışılmış örnekler, tamamlama örnekleri ve alıştırmaların sırasıyla kullanılması bu etkilerin kullanımına örnektir.

Kısacası, BYK, öğretim tasarım etkilerini ve bilişsel mimari ilkelerini birleştirerek, birçok öğrenme ortamına etkin bir şekilde uygulanabilir.

BYK, bilişsel mimariye, çalışan bellek ve uzun süreli bellek yapılarına dikkat edilmeden tasarlanan bir öğretimin verimli olmayacağını savunmaktadır. Bilişsel mimarinin ilkelerini ve BYK'nın önerdiği etkiler dikkate alınarak geliştirilen bu çalışmada amaç, BYK ilkelerine göre geliştirilmiş bir öğretim etkinliğinin 7. sınıf öğrencilerinin Cebir başarısına ve bilişsel yüklerine etkisini incelemektir.

Bu çalışmanın bulguları birçok açıdan değer taşımaktadır. İlköğretim okullarında şu anda uygulanmakta olan matematik programı her çocuk matematik öğrenebilir ilkesine dayanmakta ve öğrencilerin araştırma yapabilecekleri, keşfedebilecekleri öğrenme ortamları önermektedir. Programın yaklaşımı oluşturmacı olarak tanımlanabilir (Bulut, 2005; Babadogan & Olkun, 2006). BYK'ya göre öğrenci merkezli olarak tasarlanmış olan öğrenme ortamları ancak öğrenciler konu hakkında deneyim sahibi olduktan sonra başarılı olabilmektedir. Başka bir deyişle sınıf içi aktivitelerin ve grup çalışmalarının ders sonlarında planlanmasının öğrenmeyi artıracağı belirtilmiştir. Bu bağlamda, oluşturmacı yaklaşımın BYK ilkeleri ile entegre edilmesi daha etkin öğrenme ortamları için yarar sağlayacaktır.

Çalışmanın tüm materyalleri geliştirilirken ve uygulamalar sırasında ‘‘az çoktur’’ minimalist yaklaşımına yer verilmiştir. Bu yaklaşım kolaylıkla oluşturmacı öğretim ortamlarına uyarlanabilir.

Türkiye’de sınıf ortamlarının başarı yönünden genellikle karma olması bazı BYK ilkelerinin kullanılarak öğretimin tasarlanmasının önemini artırmaktadır. Örneğin konu hakkında deneyim sahibi olmayan bir öğrencinin ihtiyaçları ile konu hakkında deneyimi olan bir öğrencinin konuya yaklaşımı oldukça farklı olacaktır.

Tatar ve Dikici’ye (2008) göre matematik dersinde öğrencilerin öğrenme güçlü çekmelerinin sebeplerinden biri, ön öğrenmelerindeki eksikliklerdir. BYK’ın ön öğrenmelere verdiği önem ile deneysel çalışmalara dayanan önerileri, matematik öğrenme öğretme süreçleri için etkili olabilir ve matematik programına katkı sağlayabilir.

Çalışmanın yapıldığı Cebir konusu hayatın her alanında karşımıza çıkan, matematiğin önemli bir konusudur. Cebir öğretiminin gelişmesine katkı sağlayacak her türlü çalışma anlamlı ve değerlidir. Cebir öğrenmede, Cebir’in yapısından, öğrenci bilişsel gelişiminden ve öğretim yöntemlerinden kaynaklanan sorunlar vardır. BYK ilkelerine göre tasarlanmış dersler, Cebir öğretimine yeni bir yaklaşım getirip, öğretmenler ve program geliştirme uzmanları tarafından kullanılabilir.

BYK ilke ve bir veya iki etki kullanılarak Cebir konusunda laboratuar ortamında gerçekleşmiş birçok çalışma vardır. Bu çalışmada ikiden fazla etki kullanılmış ve çalışma gerçek sınıf ortamında gerçekleşmiştir. Ayrıca, BYK ile ilgili olarak Türkiye’de yapılan çalışmalar genellikle çoklu ortamlar ile ilgili olmuştur. Bu çalışma sınıf ortamında yapılacak çalışmaların önünü açabilir.

2. Literatür Taraması

Bu bölüm, BYK ile ilgili olarak kuramsal açıklamaları ve ilgili araştırmaları içermektedir.

Bilişsel Yük Kuramı (BYK), Miller (1956) tarafından geliştirilen ‘‘bilgiyi hafızada tutma açısından, çalışan bellek bir anda en fazla dokuz parça ya da öğeyle ilgilenebilmektedir ilkesine dayanmaktır’’. Bu ilke yapılan araştırmalar ile geliştirilmiş ve yeniden tanımlanarak Bilişsel Yük Kuramı adını almıştır.

BYK, öğrencilerin işlem açısından sınırlı olan bilişsel kapasitelerini verimli bir biçimde kullanarak yeni öğrenmeler edinmesini sağlayacak öğretim tasarımlarının geliştirilmesiyle ilgilenmektedir.

BYK’nın merkezinde öğretim tasarlarken çalışan bellek yapısı ve sınırlılıkları göz önünde bulundurulmalı ve çalışan bellek kapasitesi en verimli şekilde kullanılmalıdır görüşü yer almaktadır. Bilginin çalışan belleğin sınırlılıkları göz önüne alınarak uzun süreli bellekte etkin bir şekilde saklanması amaçlanmıştır.

BYK’a göre insanlar, sınırlı olan çalışan belleğe ve sınırlı olmayan uzun süreli belleğe sahiptirler ve belli problemlerin çözümünde kullanmak için zihinsel yapılar geliştirirler. Zihinsel yapıların geliştirilmesi sonucunda çalışan bellek üzerindeki yük azalır. Bu nedenle öğrenme-öğretme süreçlerinin amacı, öğrencilerin zihinsel yapılarını geliştirmelerine yardım etmek olmalıdır.

Bilişsel yük kuramının amacı, yeni öğretim yöntemleri geliştirerek, çalışan belleğinin kapasitesinin etkili bir şekilde kullanılmasını sağlamak olduğundan, öğretim tasarımı sürecinde odaklandığı nokta, çalışan bellek ve bu belleğin sınırlılıklarıdır. Hitch ve Baddeley’in (1974) çalışan bellek modeline göre çalışan bellekte iki alt sistem vardır. Bunlardan birincisi yazılı metin ya da resim gibi görsel bilgilerin algılandığı *görsel alt sistem* diğeri ise sözel metin ya da müzik gibi sesli bilgilerin algılandığı *sözel alt sistemdir*. Bu model 2000 yılında ‘‘çoklu modlu bölümsel arabellek’’ sistemi eklenerek genişletilmiştir.

Bilişsel yük çok boyutlu bir yapı olarak belirli bir öğrenme işinin öğrencinin bilişsel sistemi üzerinde yaptığı baskı olarak tanımlanmaktadır. Üç tür bilişsel yük vardır: asıl yük, konu dışı yük ve etkili yük.

Asıl yük, öğrenilmesi zor olan içeriğe bağlı olarak çalışan belleğe yüklenmenin olmasıdır. Eğer sunulan bilgi karmaşıksa asıl yük, yüksek olmaktadır. Konu dışı bilişsel yük ise, iyi tasarlanmamış öğretim materyalleri ve iyi olmayan öğretim tasarımı sonucunda çalışan belleğe yüklenilmesidir. Tasarlanan öğrenme ortamı, uygun olmayan bilgileri ya materyalleri içeriyorsa konu dışı yük yüksek olmaktadır. Etkili yük ise zihinsel yapıların oluşması ve düzenlenmesini sağlayan süreçlerde ortaya çıkar. Konu dışı ve etkili yük öğretim tasarımından etkilenir ve öğretim tasarımcılarının kontrolündedir. Bu üç yük arasındaki ilişki bir döngü şeklindedir. Konu dışı yükün, öğretim tasarımı sürecinin etkili şekilde yapılandırılması ile azalması, çalışma belleğindeki boşluğun etkili yüke ayrılmasını sağlamakta ve böylece zihinsel yapılar daha rahatlıkla oluşabilmektedir. Zihinsel yapıların oluşması ile bir sonraki aşamada asıl yük azalmakta ve bu nedenle öğretim tasarımı sürecinde konu dışı yükün azaltılmasına yönelik öğretim teknikleri (BYK etkileri) geliştirilmeye çalışılmaktadır .

Bilişsel yük yapısını etkileyen faktörler nedensel ve değerlendirme olmak üzere iki temel başlık altında açıklanmaktadır. Nedensel faktörler öğrenme işini, öğrenci özelliklerini ve iş ile öğrenci özelliklerinin etkileşimini içermektedir. Nedensel faktörler ise zihinsel yük, zihinsel çaba ve performans kavramlarıyla açıklanmaktadır. Bilişsel sisteminde oluşan baskı *zihinsel yük* olarak tanımlanmaktadır. Zihinsel yüke maruz kalan öğrencinin belirli bir iş için bilişsel kapasitesini kullanarak sarf ettiği emek ise *zihinsel çaba* olarak tanımlanmaktadır. Zihinsel yüke maruz kaldığında bilişsel kapasitesinin bir kısmını ya da tamamını zihinsel çaba olarak harcamakta ve bunun sonucunda ulaştığı öğrenme düzeyi ise onun *performans* miktarını göstermektedir.

Bilişsel yük ölçümünün değişik kaynaklarda analitik ve deneysel olmak üzere iki yönteme dayalı olarak yapılabileceği vurgulanmaktadır. Bilişsel yük ölçümü ile ilgili teknikler öznel, fizyolojik ve performans olmak üzere üç başlık altında toplanmaktadır. Öznel teknikler, "insanlar kendi bilişsel süreçlerinin farkındadır ve harcadıkları zihinsel çaba miktarını doğru şekilde rapor edebilirler" sayıltısına dayanmaktadır. Fizyolojik teknikler ise bilişsel fonksiyonlar, fizyolojik ölçümlerle tespit edilebilir kabulüne dayanmaktadır. Fizyolojik teknikler zihinsel çaba miktarını belirleyebilmek için deneğin kalp atış oranı, beyin ve göz hareketleri ölçmektedir. Bilişsel yük ölçümünde performans, öğrencinin performansı öğretim ya da öğretim sonrası sınav aşamasında ölçülebilmektedir.

Öznel tekniklere dayanan zihinsel çaba ölçümü ilk defa Paas ve Van Merrienboer (1994) tarafından gerçekleştirilmiştir. Paas ve Van Merrienboer (1994) zihinsel çaba düzeyini ölçmek amacıyla, verilen işin zorluk derecesini belirlemeye yarayan ölçeği zihinsel çaba ölçümünde kullanmışlardır. Ölçekte deneklerin zihinsel çaba algılarını yansıtmaları için 1'den 9'a kadar, "çok, çok düşük zihinsel çaba" dan "çok, çok yüksek zihinsel çaba" ya doğru seçenekleri olan ölçeği kullanmışlardır.

Öğretimin verimliliği ilk kez Paas ve Van Merrienboer (1994) tarafından kullanılmış olan öğretim durumlarının birbirine oranla verimlilik düzeylerini karşılaştırmaya yarayan bir ölçme yöntemidir. Öğretim durumlarının verimlilik düzeyinin değerlendirilmesinde test puanı ya da öğrenme düzeyi ve öğrencinin zihinsel çaba düzeyi değişken olarak kullanılmaktadır. Her bir deneğin zihinsel çaba ve performans değerleri z-puanına dayalı olarak standart puan cinsine çevrilip bu puanlar $E = \frac{z_{performans} - z_{bilişsel\ yük}}{\sqrt{2}}$ formülüne yerleştirilerek öğretim verimliliği hesaplaması yapılmaktadır. Verimlilik yaklaşımına göre; eğer öğrenme düzeyi z-puanı zihinsel çaba z-puanından büyükse hesaplanan verimlilik pozitif; küçükse verimlilik negatif değer almaktadır. Diğer taraftan öğrenme düzeyi zihinsel çaba puanına eşitse verimlilik sıfır olarak bulunmaktadır.

Bilişsel Yük Kuramı Etkileri öğretim tasarımı sürecinde konu dışı yükün azaltılmasına yönelik öğretim teknikleri sağlamaktadır (Sweller, 2008). Bu tezde kullanılan etkiler çalışılmış örnekler, tamamlama örnekleri, bölünmüş dikkat, biçem, gereksizlik, uzmanlık etkisi ve destek etkisidir.

Çalışılmış örnekler etkisi, çözülmüş örneklerin alıştırmaların yerine kullanılması ile ilgili bir etkidir. Öğrenenlerin dikkati soru çözmekten çok problemin kendisine ve çözüm aşamalarına yönlendirilmeli ilkesine dayanmaktadır. Sweller ve Cooper' a (1985) göre öğrencilerin konu hakkında bilgi düzeylerine göre örnekler kullanılmalı ve şema oluşumu tamamlandıktan sonra alıştırmalara geçilmelidir. Tamamlama örnekler, BYK'ya göre öğrencilerin dikkatini problem cümlesine ve çözüm adımlarına vermesini sağlamaktadır. Tamamlama örnekleri, çalışılmış örneklerden alıştırmalara özellikle zor konularda yumuşak bir geçiş sağlamaktadır.

Bölünmüş dikkat etkisi, öğrencilerin, aynı algıya hitap eden farklı bilgilerin sunulması ile dikkatlerinin bölünmesine bağlı olarak, konu dışı yükün artacağını vurgulamakta ve bundan kaçınılması gerektiği üzerinde durmaktadır. Bölünmüş dikkat etkisinde öğrenme için birbiri ile bütünleşmiş kaynağa ihtiyaç duyulurken, bu bilgiler birbirinden ayrı sunulduğunda öğrenme süreci etkili olmamaktadır. Bu şekilde bölünmüş kaynaklarla sunulan bilgi bilişsel yükün artmasına neden olmaktadır.

Biçem etkisi, yazılı veya görsel kanala hitap eden bir takım şekillere dayanan bilginin aktarımında bilgi akışı yazılı anlatımdan sözlü anlatıma kaydırılması ile ilgilidir. Yapılan araştırmalara göre bilginin yazılı olarak değil de işitsel kanala hitap edilerek anlatılması öğrenmeyi artırmaktadır (Clark, et al., 2005).

Gereksizlik ilkesi, aynı bilgiyi birkaç formda sunmanın gereksiz olduğunu savunmaktadır. İlginç ancak öğrenmeye katkısı olmayan bir takım materyallerin öğretimden çıkartılması gerekliliği üzerinde durmaktadır (Clark, et al., 2005).

BYK öğrencilerin konu hakkındaki bilgi ve deneyim seviyelerinin öğretimi tasarlarken önemli faktörler olduğunu önermektedir. Uzmanlık etkisi adlandırılan bu etki gereksizlik ilkesi ile yakından ilişkilidir. Konu hakkında deneyim sahibi olmayan öğrenciler için gerekli olan bir bilgi, deneyim sahibi öğrenciler için gereksiz olabilir.

Çalışılmış örnekler-alıştırma birlikteliği olan derslere, uzmanlık etkisi eklenince yeni bir BYK etkisi ortaya çıkmaktadır: destek etkisi. Bu etki özellikle karma ön öğrenme seviyesine sahip olan sınıflarda, her düzeyden (düşük, orta, yüksek) bilgiye sahip olan öğrenciler için öğretimin tasarlanmasını önermektedir. Ders çalışılmış örneklerle başlamalı, tamamlama örnekleri ile devam etmeli ve daha sonra tamamen alıştırmaya geçerek kademeli olarak ilerlemelidir.

Dünyada BYK ile ilgili araştırmalara baktığımızda Sweller ve Cooper'in (1988) problem çözme ile ilgili olarak gerçekleştirdiği araştırma ilk olarak sayılır. Bu araştırmada problem çözmede daha önceki örneklerin kullanılmasının genelleme yapmaya yardımcı olup olmadığını araştırmışlardır. Araştırma bulguları, önceki örneklerin daha sonraki problem çözme performansını artırdığını göstermektedir. Bu araştırma problem çözmede örnek vermenin önemi vurgulanmış ve çalışılmış örneklerle ilgili olarak araştırmaların başlamasını sağlamıştır.
Zhu ve Simon (1987) geçekleştirdikleri boylamasına araştırmada çalışılmış örnekler kullanarak üç yılda tamamlanan matematik programını iki yılda daha yüksek öğrenci performansı ile tamamlamışlardır.

Paas (1992) yaptığı araştırmada tamamen veya kısmen tamamlanan örnekler ile tasarlanmış bir öğretimin yüksek öğrenci başarısına ve düşük bilişsel yüke yol açtığını bulmuştur. Carroll (1994)'da verilen problemlerin cebirsel olarak yazılması ile ilgili çalışmasında, çalışılmış örnekler sayesinde öğrencilerin daha az hata yaptıklarını ve öğretmenlerinden daha az destek istediklerini ortaya çıkarmıştır.

Bölünmüş dikkat ile ilgili olarak yapılan araştırmalara genellikle fen ve matematik eğitimi ile başlamıştır. Tarmizi ve Sweller (1988) geometri soruları üzerinde yaptıkları araştırmada bölünmüş dikkat etkisini çalışılmış örneklerle birlikte kullanmışlardır. Geometri sorularında şekil ile açıklamasının bir arada yazılmasını ve çözülmüş örneklere yer verilmesinin geleneksel soru çözme yöntemine göre daha yüksek öğrenci başarısı sağladığı bulunmuştur.

Mousavi ve diğerleri de (1995) geometri konusunda bölünmüş dikkat ve biçem etkilerini birlikte kullanmışlardır. Araştırma sonuçları işitsel olarak sunulan içeriğin görsel şekilde sunulan içeriğe göre daha etkili olduğunu göstermektedir.

Kalyuga ve diğerleri (2001) uzmanlık etkisi ile ilgili olarak yaptıkları araştırmada, çalışılmış örneklerin konu hakkında deneyimsiz öğrenciler için yararlı, ancak deneyimli öğrenciler için yararsız olduğunu ortaya çıkarmışlardır. Bu çalışmanın sonucunda çalışılmış örneklerin yeni bir konu öğretildiği zaman başlangıçta faydalı olduğunu, ancak öğrenciler deneyim kazandıkça alıştırmalara yer verilmesi gerektiğini vurgulamışlardır. Yukarıda belirtildiği gibi destek etkisi, uzmanlık etkisi ile ilişkili bir etkidir. Bu etki ile ilgili yapılan çalışmalarda da benzer sonuçlar bulunmuştur. Türkiye'de Kılıç (2006), Kablan and Erden (2008) ve Sezgin (2009) tarafından yapılan çalışmalara bakıldığında çoklu ortamlar için BYK ilke ve etkilerine göre dersler geliştirildiğini ve deneysel çalışmalarla bu derslerin verimliliğinin ortaya konulduğu görülür. Tüm bu çalışmalarda, BYK ilke ve etkilerine göre tasarlanmış çoklu ortamlar lehine anlamlı farklılık bulunmuştur.

3. Yöntem

Bu bölümde araştırma deseni, araştırma soruları, araştırmada kullanılan değişkenler, araştırmanın hipotezleri, uygulamanın tanıtılması, araştırmanın kapsamı, katılımcı özellikleri, veri toplama araçları ve süreci, verilerin analizi, sınırlılıklar ve araştırmanın geçerliliği bölümlerine yer verilmiştir.

Araştırmanın Deseni

Bilişsel Yük Kuramı (BYK) ilkelerine göre geliştirilmiş bir öğretim etkinliğinin 7. sınıf öğrencilerinin Cebir başarısına ve bilişsel yüklerine etkisini incelemek üzere gerçekleştirilen bu çalışmada yarı-deneysel araştırma deseni kullanılmıştır. Araştırmanın bağımsız değişkeni, deney grubunda uygulanan BYK ilkelerine göre hazırlanmış öğretim; bağımlı değişkenler ise öğrencilerin Cebir başarısı ve bilişsel yükleri olarak belirlenmiştir.

Araştırma, 2010-2011 öğretim yılında, İstanbul Kağıthane'de bulunan bir devlet okulunda toplam 6 hafta sürmüştür. Çalışmaya deney ve kontrol gruplarından 40'ar öğrenci olmak üzere toplam 80 öğrenci katılmıştır. Sınıflar öğretim yılı başında okul idaresi tarafından oluşturulmuş; dolayısı ile katılımcıların evrenden tesadüfi atama yoluyla belirlenme durumu sağlanamamıştır. Gruplar, başarı ve cinsiyet açısından karmadır.

Deney ve kontrol gruplarının denkliğini sağlamak amacıyla deney ve kontrol grupları arasında geçen yılın Matematik puanları açısından anlamlı bir fark olup olmadığı t-testi aracılığıyla kontrol edilmiş ve iki grup arasında anlamlı bir fark bulunmadığı tespit edilmiştir. Her iki grupta aynı ders içeriği farklı öğretim yöntemleri ile işlenmiştir.

Araştırma altı Cebir ünitesinde uygulanmıştır. Bunlar, Üslü Nicelikler, Cebirsel ifadelerle İşlemler, Denklemler, Kartezyen Koordinat Düzlemi, Birinci Dereceden Bir Bilinmeyenli Denklemlerin Grafikleri ve Örüntü ve İlişkiler üniteleridir. Her bir ünite ‘‘Öğretmen ve Öğrenci Kitapçıkları’’ araştırmacı geliştirmiştir. Her bir ünitenin sonunda deney ve kontrol grubundaki öğrencilerin bilişsel yüklerini belirlemek amacıyla Paas ve Van Merrienboer (1993) tarafından geliştirilen Bilişsel Yük Ölçeği (BYÖ) kullanılmıştır. Uygulamanın sonunda ise öğrencilerin Cebir başarısını belirlemek amacı ile araştırmacı tarafından geliştirilen Cebir Başarı Testi (CBT) deney ve kontrol gruplarına uygulanmıştır. CBT’in pilot çalışması İstanbul’da bulunan üç devlet okulunda gerçekleştirilmiştir. Yine uygulama sonunda deney grubu öğrencilerinin görüşlerini belirlemek amacıyla Öğrenci Görüş Anketi (ÖGA) kullanılmıştır. Ders başarıları göz önünde bulundurularak seçilen toplam 12 öğrenci ile uygulama sonunda görüşmeler yapılmıştır. Görüşme Formu (GF), ÖGA sorularına paralel olarak hazırlanmış 12 adet yarı yapılandırılmış sorudan oluşmuştur.

Araştırma Soruları

Araştırmanın amacı, Bilişsel Yük Kuramı (BYK) ilkelerine göre geliştirilmiş bir öğretimin etkinliğinin 7. sınıf öğrencilerinin Cebir başarısına ve bilişsel yükleri üzerine etkisini incelemektir. Buna göre, araştırma sırasında şu sorulara yanıt aranmaya çalışılmıştır:

1. Bilişsel Yük Kuramı (BYK) ilkelerine göre geliştirilmiş öğretimin öğrencilerin Cebir başarılarına ve bilişsel yüklerine anlamlı bir etkisi var mıdır?

2. Bilişsel Yük Kuramı (BYK) ilkelerine göre geliştirilmiş öğretimin uygulandığı gruptaki öğrencilerin verimlilik puanları ile MEB önerilerine göre geliştirilmiş öğretimin uygulandığı gruptaki öğrencilerin verimlilik puanları arasında anlamlı bir farklılık var mıdır?

3. Bilişsel Yük Kuramı (BYK) ilkelerine göre geliştirilmiş öğretimin uygulandığı gruptaki öğrencilerin uygulamaya ilişkin algıları nelerdir?

Hipotezler

Araştırma soruları doğrultusunda belirlenen hipotezler sıfır hipotezi formatında aşağıda belirtilmiştir:

Sıfır Hipotezi 1.1: Bilişsel Yük Kuramı (BYK) ilkelerine göre geliştirilmiş öğretimin öğrencilerin Cebir başarılarına ve bilişsel yüklerine anlamlı bir etkisi yoktur.

Sıfır Hipotezi 2.1: Bilişsel Yük Kuramı (BYK) ilkelerine göre geliştirilmiş öğretimin uygulandığı gruptaki öğrencilerin verimlilik puanları ile MEB tarafından geliştirilmiş öğretimin uygulandığı gruptaki öğrencilerin verimlilik puanları arasında anlamlı bir farklılık yoktur.

Değişkenler

Araştırmada biri bağımsız, ikisi bağımlı olmak üzere toplam üç değişken kullanılmıştır.

Bağımsız Değişken: Uygulama (öğretim metodu): Deney grubunda uygulanan BYK ilkelerine göre hazırlanmış öğretim, kontrol grubunda uygulanan MEB tarafından geliştirilmiş öğretim.

Bağımlı Değişkenler: Öğrencilerin Cebir Başarısı ve Bilişsel Yükleri.

Ortam Yapısı

Çalışmanın yürütüldüğü okul, düşük sosyo-ekonomik yapıya ait bir bölgede, bir sivil toplum örgütü tarafından yapılmıştır. Okul, şu an, bu örgütten herhangi bir destek almamaktadır. Okul, fiziki olarak oldukça yetersiz şartlara sahiptir.

Çalışmanın uygulamasına gönüllü iki matematik öğretmeni katılmıştır. Her iki öğretmende bayan olup, 4 yıllık eğitim veren ilköğretim matematik öğretmenliği programından mezundurlar. Deney grubunda bulunan öğretmen 5 yıllık, kontrol grubundaki öğretmen ise 4 yıllık mesleki deneyime sahiptir. Çalıştıkları okulun şartlarından dolayı öğretim yaklaşımlarını öğretmen merkezli olarak tanımlamışlardır.

Okulda MEB tarafından geliştirilen Matematik öğretim programı kullanılmaktadır. Bu program öğrenci merkezli eğitim ve oluşturmacı öğretim yaklaşımını önermektedir. Matematik programı beş öğrenme alanı içermektedir: Sayılar, Cebir, Geometri, Olasılık ve İstatistik, Ölçme. Derslerde, MEB tarafından önerilen öğrenci ve öğretmen kitapları kullanılmaktadır. Bu çalışma Cebir öğrenme alanında, Tablo 3.1'de verilen konularda ve kazanımlarda uygulanmıştır.

Tablo 3.1
Cebir Öğrenme Alanı konuları ve kazanımları.

Konular	Kazanımlar
Üslü İfadeler	Tam sayıların kendileri ile tekrarlı çarpımını üslü nicelik olarak ifade eder.
Cebirsel İfadeler	Cebirsel ifadelerle toplama ve çıkarma işlemleri yapar. İki cebirsel ifadeyi çarpar.
Birinci Dereceden Bir Bilinmeyenli Denklemler	Birinci dereceden bir bilinmeyenli denklemleri çözer. Denklemi problem çözmede kullanır.
Kartezyen Koordinat Düzlemi	İki boyutlu kartezyen koordinat sistemini açıklar ve kullanır.
Denklemlerin Grafikleri	Doğrusal denklemlerin grafiğini çizer.
Örüntü ve İlişkiler	Sayı örüntülerini modelleyerek bu örüntülerdeki ilişkiyi harflerle ifade eder.

Öğretmen ve Öğrenci Kitapçıkları

Öğrenci Kitapçıkları, 7. Sınıf tüm Cebir konularını içerecek şekilde; Cebir kazanımlarını ve BYK ilkelerini ele alarak sınıf içi öğretim materyali olarak hazırlanmıştır. Kitapçıklar hazırlanırken kullanılan BYK etkileri: çalışılmış örnekler, tamamlanan örnekler, bölünmüş dikkat, biçem, gereksizlik ve destek etkileridir.

Kitapçıklar hazırlandıktan sonra içerikleri, kullanılan dilin uygunluğu ve BYK etkilerinin kullanımı bakımından değerlendirilmek üzere uzman görüşüne başvurulmuştur. Uzmanlardan gelen eleştiriler ve öneriler doğrultusunda soruların yazımında ve sırasında bir takım değişiklikler yapılmıştır.

Öğretmen Kitapçıkları araştırmacı tarafından hazırlanmış olup, genel açıklamalar, süre, ön öğrenmeler, kullanılan materyaller ve dersin işlenişi gibi bölümler içermektedir.

Çalışma Grubu

Araştırmanın çalışma grubunu, İstanbul, Kağıthane semtinde bulunan bir devlet okulundaki 7. sınıf öğrencilerden toplam 80 öğrenci oluşturmuştur. Gruplar deney ve kontrol grupları olarak tesadüfi olarak atanmıştır. Deney grubunda 19 erkek, 21 kız öğrenci; kontrol grubunda ise 20 erkek, 20 de kız öğrenci bulunmaktadır. Uygulamanın başında, gruplarının denkliğini sağlamak amacıyla geçen yılın matematik puanları açısından anlamlı bir fark olup olmadığı t-testi aracılığıyla kontrol edilmiş ve iki grup arasında anlamlı bir fark bulunmadığı tespit edilmiştir.

Uygulamanın sonunda gerçekleştirilen görüşmeler için öğrencilerin matematik başarısına bakılmış; yüksek, orta ve düşük başarılı öğrencilerden toplam 12 öğrenci seçilmiştir.

Veri Toplama Araçları

Araştırmanın sorularını yanıtlamak ve hipotezlerini test etmek amacıyla bu çalışmada dört farklı veri toplama aracı kullanılmıştır:

- Cebir Başarı Testi (CBT): Uygulamanın sonunda deney ve kontrol gruplarında son test olarak kullanılmıştır.
- Bilişsel Yük Anketi (BYA): Her bir Cebir konusunun bitiminde deney ve kontrol gruplarında kullanılmıştır.
- Öğrenci Görüş Anketi (ÖGA): Uygulamanın sonunda deney grubunda kullanılmıştır.
- Görüşme Formu (GF): Uygulamanın sonunda deney grubunda kullanılmıştır.

Cebir Başarı Testi (CBT)

Cebir Başarı Testi (CBT) 7.sınıf öğrencilerin Cebir konularında başarılarını belirlemek amacıyla araştırmacı tarafından geliştirilmiş olan toplam 20 açık uçlu sorudan oluşmaktadır. Tüm sorular 7.sınıf Cebir konularının içeriğine ve kazanımlarına uygun olarak hazırlanmıştır. Test, verilen bir cebirsel ifadenin değerini bulma, verilen bir cebirsel ifadenin en sade halini yazma, verilen bir örüntünün genel terimini bulma, denklem çözme, problemleri denklem kurarak çözme, denklemi verilen problem kurma, Kartezyen Koordinat Düzlemindeki bir noktayı bulma ve grafik çizme konularından sorular içermektedir. Test 80 puan üzerinden dereceli puanlama anahtarı ile değerlendirilmiştir. Testin kapsam geçerliliği, biri ilköğretim matematik bölümü doktora programından mezun olan dört tane öğretmen tarafından incelenmiştir. Soruların, amaçlar için uygun olup olmadığına ilişkin uzman cevapları, Likert tipi üçlü derecelendirme ölçeği kullanılarak elde edilmiştir. Uzman görüşlerine göre soruları daha anlaşılır kılmak adına bir takım değişiklikler yapılmıştır.

CBT'nin pilot çalışması 8.sınıf toplam 229 öğrenci ile 2010-2011 sonbahar döneminde bir devlet okulunda gerçekleştirilmiştir. Pilot çalışmanın amacı soruların anlaşılırlığını, teste verilen sürenin uygun olup olmadığını ve güvenirliğini bulmaktır. Pilot çalışma sonunda tüm kağıtlar dereceli puanlama anahtarına göre araştırmacı tarafından değerlendirilmiş, ayrıca iç tutarlılık katsayısı hesaplanması için de rasgele seçilen 80 kağıt bir matematik öğretmeni tarafından değerlendirilmiştir. ICC iç tutarlılık katsayısı .90 olarak bulunmuştur.

Bilişsel Yük Anketi (BYA)

Bilişsel yükün ölçülmesinde, Paas & Van Merrienboer (1993) tarafından geliştirilen 9'lu derecelendirme ölçeği deney ve kontrol gruplarında her bir Cebir konusunun bitiminde uygulanmıştır. Ölçek "çok, çok az"dan, "çok, çok fazla"ya kadar 9 derece içermektedir. Ölçeğin Türkçe'ye uyarlama çalışması Kılıç ve Karadeniz (2004) tarafından yapılmıştır. Kılıç ve Karadeniz, ölçeğin anlaşılırlığı ve çevirinin uygunluğu için uzmanlardan görüş almışlar ve deneme formu oluşturmuşlardır. Cronbach Alfa iç tutarlılık katsayısı .90 olarak bulunmuştur. Sezgin (2009) de yaptığı çalışmada BYA için .78 Cronbach Alfa iç tutarlık katsayısı bulmuştur.

BYK, öğretimin verimliliği ilgili bir kuramdır. Paas and van Merriënboer (1993) verimliliğin hesaplanması için performansa ve bilişsel yüke dayalı bir yöntem geliştirmişlerdir. Bu yöntemde, zihinsel çaba, performanstan çıkartılarak öğretimin verimliliği hesaplanmaktadır. Zihinsel çaba ve performansın etkisini birlikte görmek adına z-koordinat düzlemi kullanılmaktadır. Zihinsel çaba, x ekseninde ve performans ise y ekseninde gösterilmektedir. Öğretim ortamlarının etkililiğinin hesaplanmasında, bir noktanın doğruya olan uzaklığı formülü temel alınmış ve $E = \frac{z_{performans} - z_{bilişsel\ yük}}{\sqrt{2}}$ formülü kullanılmıştır.

Formüle göre, düşük bilişsel yük ve yüksek başarı puanı, yüksek verimliliği; yüksek bilişsel yük ve düşük başarı puanı, düşük verimliliği göstermektedir.

Bu çalışmada verimliliği hesaplamak için CBT ve BYA puanları z-puanına dönüştürülmüş ve yukarıda verilen formüle göre hesaplanarak verimlilik grafiği oluşturulmuştur.

Öğrenci Görüş Anketi (ÖGA)

Öğrencilerin uygulamaya ilişkin algılarını belirleme amacıyla hazırlanmış olan ÖGA araştırmacı tarafından geliştirilmiş olup 19 likert tipi ve beş açık uçlu sorudan oluşmaktadır. ÖGA, öğretim yöntemi, kullanılan materyaller, etkinlikler ve grup çalışmaları yanında BYK etkilerinden çalışılmış örnekler, tamamlama örnekleri ve biçem etkisi ile ilgili sorular da içermektedir. Cronbach Alfa iç tutarlılık katsayısı .91 olup, betimsel istatistik teknikleri ile analiz edilmiştir.

Görüşme Formu (GF)

Görüşme soruları araştırmacı tarafından anket sorularından türetilmiş olup araştırma sonrasında deney grubundan başarı durumları doğrultusunda seçilen 12 öğrenci ile gerçekleştirilmiştir. Görüşme yapılan her bir öğrenciye aynı sorular aynı sıra ile sorularak toplanan verinin daha detaylı ve analiz bakımından daha sistemli olacağı düşünülmüştür. Toplanan veri bilgisayar ortamında aktarılıp, nitel içerik analizi tekniği ile analiz edilmiştir.

Veri Toplama Süreci

Uygulamada kullanılacak olan Öğrenci ve Öğretmen Kitapçıkları araştırmacı tarafından geliştirilmiştir. Konular, kazanımlar, sınıf düzeyi, açıklığı ve genel düzeni bakımından kitapçıklar için uzman görüşü alınmıştır. Uygulama başlamadan önce araştırmacı tarafından deney ve kontrol grubu öğretmenlerine BYK ile ilgili olarak açıklamalar yapılmıştır. Uygulamanın başında, grupların denkliğini kontrol etmek amacıyla t-testi yapılmıştır. Uygulama toplam 6 hafta sürmüş ve araştırmacı tarafından sürekli gözlemler yapılmıştır. Uygulama süresince deney grubunda tüm Cebir konuları BYK ilkelerine göre hazırlanmış kitapçıklar üzerinden yürütülmüştür. Her bir ünitenin sonunda BYA uygulanmıştır. Uygulamanın bitiminde ise CBT her iki gruba da uygulanmıştır. ÖA ve GF araçları deney grubunda uygulanmıştır.

Veri Analizi

Araştırma sorularına göre bu araştırmada farklı veri analizi yöntemleri kullanılmıştır. İlk araştırma sorusu için MANOVA, ikinci araştırma sorusu için t-testi ve son soru için ise nitel içerik analiz tekniği kullanılmıştır.

Sınırlılıklar

Çalışma, seçilen devlet okulundaki 7.sınıflardan 80 öğrenci ve 2010-2011 öğretim yılı güz döneminde Cebir öğrenme alanı içeriğiyle sınırlıdır. Araştırmada ulaşılabilir örnekleme yoluna başvurulduğu için genelleme problemi oluşabilir. BYA'nın 9-likert tipi bir ölçek olması, öğrencilerin ölçeği anlaması bakımından bir takım sınırlılıklar getirebilir. BYK'nın yeni gelişen bir kuram olması ve deney grubu öğretmeninin kuramı anlama seviyesi çalışmanın sınırlarından biri olabilir.

Araştırmanın Geçerliliği

Bu bölümde çalışmanın geçerliliğine etki edecek bir takım tehditlere ve bunların nasıl önlenmeye çalışıldığına yer verilmiştir.

Katılımcı özellikleri tehdidini sabit tutmak amacıyla deney ve kontrol grubundaki katılımcıların ön test puanları karşılaştırılmış ve sonuçta iki grup arasında anlamlı bir fark bulunmamıştır. Araştırmada deney ve kontrol gruplarına uygulanan tüm ölçme araçları aynı yer ve zamanda yapılarak tarih ve yer tehditleri kontrol altında tutulmuştur. Veri toplama ve uygulayıcı tehditleri araştırmacı tarafından gözlemler yapılarak kontrol altına alınmıştır. Beklenti tehdidi CBT kağıtlarının araştırmacı dışında başka bir matematik öğretmeninin de okuması ile kontrol altına alınmıştır. Çalışmaya katılan tüm öğretmen ve öğrencilerin isimleri gizli tutularak gizlilik tehdidi kontrol altına alınmıştır.

4. Sonuçlar

Araştırmanın sonuçları aşağıda özetlenmiştir.

1. Deney ve kontrol gruplarının denkliğini kontrol etmek amacıyla yapılan t-testi sonuçlarına göre, grupların bir önceki yıl matematik başarı puanları arasında anlamlı bir farklılık yoktur. Bu sonuçlara göre uygulamanın başında grupların denk olduğu söylenebilir.

2. Betimsel istatistik sonuçlarına göre deney grubu CBT sonuçları (*M=41.18, SD=12.86*), kontrol grubu CBT sonuçlarından anlamlı bir şekilde daha yüksektir (*M=14.88, SD=8.28*). BYA sonuçlarına göre ise, deney grubu sonuçları (*M=3.58, SD=1.55*), kontrol grubu sonuçlarından anlamlı bir şekilde (*M=5.05, SD=1.39*) daha düşüktür.

3. Öğrencilerin BYA puanlarına göre tanımlanan bilişsel yüklenme durumlarına bakıldığında, Paas ve Merriënboer (1993)'in tanımladığı aralıklara göre, yüksek bilişsel yüke sahip deney grubunda 7 öğrenci, kontrol grubunda ise 23 öğrenci vardır. Benzer şekilde, düşük bilişsel yüke sahip deney grubunda 33, kontrol grubunda ise 17 öğrenci vardır. Buna göre kontrol grubunda yüksek bilişsel yüke sahip öğrencilerin sayısı daha fazladır.

4. MANOVA testi sonuçlarına göre BYK ilkelerine göre geliştirilmiş olan öğretimin öğrencilerin akademik başarılarına ve bilişsel yüklenmelerine anlamlı bir etkisi vardır. Tekli varyans analizi (ANOVA) sonuçlarına göre, öğrencilerin CBT ve BYA testlerinden aldıkları puanlar, kullanılan öğretim yönetimine göre anlamlı bir şekilde değişmektedir $F(1,78)=118.26$, $p<.05$ ve $F(1,78)=19.86$, $p<.05$. Gruplar CBT'indeki değişimin %60'ını, BYA'ndeki değişimin ise %20'sini açıklamıştır.

5. Deney ve kontrol grubundaki öğrencilerin CBT ve BYA sonuçları öğretimin verimliliği bakımından karşılaştırılmıştır. Deney grubunun verimlilik puanı (0.86), kontrol grubunun verimlilik puanından (-0.86) anlamlı bir şekilde yüksektir.

6. Öğrenci Anketi (ÖA) sonuçları, öğrencilerin büyük çoğunluğunun öğretim şeklinden (70%), kullanılan materyallerden (77.5%), ve sınıf içi etkinliklerden (77.5%) hoşlandığını göstermektedir. Ayrıca, öğrenciler kullanılan sınıf içi materyallerin öğrenmelerini kolaylaştırdığını (77.5%) ve BYK etkilerinden biçem etkisini (%72.5) yararlı bulduklarını belirtmişlerdir. Öğrencilerin büyük çoğunluğu verimliliği öğrenme süresi açısından değerlendirdiğinde, daha kısa sürede öğrendiğini belirtmiş (72.5%) ve bu öğretiliş şeklini diğer matematik derslerinin öğretilişinde de görmek istemiştir (72.5%).

7. Uygulama sonunda yapılan görüşmelerde, öğrenciler ders başında yapılan hatırlatmalar ve sorulan sorular hakkında olumlu görüş bildirmişlerdir. Tüm başarı gruplarındaki (düşük, orta, yüksek) öğrenciler çalışılmış örnekleri dersi öğrenmesi açısından yararlı bulduğunu belirtmiştir. Yarı Çalışılmış örnekler hakkında ise öğrenciler genellikle olumlu görüş belirtmiş ancak yüksek matematik seviyesine sahip öğrenciler, bu örneklerin kendileri için gereksiz olduğunu söylemişlerdir.

8. Öğrenciler, görüşmelerde Öğrenci Kitapçıklarının en büyük yararının ders işlenişinde not tutmanın yol açtığı dikkat dağınıklığını engellemesi olduğunu vurgulamışlardır. Ayrıca tahta kullanmak yerine öğretmen tarafından yapılan sözel açıklamaların öğrenmelerine olumlu olarak etki ettiğini ve sınıf içi aktivitelerin, konu hakkında deneyim kazandıktan sonra yapılmış olmasının, yani sınıf içi aktivitelerin dersin başlangıç noktası olmaması konusunda olumlu görüş belirtmişlerdir. Grup çalışmaları için ise sınıflarının kalabalık olması yüzünden ideal bir ortam olmadığını vurgulamışlardır.

9. Görüşmeye katılan tüm öğrenciler, bu öğretim tarzı ile daha kolay, daha çok ve daha kısa zamanda öğrendiklerini vurgulamışlardır. Öğrenciler bu öğretim şeklini başka matematik konularında ve diğer derslerde de görmek istediklerini belirtmişlerdir.

5. Tartışma

Bu bölümde elde edilen bulgulara yönelik tartışmalara yer verilmiştir.

Deney grubu öğrencilerinin, CBT sonuçları kontrol grubu öğrencilerinin CBT sonuçlarından yüksektir. BYA sonuçları karşılaştırıldığında ise, deney grubu öğrencilerinin BYA puanları kontrol grubu öğrencilerinden daha düşüktür. Bu sonuçlar yüksek performans ve düşük bilişsel yük sağlayan öğretim ortamlarının daha verimli olduğunu öneren literatür bulgularını destekler niteliktedir.

Deney grubu öğrencilerinin, CBT sonuçları kontrol grubu öğrencilerinin CBT sonuçlarından yüksek olmasına rağmen yine de her iki grubun da CBT başarısı düşüktür. Bunun bir sebebi olarak, öğrencilerin ön öğrenmeleri gösterilebilir. Uygulamanın başında grupların denkliğini kontrol etmek maksadıyla yapılan testte de öğrencilerin geçen yılki matematik puanlarının ortalamasının da çok fazla yüksek olmadığı görülür. Tatar ve Dikici (2008) öğrencilerin matematikte öğrenme güçlüğü yaşamasının sebeplerinden biri olarak yeterli ön öğrenmeye sahip olmamalarını göstermektedir.

Yapılan çalışmalarda sosyo-ekonomik çevrenin başarı üzerinde anlamlı bir farklılığa yol açtığı bulunmuştur. Ayrıca TIMMS 98-99 (Yayan, 2003) verilerine göre sosyo-ekonomik çevrenin matematik başarısı üzerine anlamlı olarak etki ettiği vurgulanmıştır. Ersoy ve Erbaş (1998) düşük sosyoekonomik çevrede bulunan bir okuldaki 7.sınıf öğrencilerle yaptıkları çalışmada, Cebir öğretiminin bu çevrede oldukça problemli olduğunu ortaya çıkarmışlardır. Orta ve yüksek sosyo-ekonomik durumlu öğrencilerle karşılaştırıldığında, düşük sosyo-ekonomik çevrede bulunan öğrencilerin cebir başarısı düşük bulunmuştur.

Düşük başarının bir başka sebebi ise okul özellikleri olabilir. Yapılan çalışmalar, okul donanımının ve sınıftaki öğrenci sayısının başarı üzerinde etkisi olduğunu göstermektedir.

CBT sonuçlarının deney grubunda yüksek çıkması BYK'nın düşük sosyo-ekonomik çevrede bulunan öğrenciler için verimli olduğu söylenebilir. Başka bir deyişle düşük sosyo-ekonomik çevrede bulunan okullardaki cebir öğretiminde BYK etkin bir öğretim yöntemi olarak kullanılabilir.

Çalışmanın sonuçları BYK ilkelerine göre geliştirilmiş olan öğretimin, öğrencilerin Cebir başarısına ve bilişsel yüklenmelerine etkisi olduğunu göstermiştir. Elde edilen sonuçlar literatürde rapor edilen birçok çalışmayla benzerlik göstermiştir. Bu bağlama, geliştirilmiş olan bu öğretimin, Cebir öğrenmede başarıyı artırmak ve bilişsel yüklenmeyi azalmakta etkin olduğu söylenebilir.

Araştırma bulgularına göre, BYK ilkelerine göre geliştirilmiş olan öğretimin kullanıldığı deney grubu ile MEB önerilerine göre geliştirilmiş öğretimin uygulandığı kontrol grubunun CBT ve bilişsel yük puanlarına göre hesaplanan öğretim verimliliği ile ilgili puan ortalamaları arasında deney grubu lehine anlamlı bir fark görülmüştür. Deney grubundaki öğretim, kontrol grubundaki öğretime göre daha verimli olmuştur. Literatürde rapor edilen BYK ilkelerine göre geliştirilmiş öğretimin daha verimli olduğu savını destekler niteliktedir. Türkiye'de yapılan çalışmalarda da benzer sonuçlara ulaşılmıştır. Kılıç (2006), Kablan ve Erden (2008), ve Sezgin (2009)'in yaptığı çalışmalarda, BYK ilkelerine göre tasarladıkları öğretim ortamları, karşılaştırıldıkları ortamlara göre daha verimli bulunmuştur.

Görüşmelere katılan öğrencilerin tamamı BYK ilkelerine göre tasarlanmış öğretim ile ilgili olarak olumlu görüşler belirtmişlerdir. Literatüre göre, sınıf ortamında öğrencilerin başarı seviyelerinin karma olması, ön öğrenmelerin önemi artırmaktadır ve buna önem vererek tasarlanan öğretim ortamlarını daha etkin kılmaktadır. Görüşmeler sırasında öğrenciler ders başında yapılan tekrarlar ve sorulan sorular hakkında olumlu görüş bildirmişlerdir. Öğrencilerin bu görüşleri literatürü destekler niteliktedir.

Tüm öğrenciler çalışılmış örnekler ve tamamlama örnekleri etkisi ile ilgili olarak olumlu görüş belirtmişlerdir. Clark ve diğerlerine (2005) göre çalışılmış örnekler çalışan belleğin sınırlı olan bilgi işleme kapasitelerini etkili kullanmalarını sağlayacak BYK etkilerinden biridir. Çalışılmış örnekler ile daha az çaba ile daha kısa sürede öğrenme sağlanabilmektedir. Özellikle düşük matematik seviyesine sahip olan öğrenciler, çalışılmış ve yarı çalışılmış örnekler hakkında olumlu görüşe sahiptir. Bu durum yeterli şemaya sahip olmamaları ile açıklanabilir. Öte yandan orta ve yüksek matematik başarısına sahip olan öğrenciler konuyu öğrendikten sonra hemen alıştırmalara geçmek istediklerini ve örnekleri incelemediklerini vurgulamışlardır. Bu sonuçlar konuyla ilgili literatürü destekler niteliktedir. Öğrencilerin konu hakkında deneyimleri arttıkça bu örneklerin yerini alıştırmalar almalıdır.

Görüşmelerde öğrenciler kullanılan sınıf içi materyaller hakkında olumlu görüş bildirmişlerdir. Ders esnasında not tutmayı azaltıp, dikkatlerinin dağılmasını engellediği için yararlı bulmuşlardır. Ayrıca, ders esnasında tahtayı kullanmak yerine yapılan sözel açıklamaların da faydalı olduğunu vurgulamışlardır. Tüm bu görüşler, literatürde BYK etkilerinden olan bölünmüş dikkat ve biçem etkileri ile ilgili yapılmış çalışmalarla desteklenmektedir.

Öğrenciler sınıf içi etkinlikler için bir takım öğrenmelerin gerçekleşmesini ve daha sonra bunu bir sınıf içi etkinlikler ile pekiştirmenin, öğrenmelerini ve motivasyonlarını etkilediğini belirtmişlerdir. Kısacası öğrenciler, ilgili literatür ile tutarlı olarak, konu hakkında deneyim kazandıktan sonra sınıf içi etkinliklere yer verilmesi gerektiğini vurgulamışlardır. Benzer yorum grup çalışmaları içinde geçerlidir.

Öğrencilerin uygulama ile ilgili olarak belirttiği tek olumsuz görüş konular hakkında deneyim kazandıktan sonra da çok fazla çok fazla yer verilmesidir. Literatürde, yapılan çalışmalar bu görüşü destekler niteliktedir. Öğrenciler daha az yoruldukları, ders esnasında not tutmadıkları gibi sebeplerden dolayı, bu öğretim tarzını başka matematik konularında ve derslerde de görmek istediklerini belirtmişlerdir. Öğrencilerin vurgu yaptığı konu bilişsel yüklenme seviyelerinin bu öğretim ile daha az olduğudur.

Uygulamadaki Öneriler

1. BYK'na göre verimli öğretim ortamları bilişsel mimariye bağlıdır. Bu nedenle bu sistemin özellikleri öğretim tasarımcıları tarafından iyi bilinmelidir.

2. Öğretimi tasarlarken çalışan bellek yapısı ve sınırlılıkları çok iyi bilinmeli ve çalışan bellek kapasitesi en verimli şekilde kullanılmalıdır.

3. Asıl yük yüksek olduğu durumlarda, çalışılmış örnekler, tamamlama örnekleri gibi uygun olan BYK etkileri kullanılarak asıl yük azaltılmalıdır.

4. Çalışan belleğin yükünü azaltmak ve uzun süreli belleğe aktarımı kolaylaştırmak için konu dışı yükü azaltmak gerekmektedir. Konu dışı yükü azaltmak için gerekli olan BYK etkileri göz önünde bulunmalıdır.

5. Çalışılmış örnekler konu dışı yükü azaltmak için kullanılmalıdır.

6. Çalışılmış örneklerin hemen ardından bir benzerinin alıştırma olarak verildiği ders tasarımları da konu dışı yükü azaltmak için kullanılmalıdır.

7. Destek etkisi özellikle öğrencilerin konu hakkında ön öğrenmelerinin bulunmadığı durumlarda kullanılmalıdır.

8. Öğrencilerin bilgi seviyesi öğretimi tasarlarken mutlaka göz önünde bulundurulmalıdır. Ön öğrenmeleri yetersiz olan bir öğrenci için gerekli olan bir bilgi, daha yüksek bilgi seviyesine sahip bir öğrencide yük oluşturabilir.

9. Ders esnasında not tutmak öğrencilerde bilişsel yüke sebep olabilir. Bu sebeple öğrenciler için küçük ders notları ve destekleyici materyaller kullanılabilir.

10. Öğretmenler için BYK ilke ve etkiler hakkında seminerler planlanabilir.

11. MEB tarafından uygulanan programlara BYK ilkeleri entegre edilerek bilişsel yükün azaltılması sağlanabilir.

Diğer Araştırmalar için Öneriler

1. Aynı araştırmanın tekrarı daha geniş örneklem gruplarında genelebilirlik sağlamak için tekrarlanabilir.

2. Gelecekteki araştırmalar farklı sınıf seviyelerinde, farklı matematik derslerinde ve diğer derslerde yapılabilir.

3. Gelecekteki araştırmalar, tesadüfi örneklem ile gerçek deneysel desenler tasarlanılarak gerçekleştirilebilir.

4. Bu çalışma düşük sosyo-ekonomik yapıya sahip bir okulda gerçekleştirilmiştir. Aynı çalışma özel okul gibi farklı okul şartlarında tekrar edilebilir.

5. Gelecekteki araştırmalar, motivasyon ve kalıcılık gibi farklı değişkenler eklenerek gerçekleştirilebilir.

6. Bu çalışmada bilişsel yük ölçümleri 9'lu derecelendirme ölçeği kullanılarak öznel olarak ölçülmüştür. Başka uygulamalarda kalp atışı, kalp atışı değişimi, beyin dalgası gibi fizyolojik ölçümler kullanılabilir.

7. Bu çalışmada BYK etkileri bir arada kullanılmıştır. Gelecekteki araştırmalarda bu etkilere ayrı bakılabilir.

8. Bu çalışmada verimlilik, başarı ve bilişsel yük puanları ile hesaplanmıştır. Gelecekteki çalışmalarda zaman faktörü de eklenebilir.

APPENDIX P

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: TAKIR, Aygil
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Date and Place of Birth: 07 November 1978, KKTC
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EDUCATION

Degree	Institution	Year
PhD	METU	2005-2011
MS	EMU Applied Mathematics	1999-2001
BS	EMU Applied Mathematics	1995-1999
High School	Namık Kemal Lisesi	1992-1995

WORK EXPERIENCE

Year	Place	Enrolment
2009-2010	İKMYO	Instructor
2005-2009	TED Ankara Koleji	Mathematics Teacher
2001-2002	EMU	Instructor
2002 Spring	Denklem Eğitim Merkezi	Mathematics Teacher
1999-2001	EMU	Research Assistant

FOREIGN LANGUAGE

English