THE EFFECT OF THE HYPOTHETICAL LEARNING TRAJECTORES AND THE CONTRIBUTION OF EYE-TRACKING TECHNOLOGY IN UNDERSTANDING YOUNG CHILDREN'S MATHEMATICAL PATTERNING RECOGNITION AND GENERALIZATION

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Prof. Dr. Yaşar Kondakçı
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Doctor of Philosophy.

Assist. Prof. Dr. H. Özlen Demircan
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Doctor of Philosophy.

Prof. Emeritus Dr. Arthur J. Baroody
Co-Supervisor

Assist. Prof. Dr. Volkan Şahin
Supervisor

Examining Committee Members

Prof. Dr. Kürşat Çağıltay (METU, CEIT)

Assist. Prof. Dr. Volkan Şahin (METU, EECE)

Prof. Emeritus Dr. Arthur J. Baroody (UIUC, EC&EME)

Prof. Dr. Douglas H. Clements (Denver Uni., ECE&EME)

Prof. Dr. Erdinç Çakıroğlu (METU, MSE)

Assist. Prof. Dr. Arif Yılmaz (Hacettepe Uni., EECE)

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

Name, Last name: Nursel YILMAZ

Signature :

ABSTRACT

THE EFFECT OF THE HYPOTHETICAL LEARNING TRAJECTORIES AND THE CONTRIBUTION OF THE EYE-TRACKING TECHNOLOGY IN UNDERSTANDING THE YOUNG CHILDREN'S MATHEMATICAL PATTERNING RECOGNITION AND GENERALIZATION

YILMAZ, Nursel

Ph.D., Department of Early Childhood Education

Advisor: Assist. Prof. Dr. Volkan ŞAHİN

Co-advisor: Prof. Emeritus Dr. Arthur BAROODY

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The primary aim of this study is to evaluate whether patterning instruction based on a hypothetical learning trajectory (HLT) is more efficacious than the same instruction presented in an integrated manner or business as usual. The HLT-based and integrated instruction were developed using Design-Based Research (DBR) involving three phases and two iteration cycles. The patterning HLT and accompanying instructional activities proposed by Clements and Sarama (2009) was the starting point for the HLT-based instruction and a modified HLT version of this HLT was evaluated in the present study. A randomized control trial involved [n=48] 4- and 5-year-olds assigned to an experimental condition (HLT-based instruction), an active control (integrated instruction), and a passive control (business as usual). Both concrete and computer-supported activities were utilized during the training. Eye-tracking technology data were collected to better understand the cognitive processes underlying patterning learning. Quantitative and qualitative analyses were used to analyze the collected data. While descriptive statistics and inferential statistics such as ANOVA and ANCOVA were used for quantitative analyses, the heat maps and gaze plots were benefited for qualitative analyses. A significant and substantial difference was found between the treatment and the passive control condition (on the overall score at the delayed posttest. The active control condition likewise significantly outperformed and business-as-usual condition. When each patterning skill (i.e., extension, translation, and core identification) was separately investigated, resuts showed a s ignificant and substantial difference between the groups. Eye-tracking methodology and qualitative analyses revealed a number of interesting findings. Different cognitive behaviors were observed during the extension, translation, and the core-identification of the AB, ABB, ABC patterns. The possible reasons and extensive discussions were followed to lead the implementations and recommendations.

Keywords: Hypothetical Learning Trajectories, Young Children, Early Mathematical Patterning, Eye-tracking, Cognition

ÖZ

ÇOCUKLARIN MATEMATİKSEL ÖRÜNTÜLERİ TANIMLAMA VE GENELLEMESİNDE VARSAYIMSAL ÖĞRENME ROTALARININ ETKİSİ VE GÖZ İZLEME TEKNOLOJİSİNİN KATKISI

Yılmaz, Nursel
Doktora, Okul Öncesi Eğitimi Bölümü
Tez Yöneticisi : Dr. Öğr. Ü. Volkan Şahin
Ortak Tez Yôneticisi : Prof. Dr. Arthur Baroody

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Bu çalışmanın temel amacı, 4- ve 5 yaş çocukların [n = 48] matematiksel örüntüleri öğrenmelerinde, kullanılan öğretimin etkiliğini değerlendirmektir. Bu amaçla, bu çalışma, Tasarım Tabanlı Araştırma (Design-Based Research, DBR) modeli kapsamında, gerçek deneysel desen (öntest-sontest-kontrol gruplu seçkisiz desen) olarak tasarlanmış ve üç farklı deneysel grup oluşturulmuştur. Ayrıca, örüntü öğrenmenin temelinde yatan bilişsel süreçleri daha iyi anlamak için göz izleme verileri toplanmıştır. Tanımlayıcı istatistikler ve ANOVA/ANCOVA gibi çıkarımsal istatistikler nicel analizler için kullanılırken, nitel analizler için ise ısı haritaları ve bakış grafikleri kullanılmıştır. Yapilan analizler sonucunda, gruplar arasında anlamlı bir fark ortaya çıkmıştır. Sonuçlara göre kontrol ve aktif kontrol grubunun, geleneksel kontrol grubuna kıyasla daha başarılı olduğu bulunmuştur. Her bir örüntü becerisi ayrı ayrı incelendiğinde ise yine gruplar arasında önemli farklılıklar bulunmuştur. Spesifik olarak, örüntüleri devam ettirme becerisi için, deney grubu ile pasif kontrol grubu arasında anlamlı bir fark tespit edilmiş. Örüntüleri farklı materyaller ile oluşturma becerisi açısından, aktif kontrol grubu ile pasif kontrol grubu arasında önemli bir fark tespit edilirken, örüntünün çekirdek birimini tanımlama becerileri ile ilgili olarak, hem deney grubu ve hem de aktif kontrol grubu ile pasif kontrol grubu arasında önemli bir fark bulunmuştur. Bu bulgulara ek olarak, göz izleme metodolojisi de çok sayıda ilginç bulgular ortaya çıkarmıştır. Cocuklarin AB, ABB ve ABC örüntülerine ilişkin verilen gorevleri yaparken farkı bilişsel davranışlar sergiledikleri gözlemlenmiştir. Bu durumlarin olası nedenleri detaylı olarak tartılmış ve öneriler sunulmuştur.

Anahtar Kelimeler: Varsayımsal Öğrenme Rotaları, Çocuklar, Erken Örüntü Becerileri, Göz İzleme, Biliş

To My Beloved Dad

-Yusuf Yılmaz-

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LIST OF ABBREVIATIONS

AOI	Area of Interest
BAU	Business as Usual
DBR	Design Based Research
HLT	Hypothetical Learning Trajectories
IRB	Institutional Review Board
NAEYC	National Association for the Education of Young Children
NCCA	National Council for Curriculum and Assessment
NCTM	National Council of Teachers of Mathematics
METU	Middle East Technical University
MoNE	Ministry of National Education (Turkey)
REMA	Research-based Early Math Achievement
UIUC	University of Illinois at Urbana-Champaign

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Mathematics education is seen as a key aspect of early childhood education. Indeed, mathematics is described as a way of thinking, seeing, and organizing the world (Van de Walle, Karp, Bay-Williams & McGarvey, 2018; Zevenbergen, Dole, & Wright, 2004). The National Association for the Education of Young Children (NAEYC, 2002; 2012) and the National Council for Teachers of Mathematics (NCTM, 2002) have underscored the importance of early mathematics instruction as a fundamental basis for future mathematics learning. It is widely recognized that such instruction should include patterning (e.g., the recognition, duplication, and extension of patterns; National Council for Curriculum and Assessment [NCCA] 2014; NCTM, 2010). Patterning is an important aspect of early childhood mathematics education, because it plays a crucial role in children's mathematical thinking and development (NCTM, 2010), particularly, algebraic thinking (NCCA, 2014). Hypothetical Learning Trajectories (HLTs) can play an important tool for teachers in helping them to understand, promote, and assess children's mathematical thinking and development (Butterfield, Forrester, McCallum, & Chinnapan, 2013; Sarama & Clements 2009). HLTs consist of three parts: "a goal (what children should learn), a developmental progression (a learning path through which children move through levels of thinking), and instruction that helps them move along that path" (Sarama & Clements 2009, p. 17).

However, little research exists on the early teaching and learning of patterning (Clements & Sarama, 2009), and -at the time of the writing- no research has focused on whether hypothetical learning trajectories (HLTs) might facilitate patterning instruction with preschoolers (Frye, Baroody, Burchinal, Carver, Jordan, & McDowell, 2013). A primary goal of the present research was to evaluate the efficacy of using a HLT-based approach by comparing such an approach with instruction that used the same activities but did not follow the HLT and a business-as-usual comparison condition. This research served to evaluate a key and largely untested assumption of an HLT approach—that following the developmental sequence prescribed a HLT is more likely to impact meaningful leaning than instruction that does not. Another anticipated outcome was that the research would confirm the developmental progression suggested by Sarama and Clements's (2009) or suggest revisions to this HLT.

A second goal was to examine the underlying cognitive processes of patterning learning. This was done by using the eye-tracking methodology in conjunction with observations of children's patterning activities. This research helped to understand how children perform patterning skills namely, extension, translation, and core-identification. Moreover, the findings from eye-tracking data would support the early patterning research results or give a new insight into the related literature.

CHAPTER 2

LITERATURE REVIEW

In this chapter of the study, the theories and the related literature as the basis of the present research are described. For this purpose, first, the patterns and the importance of mathematical patterning in early childhood education are explained. Second, the theoretical framework underlined and the Hypothetical Learning Trajectories (HLTs) are explained. Third, the eye-tracking methodology is defined. Finally, the studies conducted in early patterning and eye-tracking literature as well as the need for the present study are presented in detail.

2.1 Patterns and Patterning Instruction

2.1.1 Patterns and Patterning

Mathematics has been described as the "science of patterns" (Steen, 1998) and Papic, Mulligan, and Mitchelmore (2011) define a pattern as "any replicable regularity" (p. 238). Looking for patterns and making generalizations based on patterns are key strategies for solving problems and extending mathematical knowledge (Polya, 1973; Stacy, 1989). Indeed, patterning refers to operating on patterns (e.g., recognizing, identifying, duplicating or extending repeating patterns). For example, Clements and Sarama (2009) define patterning as "the search for mathematical regularities and structures" (p. 190). Moreover, Pasnak (2017) describes patterning as “the ability to abstract the rule that defines a predictable sequence of items” (p.2276). Therefore, pattering is seen as a “habit of thinking” rather than a content area (Clements & Sarama, 2009).

There are three common types of patterns such as “repeating pattern, growing pattern, and spatial pattern” (Lüken, 2018; Papic & Mulligan, 2007). To explain each of them, a repeating pattern is one type of patterns, ”the pattern has a cyclic structure that can be generated by the repeated application of a smaller portion of the pattern” (Liljedahl, 2004, p. 27). For example, red-blue, red-blue, red-blue pattern or ABABAB pattern, or circle-square, circle-square, circle-square pattern are some instances for the repeating patterns. A growing pattern, however, includes systematic decreases and increases (Papic & Mulligan, 2007). A pattern such as O◊, O◊◊, O◊◊◊, is one of the examples for growing pattern. Lastly, a spatial pattern is defined as “the mental organization of objects or groups of objects and their components (Papic & Mulligan, 2007) (e.g., a rectangular grid pattern made with 3 squares, Papic & Mulligan, 2005, p. 614). In this study, the repeating patterns in which the unit cores cyclically repeat were used as the type of pattern. The unit core is the shortest sequence of elements that repeats to form the rest of the pattern (Sarama & Clements, 2009).

2.1.2 Patterning Instruction

In the report published by The National Council of Teachers of Mathematics (NCTM) (2000), it is advised to design instruction curriculum to enable all students from Pre-Kindergarten to Grade 12 “to understand patterns, relations, and function; to represent and analyze mathematical situations and structures using algebraic symbols; to use mathematical models to represent and understand quantitative relationships; and to analyze change in various contexts" (p. 394). Accordingly, some early childhood programs such as Big Math for Little Kids (Ginsburg, 2002), Building Blocks (Clements & Sarama, 2007b), and the Pattern and Structure Mathematics Awareness Program (PASMAP) (Mulligan, Mitchelmore, & Prescott, 2006; Mulligan et al., 2008) included mathematical patterning to improve children's mathematical development. In order for children to gain deep insights into these mathematical skills and learning areas, effective pedagogical practices are necessary to be designed and children need to have high-quality mathematics experiences. What is more, it is emphasized that children's interests, needs, wonders, curiosity, and daily experiences should be considered as a necessity for good mathematics activities in order to enhance those skills and learning areas (NAEYC, 2002; 2012; NCCA, 2014). For example, while mathematically talented children can be supported to advance their understanding by differentiated tasks (NCCA, 2014); children having mathematical difficulties can be guided and assisted by small group activities (Kroeger, Brown, & O'Brien, 2012). In addition, some researchers (e.g., Davies, 2002; Ginsburg & Golbeck, 2004) supported that play provides a valuable source for children to improve spontaneously their mathematical development. Moreover, daily activities such as cooking, moving around the environment can be benefited to provide young children opportunities for practicing and developing their mathematical ability (Anthony & Walshaw, 2009). For example, rhymes and songs can be used for the teaching of time and pattern (Ginsburg, 2017). Therefore, early childhood teachers can benefit from a variety of tools including digital tools. Likewise, computer technologies can be used to provide this variety. For example, Clements (1999) stated that since computers let children manipulate the objects, they have a unique environment. Moreover, it is stated that computers can provide a great opportunity to children for discovering the situations that could be impossible even in the real world (Clements, 1999; Clements & Battista, 2002; Clements & Burns, 2000; Reimer & Moyer, 2004; Resnick, 2000; Seng, 1998). Although there was a debate on whether technology should be integrated in early childhood classrooms and activities in the 1980s (Barnes & Hill, 1983; Cuffaro, 1984), the research has replaced this debate on how technology can be used effectively and appropriately to contribute the young children's whole development (i.e., cognitive, social, emotional, linguistic, and literacy) (Clements 1994, Clements & Nastasi, 1993; Clements & Sarama, 1998, 2002; Haugland 1992; Haugland & Wright, 1997; McCarrick & Li, 2007; McKenney & Voogt, 2009; Plowman & Stephen, 2003; Vernadakis, Avgerinos, Tsitskari, & Zachopoulou, 2005). However, there are some researchers who object to use of the computer and related technologies in early childhood education because they claim that children may negatively be affected from technological tools (Healey, 1998; Maynard, 2010). For example, Maynard (2010) thinks that computer activities restrict toddlers from complex movement and spontaneous dialog. Moreover, it was stated that children may have pain in their body parts because of spending much time on technological tools (Cordes & Miller, 2000). In addition, some researchers think that technological tools enable children to exposure to violence and other unsuitable contents (Funk, 2001; Wartella & Jennings, 2000). However, such kinds of concerns and threats can affect others who exposure mentioned technologies (Thompson & Haninger, 2001). Therefore, for the case of young children, proper adult guidance (American Academy of Pediatrics [AAP], 2011; Healey & Mendelsohn, 2019; Plowman & Stephen, 2003) and limited screen time (Elkind, 2007) may help to prevent the possible drawbacks of the computer and related technologies misuse. Indeed, both previous research (e.g., Clements & Sarama, 1998, 2002; Haugland & Wright, 1997; Li & Atkins, 2004; Plowman & Stephen, 2003; Sancak, 2003; Tanju, 2004; Yelland, 1998, 2002) and recent research acknowledged the positive effects of the appropriate use of computer technologies in early childhood children's development (e.g., Ayvacı & Devecioğlu, 2010; Çankaya, 2012; Demir & Kabadayı, 2008; Judge, 2005; Kaçar & Doğan, 2010; Kol, 2012; McCarrick & Li, 2007; McKenney & Voogt, 2009; Nikiforidou & Pangea, 2010; Ortega-Tudela & Gomez-Ariza, 2006; Räsänen, Salminen, Wilson, Aunio, & Dehaene, 2009; Vernadakis, Avgerinos, Tsitskari, & Zachopoulou, 2005; Weiss, Kramarski, & Talis, 2006; Zaranis, 2011). Moreover, NAEYC (1996; 2012) informs that computers could advance children's cognitive development when they are used in developmentally appropriate. Therefore, the advantage of computer activities can be taken into consideration while planning instructional activities for young children's mathematical development. For example, Sarama and Clements (2002) developed a software-based mathematics curriculum called Building Blocks for PreK and Grade 2 children. In this research-based early mathematics curriculum, many activities were prepared as software application to support children's mathematics learning (Sarama & Clements, 2002). Similarly, virtual manipulatives, which use computers are suggested to advance children's mathematical development starting from kindergarten (Moyer, Bolyard, & Spikell, 2002).

In brief then, patterning is considered at the central of the mathematics and an essential part of the early mathematics. In order for young children to gain deep understanding on patterning skills both manual activities and appropriate computer-supported activities can be utilized in early patterning instruction.

2.2 Theoretical Framework

2.2.1 Constructivism and Cognitive Theories

For many years, theorists have developed their theories to contribute to early childhood education. When it is investigated more about the human brain, psychology, and the developmental process, it is seen that learning is a complex process because it includes many variables (Molnar, 1997). Previously, it was thought that the mind is like a "black box" in the sense of response and it ignores the thought processes which occur in the mind. This view is called as a theory of behaviorism and it concentrates on only observed and measured behaviors (Sprinthall & Sprinthall, 1990). However, by the time, basic concepts and theories were updated and new theories appeared (Molnar, 1997). In other words, it is anymore expected that children should construct their own sense of the world and their own interpretations by actively involved in shaping the learning process (Donaldson & Knupfer, 2002). This view is framed as interactionalist or constructivist approach (Sarama & Clements, 2009). As being interested in the construction of the knowledge in a child's mind, constructivist theory emphasizes the term "active learning" and believes that nobody can have experiences or construct knowledge for the child. Instead, children learn best from pursuing their own interests while being actively supported and challenged by adults (Hohmann & Weikart, 1995; Wadsworth, 2004). Therefore, the learner (i.e., children) is considered in the center of the education (Perkins, 1991). Rooting from the constructivist approach and synthesis of the previous theories, a new framework, *Hierarchic Interactionalism* was proposed by Sarama and Clements (2009). This theoretical framework is constructed by "the influence and interaction of global and local (domain specific) cognitive levels and the interactions of innate competencies, internal resources, and experience (e.g., cultural tools and teaching)" (Sarama & Clements, 2009, p. 20). Therefore, it is claimed that children have an understanding of mathematical thinking and construct these understandings after metacognitively acquired mathematical ideas. Therefore, building on constructivism and hierarchic interactionalism, Hypothetical Learning Trajectories (HLTs) are presented as a powerful approach for the teaching and learning of mathematics and mathematical thinking (Clements & Sarama, 2004; 2009; Simon, 1995).

2.2.2 Hypothetical Learning Trajectory (HLT)

In mathematics education, constructivism has been considered as a fundamental basis for empirical and theoretical research studies (Steffe & Gale, 1995). As bringing new perspectives to re-define "learning and learners" in mathematics education, however, the constructivism presents no clear and specific model for teaching mathematics (Simon, 1995). Therefore, on the basis of constructivism, Simon (1995) recommends working on the specific types of teaching and learning models integrating theory and practice to enhance mathematical thinking. For this purpose, the notion of "Hypothetical Learning Trajectories" grounded in constructivism was introduced by Simon (1995) as a combination of "the learning goal, the learning activities, and the thinking and learning in which the students might engage" (p. 133). What is more, Simon (1995) deliberately uses the terms of "Hypothetical" and "Trajectory" for his definition in which he defines the trajectory as "the path that you travel" and hypothetical trajectory as "the path anticipated at any point in time" (p.137). Based on the relationships between the domains, Simon (1995) designs "Mathematics Learning Cycle" model, and puts the hypothetical learning trajectories in the central of this model (see Figure 1).

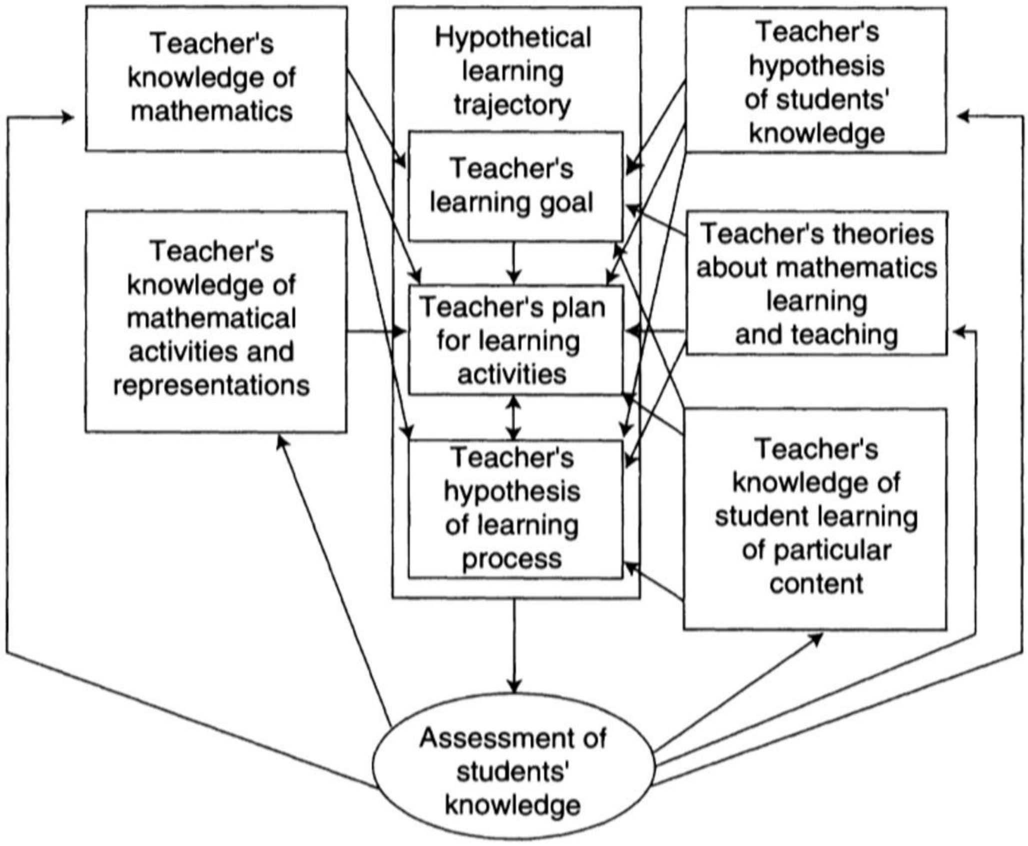


Figure 1: Mathematics learning cycle (taken from Simon, 1995, p.137)

As giving importance to Simon's framework (1995), some other researchers have also adapted the point view of hypothetical learning trajectory (HLT) to better understand and contribute to the children's mathematical thinking and development.

In addition, Battista (2011) describes learning trajectory as "a detailed description of the sequence of thoughts, ways of reasoning, and strategies that a student employs while involved in learning a topic, including specification of how the student deals with all instructional tasks and social interactions during this sequence" (p. 510). As seen from the description, Battista (2011) emphasizes the learner's cognition and tries to construct his

LT definition to around this concept. Furthermore, he mentions about the "levels of sophistications" which may include some jumps between the levels (Battista, 2011) (see Figure 2).

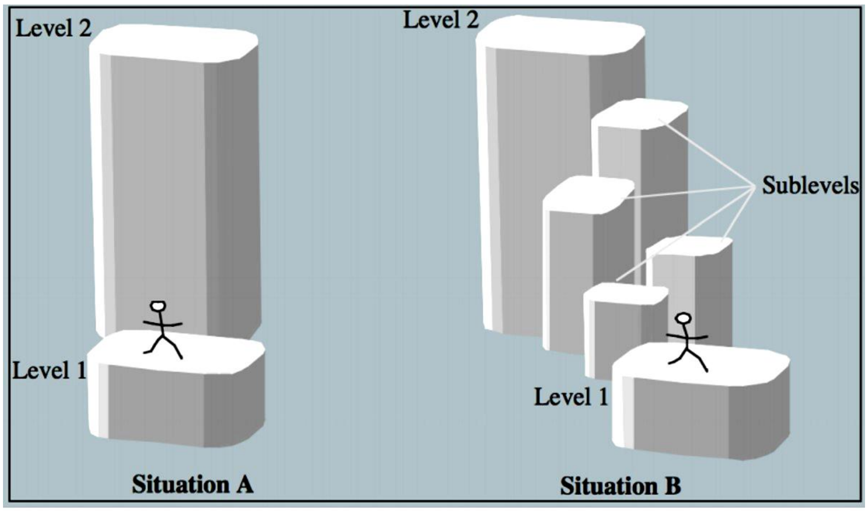
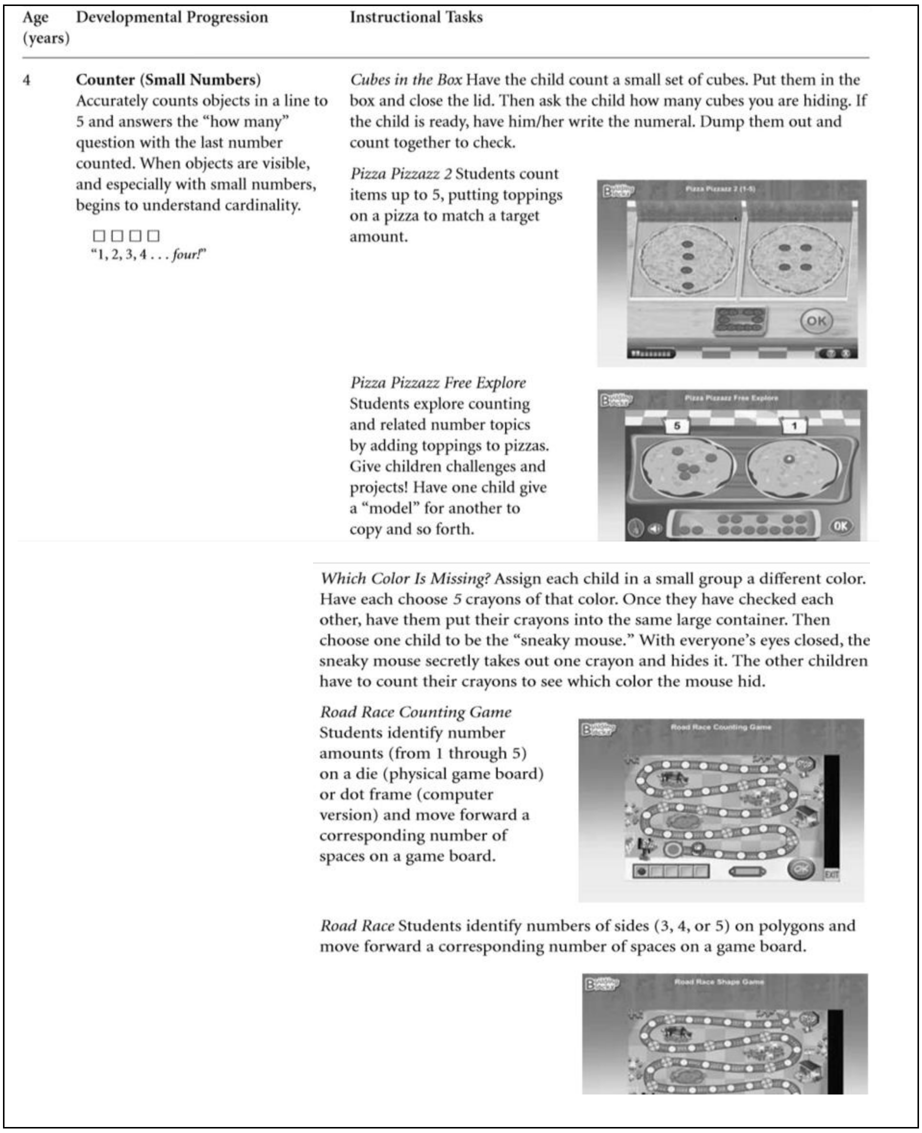


Figure 2: An illustration of the conceptualizing and reasoning between the levels (adapted from Battista, 2011, p.531)

Similarly, Ellis, Weber, and Lockwood (2014) explain the learning trajectory as "an account of changes in a student's schemes and operations; as such, it is a tool that seeks to explain learning that occurs over time, specifying the particular schemes and operations in play and elaborating how accommodation occurs to build up knowledge" (p. 2). As seen from the explanation, the researchers focus on learners and their strategies. On the other hand, Confrey and her colleagues (2009) make a different representation of the learning trajectory as "A researcher-conjectured, empirically-supported description of the ordered network of experiences a student encounters through instruction (i.e., activities, tasks, tools, forms of interaction and methods of evaluation), in order to move from informal ideas, through successive refinements of representation, articulation, and reflection, towards increasingly complex concepts over time" (p. 3). The role of the empirical findings is underlined in the definition to support the process that the students build their learning experiences.

Similar to Simon (1995), a description was made by Clements and Sarama (2004) who conceptualize the HLTs as "descriptions of children's thinking and learning in a specific mathematical domain, and a related conjectured route through a set of instructional tasks designed to engender those mental processes or actions hypothesized to move children through a developmental progression of levels of thinking, created with the intent of supporting children's achievement of specific goals in that mathematical domain" (p. 83). According to Clements and Sarama (2009), children have natural levels of development and what important is to understand these developmental levels and design the instructional activities for an effective learning environment. Sarama and Clements (2009) state that "learning trajectories have three parts: a goal (that is, an aspect of a mathematical domain children should learn), a developmental progression, or learning path through which children move through levels of thinking, and instruction that helps them move along that path" (p.17). As it is seen from the explanations, in a complete HLT, there will be three main aspects that are a mathematical learning goal, the paths of learning, and the paths of teaching. To expound, the first aspect of the HLT is learning goals which means "the big ideas of mathematics". For example, in a learning trajectory for counting, the goal is "sophisticated counting" which is seen as one of the important strategies for quantification. The second aspect is the paths of learning which are also known as the levels of thinking and guide children to accomplish the learning goal. In each developmental progression, children are expected to demonstrate some certain of behaviors corresponding to the level of thinking. For example, for the "Counter (Small Numbers)" developmental level in the counting learning trajectory, the child is expected to "accurately count objects in a line to five and answers the "how many" question with the last number counted. When objects are visible, and especially with small numbers, begins to understand cardinality…." (Sarama & Clements, 2009, p.74). Lastly, the third aspect is which mean the instructional sequences providing children an effective learning environment to attain the learning goal. For example, again for the "Counter (Small Numbers)" developmental level in the counting learning trajectory, the sequence of instructional tasks can be as "Have the child count a small set of cubes. Put them in the box and close the lid. Then ask the child how many cubes you are hiding. If the child is ready, have him/her write the numeral. Dump them out and count together to check…" (Clements & Sarama, 2009, p. 31). In the end, as seen in Figure 4, all essential parts can be formed for a complete HLT. In brief then, the essence of the learning paths is hypothesized to promote children's mathematical development using some sort of instructions to achieve the goals.



Age (years)	Developmental Progression	Instructional Tasks
4	**Counter (Small Numbers)** Accurately counts objects in a line to 5 and answers the "how many" question with the last number counted. When objects are visible, and especially with small numbers, begins to understand cardinality. □□□□ "1, 2, 3, 4 . . . *four!*"	*Cubes in the Box* Have the child count a small set of cubes. Put them in the box and close the lid. Then ask the child how many cubes you are hiding. If the child is ready, have him/her write the numeral. Dump them out and count together to check. *Pizza Pizzazz 2* Students count items up to 5, putting toppings on a pizza to match a target amount. *Pizza Pizzazz Free Explore* Students explore counting and related number topics by adding toppings to pizzas. Give children challenges and projects! Have one child give a "model" for another to copy and so forth.
		Which Color Is Missing? Assign each child in a small group a different color. Have each choose 5 crayons of that color. Once they have checked each other, have them put their crayons into the same large container. Then choose one child to be the "sneaky mouse." With everyone's eyes closed, the sneaky mouse secretly takes out one crayon and hides it. The other children have to count their crayons to see which color the mouse hid. *Road Race Counting Game* Students identify number amounts (from 1 through 5) on a die (physical game board) or dot frame (computer version) and move forward a corresponding number of spaces on a game board. *Road Race* Students identify numbers of sides (3, 4, or 5) on polygons and move forward a corresponding number of spaces on a game board.

***Figure 3*:** An illustration of the complete HLT for counting (taken from Clement & Sarama, 2009, p.31)

According to Empson (2011), the idea of learning trajectories can make a coherent relationship between the thoughts on curriculum and learning. Indeed, learning trajectories are believed the most powerful tool for both teachers and researchers to understand and improve the children's mathematical thinking and development (Daro, Mosher, & Cocoran, 2011; Sarama & Clements, 2009). Considering all the definitions and the frameworks conceptualized for learning trajectories, in this dissertation, will ground on the HLT proposed by Sarama and Clements (2009), as focusing on complete three dimensions of learning trajectories (i.e., goals, developmental progressions, and the sequence of instructional tasks) and having close similarity to the original HLT concept proposed by Simon (1995).

2.3 Eye-Tracking Methodology

Eye-tracking methodology, a new tool to understand human cognition, helps to record individuals' eye movements when they look at a screen, a printed text or a physical environment around (Holmqvist, Nyström, Andersson, Dewhurst, Jarodzka, & Van de Weijer, 2011). Therefore, eye-tracking gives unique information about participants' experience which allows researchers to interpret the related data (Duchowski, 2007). Indeed, the researchers have attempted to conduct some studies using eye-tracking to understand the cognitive process (Land, 2007; Reingold, 2014).

Eye movements are seen as crucial for understanding the behaviors of human as the eyes help to collect information around and enable the mind to react, accordingly (Just & Carpenter, 1980; Tatler, Kirtley, Macdonald, Mitchell, & Savage, 2014; Wade & Tatler, 2011). In other words, if we could track the eye movements, we may understand the clues related to the attention, concentration, consciousness, interests, and perception. That is, eye-tracking data may help the researchers to the interpret the participants' interests while they are looking at the screen, their visual attention to acquire the new information, and their perception regarding the scene they see (Duchowski, 2006; 2017; Horsley, 2014; Wade & Tatler, 2011). Therefore, eye movements can provide unique and objective data to make interpretations of human cognition and behavior. For example, when surrounded by some scenes, the eyes mostly focus on the locations or objects that are attractive to the person or new to occur learning (Land, Mennie, & Rusted, 1999; Hayhoe, 2000). This situation is measured by fixation metrics in eye-tracking terminologies (Duchowski, 2006; 2017). Fixation lengths can be ranged from 100 to 600 milliseconds and the fixation frequency is typically smaller than 3 Hz (Matos, 2010; Rayner, 2009). Moreover, when a new visual takes the attention, the eyes rapidly move to that direction either as voluntarily or reflexively, which is explained by the term "Saccades" (Duchowski, 2006). The length of the saccades may be varied from 20 to 40 milliseconds (Matos, 2010). According to Duchowski (2017), learning occurs during the fixation process and the eyes can move from one fixation area to another one with saccades (see Figure 5).

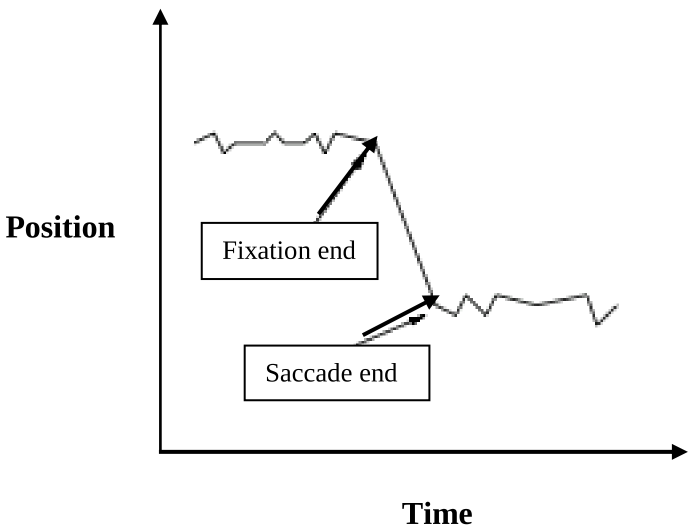


Figure 5: Eye movement signals regarding position and time (adapted by Duchowski, 2017, p.138)

Moreover, in the Tobii manual (Matos, 2010), these two terms are demonstrated in a different way but in similar understanding as illustrated in Figure 6 and Figure 7.

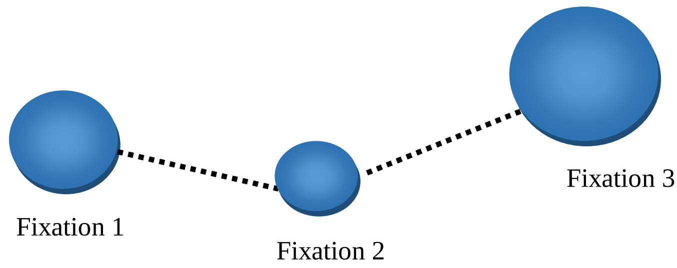


Figure 6: Demonstration of the fixations in blue circles (adapted from Tobii by Matos, 2010)

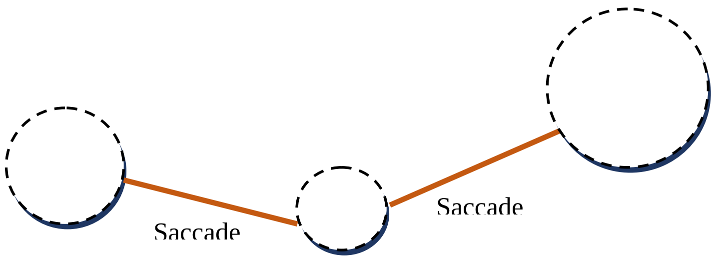


Figure 7: Demonstration of the saccades in orange line (adapted from Tobii by Matos, 2010)

As mentioned before, the fixation is an important measure that shows the brain gets ready to process the inputs coming from the eyes. And the length of the fixation gives more interpretations about cognitive activities On the other hand, saccades patterns showing backward movements can give insights about the difficulties and confusion of the scene (Matos, 2010). Heat maps and gaze plots can be used as a clear and powerful way in order to visually demonstrate these eye-movements. To define, heat maps mean “a visualization that can effectively reveal the focus of visual attention for dozens or even hundreds of participants at a time” (Tobii Tutorial, 2019). In other words, heat maps give a distributed look over the given scene without a sequence of looking and individual fixations (see Figure 8).

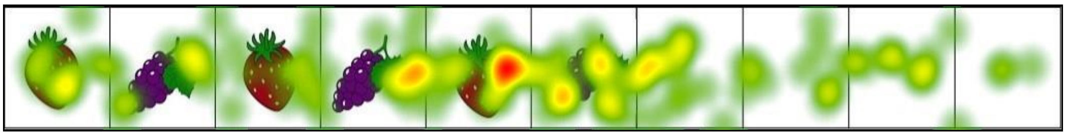


Figure 8. An example of a heat map (taken from the present study)

As it is seen from the Figure 9, there are some different colors which indicates the amount and the duration of fixations on the given picture. That is, red colors indicate that this area were looked at the most and attracted more attention, while green colors indicate the opposite (see Figure 9). Therefore, heat maps may be useful to have a general idea about the places given attention.

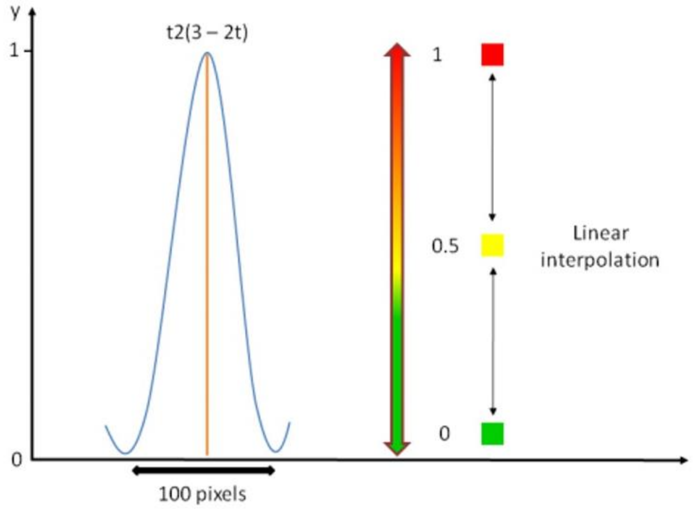


Figure 9. The illustration of the heat map color distribution (adapted from Tobii User Manual, 2019)

On the other hand, gaze plots may give more details about qualitative analysis because gaze plots aim to "reveal the time sequence of looking or where we look and when we look there". In other words, the gaze plots present "the location, order, and time spent looking at locations" on the given scene (Tobii Tutorial, 2019) (see Figure 10).

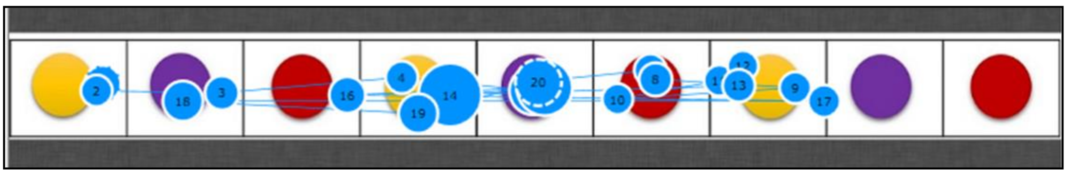


Figure 10. An example of gaze plots (taken from the present study)

As seen in Figure 10, the numbers seen in the dots reveal the order of the fixations (i.e., where the participants looked at first and last or which path did the participants follow) while the size of the dots shows the amount of the fixations. Therefore, gaze plots may help to understand the thought processes and strategies that participants employed (Tobii Tutorial, 2019).

Eye-tracking data can be analyzed qualitatively and quantitatively. Lai and his colleagues (2013) describe a two-dimensional (i.e., type of eye movement and scale of measurement) framework to summarize the eye-tracking metrics used in the research studies (see Table 1).

Table 1

A two-dimensional framework for eye-tracking measures (adapted from Lai et al., 2013)

		The Types of Eye Movements		
		Fixation	**Saccade**	**Mixed**
The Scale of Measurement	**Temporal**	Total fixation duration, Gaze duration, Average fixation duration, First fixation duration, Time to first fixation, Revisited fixation duration, and Proportion of fixation duration	Saccade duration	Total reading time, First pass time, and Re-reading time
	Spatial	Fixation position and Fixation sequence	Saccade length	Scan path pattern
	Count	Fixation count, Average fixation count, Revisited fixation count, Probability of fixation count	Saccade count and Inter-scanning count	

As shown in the Table 1, the temporal indicators can be defined as the measurement of eye movement regarding time or duration (e.g., the total time spent on fixated areas which is labelled as “total fixation duration”) while spatial indicators are described by the space of eye movement regarding locations, directions, and relationships (e.g., the place of fixation which is titled as “fixation position”). Although temporal measures can reveal “how long” and “when” type of questions, spatial measures can answer “how” and “where” related questions. On the other hand, count indicators can be measured by frequencies of the eye movements (e.g., total number of the fixations counted which is named as “total fixation count”) and can be correlated to the “how long” questions (Lia et al., 2013). Among the indicators, fixations and saccades are the measures that mostly used in research studies (Hessels, Niehorster, Nyström, Andersson, & Hooge, 2018; van Gog & Jarodzka, 2013).

As seen in Table 2, there are some eye-tracking metrics mentioned by their names. Therefore, it can be useful to give a detailed definition of these metrics as explained by Lai and his friends (2013) and in Tobii Studio User’s Manual (2016).

Table 2

The definition of the eye-tracking metrics (adapted from Lai et al., 2013, p.93 and Tobii Studio User's Manual, 2016)

Metrics	Definitions
First fixation duration	Time spent on the first fixation
Time to first fixation	Time spent from stimuli onset to the first fixation arrival
Proportion of fixation duration	Proportion of time fixated on an AOI compared to the total fixation durations or total reading time of a whole task
Fixation duration	Duration of each individual fixation within an AOI, or within all AOIs belonging to an AOI Group (seconds)
Total fixation duration	Total time spent on fixations
Average fixation duration	Mean of fixation duration on each AOI. (i.e., Gaze duration mean)
Gaze duration	Total fixation duration within a word or an AOI
Visit Duration	Duration of each individual visits within an AOI, or an AOI Group (seconds)
Total Visit Duration	Duration of all visits within an AOI, or an AOI Group (seconds)
Probability of fixation count	Probability of fixation count within an AOI compared to the number of fixations overall
Total fixation count	Total number of fixations counted in an AOI or in a task
Saccade length	Distance between two consecutive fixations
Saccade duration	Sum of saccadic time spent within an AOI
Saccade count	Total number of saccades counted within an AOI

In order to gain more information from the data obtained by eye-tracking techniques, first of all, the signals need to be eliminated from the noises. For this purpose, the areas of interest (AOIs) are formed and the eye movement data falling outside of AOI rectangular can be assumed as noise (Duchowski, 2006). This method can make a clearer look to focus on the intended region among the crowd. After this step, more analysis using AOIs can be performed to describe the structures or to explore the differences between the groups based on the variables (Horsley, 2014).

Duchowski (2017) suggests a six-steps guideline to conduct an eye-tracking research study, namely identifying the hypothesis, explaining the design (i.e. whether it is experimental or non-experimental observational study), informing about the participant's characteristics, describing the features of the apparatus, expressing the procedure (e.g., the instruction given to participants or the statements told before or after the trials), and defining the tasks asked to the participants to do. Therefore, following this guideline may help researchers to report the eye-tracking studies in a comprehensive structure.

2.4. Related Studies

2.4.1 Related Studies on Early Patterning

Rittle-Johnson, Fyfe, McLean, and McEldoon (2013) conducted a study to examine four-year-old children's experience with repeating patterns. For this purpose, 66 children were included in the study and the difficulty of the pattern was examined. First, children were pretested, then a brief feedback session providing some assistance was applied and then a posttest was administered. Moreover, the errors made were examined and the verbal data were used to better understand children's knowledge about repeating patterns. They used ten testing items including AAB, ABB, and AABB patterns and duplication, extension, abstraction, and unit identification skills. The study was administrated to the children, individually in a quiet room. Children's answers were collected and coded as correct, partially correct, wrong, and not related responses. The obtained data were analyzed using the between-subjects t-tests. The results of the study showed that children could copy and extend the pattern while some could demonstrate translation (i.e., abstraction) skill. On the other hand, few children could be successful in identifying the core unit of the patterns. Furthermore, the accuracy results showed that the pattern had similar difficulties whether their core units with three elements or four elements. However, when examined in detail, the error data showed different results as more children could extend the pattern with a three-element unit than the pattern with a four-element unit.

In their studies, Fyfe, McNeil, and Rittle-Johnson (2015) investigated the effect of abstract labeling (i.e., letter labeling) on relational thinking. For this purpose, they worked with 62 young children whose ages ranged from 3.6 to 4.9. Children were randomly assigned to the experimental group (i.e., abstract condition) and control group (i.e., concrete condition). Children were first applied to pretest regarding pattern abstraction and received eight different testing tasks (i.e., two for AB pattern, two for AAB pattern, two for ABB pattern, one for AABB, and one for ABC pattern type) and three example tasks (i.e., one for AB pattern, one for AAB pattern, and one for ABB). The study was implemented as a single session in a quiet room and children were taken individually. For the example task, the experimenter explained the model pattern and then produced it in different materials while for the testing tasks, she just defined the pattern and asked the child to produce it with different materials. Each group was applied the same procedure but labeling was different regarding the condition. For example, children in the abstract condition group were instructed by letter labeling (AB) while children in concrete condition were instructed by physical labeling (e.g., red, blue). Children's responses were coded and analyzed using ANCOVA. The results of the study showed that children in the abstract condition group solved more tasks than the children in concrete condition and performed significantly [$F(1, 58)=14.67$, $p<.001$]. The results also revealed an age effect which showed that older children can do better than younger children [F (1, 58) = 5.08, $p=.03$].

In another research, Rittle-Johnson, Fyfe, Loehr, and Miller (2015) reported a series of three research studies to understand preschooler's patterning experiences as well as parents' and teachers' thoughts. To explain, they previously investigated 66 young children's repeating pattern knowledge and found individual differences between the children. Then, as a first study (i.e., the follow-up study) they worked with the same 64 children whose age was ranged from 4.7 to 5.9. They used 10 items including four patterning skills such as duplication (one item for AABB pattern), extension (one item for ABB pattern and one item for AABB pattern), abstraction (one item for ABB pattern, one item for AAB pattern, and two items for AABB pattern), and unit identification (two items for AAB pattern). They also used one memory task for the ABB pattern type.

The implementation was applied to each child, individually in a quiet room in the preschool. The experimenter presented the items and recorded the children's responses. According to the results, children showed growth in their patterning skills from spring to fall semesters. Core unit identification was found more difficult than pattern translation, however, this may be because of fewer activities instructed to children by their preschool teachers. Overall, the researchers claim that the findings support their four-level construct map which orders the levels as Level 1 (i.e., duplication), Level 2 (i.e., extension), Level 3 (i.e., abstraction), and Level 4 (i.e., unit recognition). In the second study, they included in the parents of the children and conducted survey research regarding the math activities done by the parents and the child. The survey was designed both in the paper-based and online forms. The response rate was calculated as low (31%) but diverse. The teachers were also surveyed regarding their patterning activities in the classroom. The collected data were analyzed using descriptive statistics. The results showed that both parents and teachers frequently supported children to experience patterning activities. For example, some activities related to the duplication, extension, describing patterns, and creating patterns were done at home. In addition to these activities, the teachers used abstraction activities in the classroom. However, no unit identification activities were reported neither by the parents nor by the teachers. Finally, in the third study, they examined the differences in the role of and the source of the explanations. They formed three groups as self-explanation group, instructional explanation group, and the combination explanation group. 123 children participated in the study and randomly assigned to the three intervention groups. All children firstly completed the pretest and half of the tutoring process in the first session and the other half of the tutoring and the posttest in the second session. The pretest included three patterning tasks such as duplication, extension, and abstraction while the posttest included four patterning tasks such as duplication, extension, abstraction, and unit identification. Moreover, in the tutoring process, children were given two abstraction tasks. For each group, the mean scores were calculated considering pretest, posttest, and tutoring tasks. At the end of the study, it was found that the source of the explanation did not make a difference and all types helped children to learn about patterning.

In their research, Tsamir, Tirosh, Barkai, and Levenson (2018) focused on the comparison of ABA repeating patterns and the other type of structures. The participants of the study were 11 children aged four and seven. The study was designed as a naturalistic approach for investigating the children's engagements with the ABA and other types of patterns and for the pieces of evidence if children see the ABA pattern as non-intuitive. For this purpose, children were engaged with the pattern activities on tablet computer children were observed during unguided play with the tablet application. In this application, there were two different pattern tasks in each screen and only the first core unit of the pattern was displayed and highlighted. However, it might have been displayed at least three core unit of pattern and just one example on each screen. Moreover, the missing items were located in different places in the pattern and there were a bunch of elements below to be chosen. Only for the correct answers, children were given feedback (e.g., great) but were allowed to try again until they find the correct one without feedback or hint. The application was used in the child's home and the sessions were video-recorded. Data were analyzed considering children's finger movements, child-adult interactions, and children's responses when they complete the patterns. According to the results, most of the children correctly did the AB pattern (92%), ABB pattern (84%), and the ABC pattern (83%). Less than half of them, however, did ABA pattern (46%) correctly. It seems that the ABA structure was the most difficult type of pattern compared to the AB, ABB, and ABC pattern types (Tsamir et al., 2018). However, no statistical test was conducted to see whether there is a significant difference between the patterns.

Moreover, there are some longitudinal studies to investigate the patterning and mathematics attainment. For example, Rittle-Johnson, Hofer, Fyfe, and Farren (2015) conducted research working with children aged 7 and then at 11. They firstly assessed the children's patterning understanding when they are seven years old, and then applied a mathematics tests (e.g. algebra, arithmetic, geometry) when they are eleven years old. They adopted patterning tasks from the Research-based Early Math Achievement (REMA) items (Clements, Sarama, & Liu, 2008). The results showed no significant relationships between the patterning scores and math achievement test. Another similar longitudinal study was conducted by Fyfe, Rittle-Johnson, Hofer, and Farren (2015) however, they found a significant relationship between the children's patterning skills and their mathematics attainment (e.g., geometry) when they are at fifth grade.

Similarly, Fyfe, Evans, Matz, Hunt, and Alibali (2017) conducted a study to examine the patterning skills and mathematics achievement. 36 children whose ages differed from 5 to 13 have participated in the study. For this purpose, five testing tasks such as working memory, pattern extension and math tasks including arithmetic, inversion, and equivalence problems were used. The materials used were printed and laminated. The sessions were implemented to children, individually in a quiet room. The results of the study revealed that children could accomplish the pattern extension tasks (90%) though older children did better. The results also showed that controlling the age and verbal working memory variables, a correlation was found between the pattern extension skill and calculation skill rather than the concept of knowledge. Moreover, the findings demonstrated that verbal working memory capacity predicts patterning accomplishment.

Regarding mathematics attainment, Rittle-Johnson, Fyfe, Hofer, and Farran (2017) also conducted a longitudinal study including 517 low-income children. Four types of tasks were adopted from standardized measures namely, Woodcock Johnson Achievement Battery III and KeyMath 3 Diagnostic Assessment. Children were first pretested when they were four years old, and then measured again when they were eleven years old. The collected data were analyzed using descriptive statistics and regression tests. The results of the study demonstrated that early patterning knowledge predicts later mathematics attainment. However, this is not the same for early shape knowledge.

Apart from other studies, some researchers used more intense instruction sessions. For example, in their studies, Papic, Mulligan, and Mitchelmore (2011) conducted an intervention study with 53 preschool children varied from 41 to 60 months. They implemented a six-month (i.e., 14 instruction sessions) intervention about repeating and spatial patterns.

Each session took approximately 18-30 minutes. Testing sessions including pretest, posttest, and a delayed-posttest using Early Mathematical Patterning Assessment (EMPA). According to their study, they found that the treatment group showed higher performance than the comparison group in accomplishing patterning tasks both in the posttest and delayed posttest. They also outperformed in recognizing the core unit of the repeating pattern and the structure of the spatial pattern. The researchers also found that unit identification is fundamental to recognize the pattern structure. The weakness of the study is that the treatment group was chosen from one school and the control group was selected other schools similar to the treatment group.

Papic and Mulligan (2007) conducted a study to examine the young children's patterning skills including repeating patterns, spatial structure patterns, and growing patterns. An intervention study was designed and data were collected using a mixed-method approach. The researcher observed the classroom teachers' instruction and at the end of the study, the teachers were surveyed. Moreover, the data related to children's explanations while constructing the pattern were recorded and children's work samples were collected in the individual portfolios. The results of the study showed that children can learn about complex patterns. The children in the intervention group had the opportunity to recognize the unit of the pattern, translate the pattern into different mediums and solve the complex pattern problems when compared to the control group.

Hendricks, Trueblood, and Pasnak (2006) worked with first-grade children conducting a randomly assigned experimental study. While the experimental group was instructed by a variety of the patterns ranging from simple to complex, the control group was instructed by academic materials with the same amount of time and duration. At the end of the study, it was found that the experimental group significantly performed better in terms of identifying and interpreting the patterns.

Recently some researchers have been interested in executive functions and patterning skills. For example, in her dissertation, Schmerold (2015) investigated the relationship between first-grade children's patterning skills and executive functions such as cognitive flexibility, inhibition, and working memory. The researcher designed 48 pattern tasks consisting of numbers, letters, shapes, pictures, and clock faces to measure fixing the missing element of the pattern and recognizing the pattern. The tasks were designed as four elements and a missing item. While half of the patterns were displayed horizontally, the rest presented, vertically. Each pattern problem was showed once but children had their time to respond to the related task. The findings of the study demonstrated that there is a significant relationship between patterning and cognitive flexibility as well as patterning and working memory. However, a significant relations relationship was not found between patterning and inhibition components. Moreover, the results showed that patterning, cognitive flexibility, and working memory have a significant relationship with mathematical skills.

Bock, Cartwright, McKnight, Patterson, et al. (2015) conducted a study to examine the relationships between patterning and executive functions such as cognitive flexibility, inhibition, and working memory. The sample of the study consisted of 88 first-grade children and they were asked to fix the missing element which was located at the end of the sequence. Children were presented a set of 18 patterns including various materials such as numbers, shapes, and letters. The results of the study showed that there is a significant relationship between patterning skill and cognitive flexibility.

A similar study was designed by Schmerold and her colleagues (2017) to examine the relationships between executive functions and patterning skills, mathematics attainment, reading attainment. First-grade children's cognitive flexibility abilities were assessed by using the "Multiple Classification Card Sorting Test", their working memory abilities by using "Wechsler Intelligence Scale for Children – Revised (WISC-R) Digit Span" test, and inhibition abilities by utilizing "Stroop Color-Word Test". The results of the study showed that there was not a significant relationship between patterning and inhibition. However, there were significant relationships between patterning skill and cognitive flexibility as well as patterning skill and working memory. Moreover, it was found that patterning was only predicted by the cognitive flexibility component.

Miller, Rittle-Johnson, Loehr, and Fyfe (2016) conducted a study to investigate the role of executive functions and relational thinking in patterning knowledge. For this purpose, they designed a pretest-intervention-posttest with 124 children aged 4 and 5. The findings of the study showed that working memory, cognitive flexibility, and relational knowledge were significant predictors of initial patterning skills while the inhibition ability was not. What is more, the results supported that working memory ability had an important role in children's pattern knowledge.

In her dissertation, Hassan (2019) investigated the relationships between preschoolers' mathematical achievement and patterning skills and their executive function abilities (i.e., working memory, inhibition, and cognitive flexibility). The results of the study showed that cognitive flexibility component was a significant predictor of patterning, however working memory and inhibition were not. In fact, working memory and inhibition components were found as significant predictors of mathematics attainment.

2.4.1.1 Summary of the Related Studies on Early Patterning

As it is presented above, early patterning skills were studied at different aspects. For example, some researchers investigated the relationship between patterning skills and later mathematics attainment (e.g., Fyfe et al., 2015; Rittle-Johnson et al., 2015; Rittle-Johnson et al., 2017) while others examined the relationships between patterning skills and relational thinking (e.g., Fyfe et al., 2015). Moreover, the researchers tried to find the results related to the difficulties of the pattern types (e.g., Rittle-Johnson et al., 2013; Tsamir et al., 2018; and patterning skill levels (Rittle-Johnson et al., 2013). Recently, some researchers were curious about the relationship between patterning and executive functions (e.g., Bock et al., 2015; Hassan, 2019; Miller et al., 2016; Schmerold, 2015; Schmerold et al., 2017). However, up to the recent research conducted, apart from one adaptation study (e.g., Rittle-Johnson, Fyfe, Loehr, & Miller, 2015), it is seen that no research has directly evaluated Hypothetical Learning Trajectories on patterning.

2.4.2 Related Studies on Eye-Tracking

Since the researchers have been aware of the powerful potential of the eye movements to understand various aspects of human cognition and behavior, eye-tracking methodologies have been used as powerful research tools in diverse disciplines for years (Duchowski, 2006; Horsley, 2014; Lia et al., 2013; Van Gog & Scheiter, 2010; Wade & Tatler, 2011). For example, eye-tracking methodologies have been used in marketing (e.g., Harwood & Jones, 2014; Li, Breeze, Horsley, & Briely, 2014), in finance (e.g., Grigg & Griffin, 2014), in psychology (e.g., Brockmole & Le-Hoa Vo, 2010; Chen & Guastella, 2014; Herwing & Horstmann, 2011; Huestegge & Koch, 2012; Koening & Lachnit, 2011; Nakabayashi, Lloyd-Jones, Butcher, & Liu, 2012; Renkewitz & Jahn, 2012), in literacy and reading (e.g., Bolger & Zapata, 2011; Brandt-Kobele & Hohle, 2010; Brusnighan & Folk, 2012; Chaffin, Morris, & Seely, 2001; Maldarelli, 2012; Schmiedtova, 2011; Tremblay, 2011; Williams & Morris, 2004) and as well as in education (Boucheix & Lowe, 2010; Canham & Hegarty, 2010; Lin, Holmqvist, Miyoshi, & Ashida, 2017; Molina, Navarro, Ortega, & Lacruz, 2018; Ozcelik, Karakus, Kursun, & Cagiltay, 2009; Schmidt-Weigand, Kohert, & Glowalla, 2010; Smith, Mestre, & Ross, 2010).

As eye-tracking technologies have been used in learning and education, some studies were also conducted in early childhood and primary education, too. For example, in a quasi-experimental study conducted by Takacs and Bus (2016), eye-tracking was used to investigate the effect of two different mediums of storybooks (i.e., animated version and static demonstration). The data were collected from thirty-nine children whose age ranged from 4 to 6 years. There were two experimental groups (i.e., animated vs static version) and one control group (i.e., non-reading). Children's eye movements were recorded with a Tobii T120 eye tracker when children listened to the animated and static storybook. To analyze the data, first of all, the metrics such as the total fixation time on the illustrations, the number of fixations for each storybook, and the average duration of fixations were calculated for two experimental groups. Moreover, the researchers defined the Areas of Interest (AOIs) and calculated the duration fixated on the AOI and the number of fixations within the AOI. Then, a repeated-measures ANOVA was conducted and a significant main effect on fixations was revealed that children in the animation group concentrated on the screen more than those in the static group did. Moreover, a significant main effect was found on the average duration of fixations regarding the groups. That is, children had longer fixations on the illustrations in the animated group compared to the static group. In addition to these analyses, some statistics were also conducted on AOIs. Similarly, a significant main effect showed that children in the animation group fixated more on the details (i.e., important parts) compared to the static group. As a result, the eye-tracking methodology helped to reveal different processing strategies regarding the children's visual attention on storybooks. Therefore, motion or animation can support learning as directing the attention of the children.

In other study conducted by Bolden, Barmby, Raine, and Gardner (2015), the eye-tracking technology was used to show how children perceive and interpret the different mathematical representations of multiplication including picture representations (i.e., groups, array, and number line) and symbolic representation (e.g., 6x7, 7x8, and 8x9). For this purpose, nine children aged 9 and 10 were included in the study and asked to match the visual and the corresponded calculation. After calibration and the brief introduction part, each child was recorded by an EyeTech VT2 eye-tracker during the presentation of the eighteen static visuals consisting of symbolic and picture representation of the tasks without time limitation. Then, the obtained data were analyzed both by quantitatively (i.e., using fixation duration on each slide and AOIs) and qualitatively (i.e., using heat maps in each representation type). A one-way ANOVA was performed and it was found that number line representation is significantly different from the array and group representations. Moreover, analyses on the AOIs showed that the percentage of time spent on number lines was significantly different from other representations. That is, it can be claimed that number line representation has less support for improving children's multiplicative thinking. Furthermore, the heat maps and video records were utilized to interpret the strategies that children used for matching three different representations and the related symbols.

McEwen and Dubé (2015) conducted a research study using a desktop-mounted FaceLab 5 eye tracker. Based on cognitive load theory, the study aimed to answer "how" type questions related to the role of educational tablet applicants in guiding children's attention. For his purpose, simple and complex mathematics applications were prepared on tablet computers and 30 children with an average age of 7.3 years were included in the study. Each child accomplished the cognitive tasks related to the attention, short-term memory, and working memory. Moreover, children were completed a four-point calibration procedure and then recorded while performing simple and complex math applications. Eye-tracking measures related to fixation count and fixation duration were calculated and the heat map was screened. Inferential statistics (e.g., ANOVA) were used to detect the differences. The results revealed that simple applications helped both children placed in lower executive functioning ability level and higher executive functioning ability level to give their attention to the content. On the other hand, regarding the complex applications, the germane content was helpful for the children with high executive functioning ability, but not for the children with low executive functioning ability.

Schneider and his colleagues (2008) conducted a study to investigate how eye movements reflect the children's use of number line when they solve estimation tasks. For this purpose, a cross-sectional design was formed and sixty-six primary school children were included in the study. Children were in grades 1, 2, and 3 with an average age of 6.8 years, 8.1 years, and 8.9 years, respectively. In order to gather more information on the children's solving process, an Eyelink 1000 eye-tracker was used and some metrics such as fixation durations and fixation locations were analyzed. The results of the study showed that the estimation task was used as an assessment of number sense during the task solution.

2.4.2.1 Summary of the Related Studies on Eye-Tracking

The related literature on eye-tracking showed that there are few research studies conducting eye-tracking studies with young children.

Indeed, it was seen that only one study (e.g., Takacs & Bus, 2016) was conducted to preschool children aged 4-6 while the others worked with primary school children aged 7-10. Moreover, it was seen that researchers mostly focused on mathematics (e.g., on multiplication, Bolden et al., 2015; and estimation, Schneider et al. 2008) and literacy (e.g., Takacs & Bus, 2016).

2.5 Need for the Present Study

2.5.1 Significance of the Study

Patterning getting more attention and has been recognizing and discussing in the worldwide educational communities (e.g., National Council for Curriculum and Assessment (NCCA), 2014; The National Council for Teachers of Mathematics (NCTM), 1989; 2000). However, few studies have been conducted on patterning skills (Burgoyne, Witteveen, Tolan, Malone, & Hulme, 2017; Clements & Sarama, 2009; Fox, 2006). The researchers conducted patterning research studies revealed scientific findings related to the importance of the patterning skills in early years (e.g., Fyfe, McNeil, & Rittle-Johnson, 2015; Papic, Mulligan & Mitchelmore, 2011; Pasnak, 2017; Rittle-Johnson, Fyfe, McLean, & McEldoon, 2013). Patterning skills are considered as an important domain for the algebraic thinking (Clements & Sarama, 2009) and later mathematical attainment (Fyfe, Rittle-Johnson, Hofer, & Farren, 2015; Rittle-Johnson, Fyfe, Hofer, & Farran, 2017). Therefore, the related literature suggests that patterning skills need to be included in early childhood education (Sarama & Clements, 2009; NCCA, 2014). However, it is crucial to know how to teach patterning to young children (Burgoyne et al., 2017). To be able to effectively design and implement the series of instruction in succession, researchers argued for the need for hypothetical learning trajectories (HLTs) (Clements & Sarama, 2004; 2009; Gravemeijer, 1994; Simon, 1995). What is more, it can be essential to know about the cognitive mechanisms underlying patterning learning. To serve this purpose, new technologies and methodologies are emerging. Eye-tracking is one of the methodologies for understanding cognitive processes and learning outcomes (Land, 2007; Tsai, Hou, Lai, Liu & Yang, 2012). Therefore, it can be said that eye-tracking can provide unique pieces of evidence about learning experiences (Duchowski, 2007). Some eye-tracking metrics are helping the researchers to interpret the tracked eye movements data.

In brief then, although there is an emerging interest in the importance of the patterning, few study has been done to empirically understand young children's knowledge about patterning skills, training and testing tasks, instructional plans, and the evaluation of patterning learning (Clements & Sarama, 2009; Rittle-Johnson et al., 2013). Therefore, this study will help to propose whether HLTs significantly support pattern learning and teaching, as well as recommendations for the development of existing HLTs on patterning. More specifically, this study aims to examine the effectiveness of revised Hypothetical Learning Trajectories (HLTs) on patterning proposed by Clements and Sarama (2009) and to benefit from the eye-tracking methodology to better understand the underlying cognitive mechanism of patterning skills

2.5.2 Research Questions of the Study

There are two main questions to answer the gaps in the literature as follows.

1) Does instruction in which Learning Trajectories (LT) levels are taught consecutively (e.g., presenting children at level n- instructional tasks from level n+1, then n+2, and so forth) result in greater learning than instruction that uses the same activities without regard to developmental order or business-as-usual instruction?

2) How do children establish their patterning skills (i.e., extension, translation, and core identification)?

CHAPTER 3

METHODOLOGY

In this chapter, the research method of the current study is introduced. First, the research method and the design of the research is presented. Second, the research cycles are elucidated with the correspondent process and procedure for serving the last research cycle are elaborated. Third, the ethical issues, validity and reliability issues, as well as limitations of the study, are explained.

3.1 Research Method

This study was designed as a randomized experimental research study as a part of big research project investigating the effectiveness of the Hypothetical Learning Trajectories (HLTs) on early patterning. The parent research project was built on Design-Based Research and involved five iteration cycles, namely preliminary investigation, modification of the existing HLT, evaluation of the modified HLT, revision of the modified HLT, and evaluation of the revised HLT (see Figure 11). These research cycles allowed the researcher to have multiple iterations to revise HLTs on patterning. In other words, this thesis aims to present the findings the last research cycle, which evaluates the effectiveness of revised Hypothetical Learning Trajectories (HLTs) on patterning and benefits from the eye-tracking methodology to better understand the underlying cognitive mechanism of patterning skills.

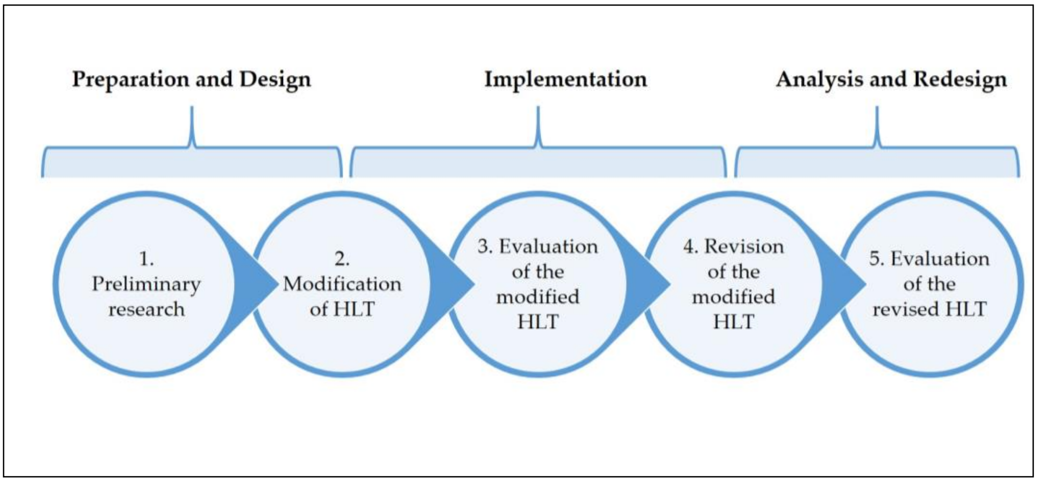


Figure 11: Overall outline of the research (adapted from Bakker, 2018)

For this purpose, first, all research cycles of design-based research (i.e., research cycle 1, research cycle 2, research cycle 3, are research cycle 4) are introduced in detail, and then the last research cycle (i.e., research cycle 5) will be explained, and discussed based on the findings revealed.

3.2 Design-Based Research (DBR) and Research Cycles

The revision of the hypothetical learning trajectory (HLT) was made based on Design-based research (DBR). In general, DBR is a new research methodology for education research, and it has the potential to increase the quality of education research (Anderson & Shattuck, 2012). It has some features that are worthy of this fame. For example, according to Anderson and Shattuck (2012), DBR is situated in a real educational context, and the results of the research aim to make a better practice of this educational context as well as similar ones. Since reality is not singular and known, it is rational to choose and utilize the different types of methods for research studies (Maxcy, 2003). Indeed, it is indicated that DBR benefits from both qualitative and quantitative methods and enables the researcher to make multiple iterations during the study (Anderson & Shattuck, 2012; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Latour, 2008). Moreover, since there are some weak sides of the other research methodology for conducting education research, DBR includes both practitioner and researcher as working collaboratively for the design and the implementation of the intervention (Anderson & Shattuck, 2012). In brief then, DBR aims to fill the gap between theory and practice by producing the educational material and revealing the implementation of this material (McKenney & Reeves, 2012).

Bakker (2018) presents three phases (i.e., macro-cycles) in design cycles (i.e., iterations) for the hypothetical learning trajectory (HLT) may have. These three phases in DBR are "preparation and design", "implementation (e.g., intervention, enactment, teaching experiment, trial)", and "analysis and redesign" (Bakker, 2018, p. 59). To explain, in the preparation and design phase, the researcher collects and produces a set of tasks from theoretical insights and practical experiences for possible HLT learning goals. Moreover, in this phase, a draft version of HLT is formulated by deciding on the instructional tasks, sequences of teaching activities, and learning materials (Bakker, 2018). Then, in the second phase: implementation phase, the researcher or the practitioner uses the most appropriate activities and teaching methods based on HLT instructional tasks (Bakker, 2018; Bakker & Van Eerde, 2015). Moreover, in this phase, the researcher has two purposes: observing the results of the implementation to assess and revise the educational materials or instruction theories. For this purpose, data are gathered by various methods such as "student work, tests before and after instruction, field notes, audio recordings of whole-class discussions, and video recordings of every lesson and the final interviews with students and teachers" (Bakker 2018, p.61). Last, in the third phase: analysis and redesign, the gathered data are analyzed. For this purpose, different analysis types can be used. For example, "task-oriented analysis" can be used to compare the students' learning in terms of their actual learning trajectory and hypothetical learning trajectory. In this way, it is possible to return the second phase of DBR and improve the teaching experiments. The other recommended type of analysis is for the additional inferences from the data. For example, the gathered data by videotaped are watched and transcribed chronologically to test the conjectures about students' learning and views against the other data material such as field notes, the student works, and tests applied (Bakker, 2018; Bakker & Van Eerde, 2015).

Based on the framework proposed by Bakker (2018), this study included the phases and iterations. To expound, in the first research cycle, preliminary research was conducted to see what is known about patterning and the related literature. In the second research cycle, the existing HLT proposed by Clements and Sarama (2009) was modified and consulted to the experts in HLT and early mathematics field. In this research cycle, instruction plans (i.e., 12 sessions), the materials (i.e., concrete-only materials), the testing tasks (i.e., two patterning tasks: extension and core identification), and scoring protocol (i.e., ranged from 0 to 1) were prepared. These were all also revised by the same experts in the field. In the third research cycle, the modified HLT was implemented in intervention groups. A randomized pretest-posttest-control experimental study with two groups was conducted, and the modified HLT was evaluated. The findings and recommendations were discussed and concluded to lead through the next process. In the fourth research cycle, the required revisions were decided with the collaboration of the experts in the field and the developer of the original HLT. Thus, the instruction plans, materials used, testing tasks, and scoring protocol were re-revised. To explain, the instruction plans were increased from 12 to 14 sessions and the materials included both concrete and computer-based rather than only-concrete activities. Moreover, the testing tasks were designed by three patterning skills (i.e., extension, core, translation), and the extensive scoring protocol was prepared (i.e., ranged from 0 to 6). In the end, the final version of HLT used in the present study was developed and eye-tracking methodology was designed in the fourth research cycle. In the last research cycle of the study, the revised HLT was implemented for the intervention groups. A randomized pretest-posttest-control experimental study with three groups was conducted, and the revised HLT was evaluated. Moreover, field notes were taken, all sessions were video-recorded, and eye-tracking data were collected. Based on the findings from the last cycle, recommendations and discussions were reported for implications and further studies.

3.2.1 Research Cycle 1: Preliminary Research

Preliminary research is seen as an important step to explore what has been known about the topic and how it can be synthesized to guide further research (Cobb et al., 2003; McKenney & Reeves, 2012; 2013). Based on the preliminary research, it was seen that there are some concept maps (Fyfe et al., 2015) and developmental Levels (Papic, 2011) and patterning development. However, when these studies were examined, it was seen that they were also inspired by Clements and Sarama (2009). Therefore, this study used the HLTs proposed by Clements and Sarama (2009) as a baseline (see Table 3). According to Clements and Sarama (2009), patterning is "the search for mathematical regularities and structures" (Clements & Sarama, 2009, p. 190). There are three levels, namely Level 1: Pre-Explicit Patterner, Level 2: Pattern Recognizer, and Level Three: Pattern Unit Recognizer. To explain, children initially may be sensitive to regularities and even have an expectation based on them but only at an implicit or intuitive level (Level 1). Children then take a step toward explicit knowledge of patterning by fixing, copying, or extending simple perceptually available repeating patterns (Level 2). Lastly, children begin to identify the smallest part of the pattern that repeats again and again. Moreover, children reproduce the given pattern in different materials (Level 3).

Table 3

The Original HLT for pattern and structure proposed by Clements & Sarama (2009, p.195-198)

Age (Years)	Developmental Progression	Instructional Tasks
2	**Pre-Explicit Patterner** Detects and uses patterning implicitly, but may not recognize sequential linear patterns explicitly or accurately. Names a striped shirt with no repeating unit a "pattern."	Emphasize the patterns in children's songs, poems, and spontaneous movements, such as dancing. Work with manipulatives such as blocks, puzzles, manipulatives to order (e.g., simple materials such as pencils of different lengths or such commercial materials as those from the Montessori group) and discussions of regularities help children use and eventually recognize patterns.
3	**Pattern Recognizer** Recognizes a simple pattern. "I'm wearing a pattern" about a shirt with black, white, black white stripes.	Count and Move in Patterns Spend only a few minutes counting with children in patterns of 2, or another appropriate even number; for example, "one, two! . . . three, four! . . . five, six! .... " For more fun, get a drum or use the corners of a wooden block to tap along with the counting, tapping harder for emphasis at each second beat. Pattern Walk Read the book, I See Patterns. Patterns in the world may be confusing because of all the irrelevant, distracting information available. The book will help explain and distinguish types of patterns. Then go on a pattern walk and find, discuss, photograph, and draw the patterns you see. Clothes Patterns Find repeating patterns in children's clothing colors. Encourage them to wear clothes with patterns and to discuss the patterns they wear to school.

Table 3 (cont'd)

	Pattern Fixer Fills in missing element of pattern, first with ABAB patterns. Given objects in a row with one missing, ABAB BAB, identifies and fills in the missing element.	Show children a geometric pattern and chant it with them (e.g., square, triangle, square, triangle, square, triangle . . . at least three complete units of the pattern). Point to a space later in the pattern where a shape "fell off." Ask children what shape they need to fix the pattern. If children need help, have them chant the pattern as you point to each block, allowing the pattern of words indicate the missing shape.
4	**Pattern Duplicator AB** Duplicates ABABAB pattern. May have to work close to the model pattern. Given objects in a row, ABABAB, makes their own ABABAB row in a different location	Show children a strip of paper with a geometric pattern pictured on it and have children describe the pattern on the strip (square, circle, square, circle, square, circle . . .). • Have the children help you copy the pattern, if necessary, by placing pattern blocks directly on the pattern strip. • Have them chant the pattern as you point to each block. Children duplicate a linear AB pattern of flags based on an outline that serves as a guide. When they complete the pattern, they help an airplane land. 

Table 3 (cont'd)

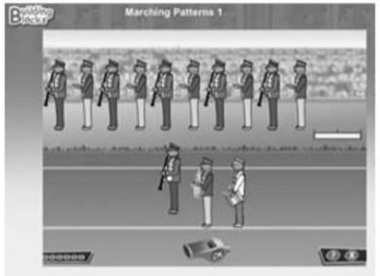
Pattern Extender AB Extends AB repeating patterns. Given objects in a row, ABABAB, adds ABAB to the end of the row.	Show children pattern strip with an ABABAB pattern and ask them to use materials to "keep going" with the pattern. Discuss how they knew how to do so. Children extend a linear AB pattern of musicians by one full repetition of an entire unit. When they complete the pattern, the musicians march in a parade. 
Pattern Duplicator Duplicates simple patterns (not just alongside the model pattern). Given objects in a row, ABBABBABB, makes their own ABBABBABB row in a different location.	Dancing Patterns Tell the children they will be dancing patterns and the first one will be clap ("one"), kick ("one"), kick ("two"); clap ("one"), kick ("one"), kick ("two"); clap ("one"), kick ("one"), kick ("two") . . . . Sing a song along with the pattern. Later, have them describe the pattern. Pattern Planes 2 (and 3) Children duplicate a linear AAB or ABB (for 2; ABC for level 3) pattern of flags based on an outline that serves as a guide. When they complete the pattern, they help an airplane land. 

Table 3 (cont'd)

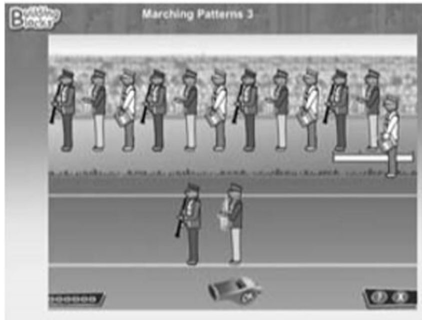
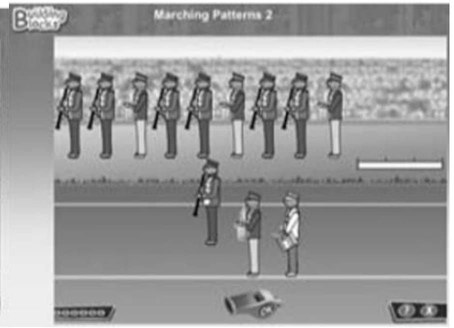
5	**Pattern Extender** Extends simple repeating patterns. Given objects in a row, ABBABBABB, adds ABBABB to the end of the row.	Creative Patterns This is a good time to add pattern-creating materials to your creative area. Someone is sure to want to make a pattern they can take home. Pattern Strips—Extend Show children pattern strip and ask them to use materials to "keep going" with the pattern. Discuss how they knew how to do so. Stringing Beads Following a "pattern tag" at the end of the string, children place beads on the string to extend the pattern and make a pattern necklace. Marching Patterns 2 (and 3): Extend Children extend a linear pattern of musicians by one full repetition of an entire unit. When they complete the pattern, the musicians march in a parade. The musicians are in patterns such as AAB and ABB in level 2, ABC in level 3.  
6*	**Pattern Unit Recognizer** Identifies the smallest unit of a pattern. Can translate patterns into new media. Given objects in an ABBABBABB pattern, identifies the core unit of the pattern as ABB.	Pattern Strips—The Core Re-introduce Pattern Strips, emphasizing the idea of the core of the pattern. • Show children a pattern strip and have children describe the pattern on the strip (vertical, vertical, horizontal; vertical, vertical, horizontal; vertical, vertical, horizontal) • Ask them what the "core" of this pattern is ("vertical, vertical, horizontal"). • Have the children help you copy the pattern using sticks. Each child should make one copy of the core. • Ask them to "keep going" by adding additional copies of the core.

Table 3 (cont'd)

Cube Patterns Put a large group of cubes in the middle of the children. Show them a "tower" of cubes of two colors, such as blue, blue, yellow.

• Have each child make a blue, blue, yellow tower.

• Have children link them together, making a long cube pattern train! • Chant the colors as you point to each cube in the long pattern train.

• Repeat with a different core tower.

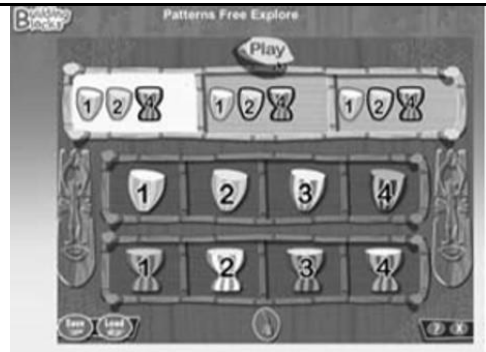
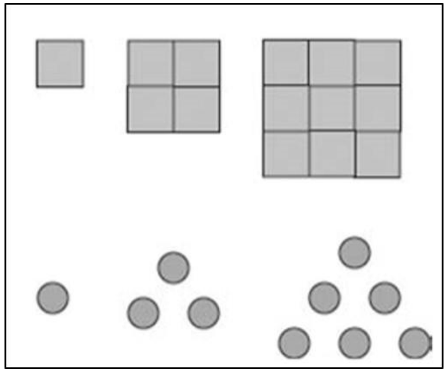
Scaffolding Strategies

• More Help—For children who have difficulty making and extending a pattern, making cube patterns step by step may be useful. Help them to stand up several towers next to each other (e.g., red cube, blue cube), and see they are all the same. "Read" the pattern, chanting each color as you read one tower after another from the bottom up. Finally, link them together and chant the pattern again.

• Extra Challenge—Use more complex patterns. Even try ones that end with the same item they begin with, such as a core unit of ABBCA, which produces the confusing pattern: ABBCAABBCAABBCA.

Patterns Free Explore Students explore patterning by creating rhythmic patterns of their own. The patterns are presented in drum beats (of two pitches), but also visually—emphasizing the core unit of the pattern.

Table 3 (cont'd)

		
7	**Numeric Patterner** Describes a pattern numerically, can translate between geometric and numeric representation of a series. Given objects in a geometric pattern, describes the numeric progression.	Growing Patterns Children observe, copy, and create patterns that grow, especially those such as the square growing pattern and triangular growing pattern, noting the geometric and numerical patterns that they embody. 

3.2.2 Research Cycle 2: Modifying the Proposed Hypothetical Learning Trajectory (HLT) on Patterning

In research cycle 2, the instruction plans, the training materials, testing materials, and scoring protocols were designed. To explain, the instruction plans adapted from patterning hypothetical learning trajectory proposed by Clements and Sarama (2009), while the training materials consisted of manual games and activities adapted from the Building Blocks Preschool Mathematics Curriculum (Clements & Sarama, 2013). Moreover, testing tasks were adapted from the study conducted by Rittle-Johnson, Fyfe, McLean, and McEldoon (2013). All these topics were prepared by the researcher and then reviewed by the expert, one of the HLT developers, in the field. Although it was planned to adapt the scoring protocol from Rittle-Johnson and her friends' study, it was seen that the protocol was not appropriate for the goal of the present study. Therefore, the researcher and one of the professors, experts in HLT development and measurement, prepared and revised the scoring protocol considering related literature.

3.2.2.1 Description of the Changes in the Existing Hypothetical Learning Trajectory

In the proposed Hypothetical Learning Trajectory (HLT) (Clements & Sarama, 2009), the first two levels of the original HLTs (i.e., Level 1 and Level 2) and the revised HLT are identical (see Table 4). Although Level 3 and 4 originally formed a single level in Clements and Sarama's (2009) HLT, the modified HLT suggested dividing this level into two levels. In other words, the revised HLT proposed that children can learn to translate a repeating pattern into a new media (e.g., represent □Δ□Δ□Δ as letters such as ABABAB, different objects such as ☺☼☺☼☺☼ or different shapes ○◊○◊○◊)—Level 3 in Table 4—before they could identify its core: the smallest portion of the pattern that repeats to create the rest of the pattern—Level 4 in Table 2. For example, the core □Δ or AB is the unit that repeats to form the pattern □Δ□Δ□Δ… and ABABAB…, respectively. The ability to identify the core or repeating unit of a repeating pattern represents relatively explicit knowledge of such patterns.

Table 4

The modified HLT (adapted from Clements and Sarama, 2009)

Levels of HLT	Explanation
Level 1: Intuitive Patterner	Children implicitly detect and may even use simple repeating patterns but may not recognize alternating or sequential patterns explicitly or accurately. For example, says "I'm wearing a pattern when wearing a striped shirt of two alternating colors or a multicolored shirt with no repeating pattern.
Level 2: Perceptual Patterner	Operates first with concrete AB repeating patterns (e.g., ●■●■●■…) and then with more complex patterns such as ABB (e.g., ●■■●■■●■■) or ABC patterns (e.g., ●■▲●■▲●■▲…).
Sublevel 2a: Pattern Fixer and Duplicator	Children can find the missing element of a repeating pattern and fix it (e.g., given square, circle, square, circle, square, circle, square, ____ or square, circle, square, circle, square, ____, square, circle, fills in the blank with a circle). Moreover, they copy can a pattern model such square, circle,

Table 4 (cont'd)

	square, circle, square, circle….
Sublevel 2b: Pattern Extender	Children can continue a repeating pattern (e.g., given square, circle, square, circle, square, circle, adds on a square and circle and another square and circle).
Level 3: Generalized Patterner	Children can abstract a pattern and translate it into new media (e.g., given a repeating pattern such as square, circle, square, circle, square, circle can translate into the movements up, down, up, down, up down; the colors red, blue, red, blue, red, blue), or the letters A, B, A, B, A, B.
Level 4: Unit Patterner	Children can identify the core of a repeating pattern (the smallest portion of the pattern that repeats to create the rest of the pattern.

Note. Only the first four levels of the HLT are shown. The portion of the HLT shown is relevant to repeating patterns only (does not apply to, e.g., growing patterns) and is hypothesized to apply to the simplest repeating (AB patterns) first and then more complex ones (ABB or ABC patterns).

3.2.2.2 Description of the Instruction Plans for Modified HLT

Twelve instruction sessions were prepared to apply patterning instruction. Level 1: Intuitive Patterner, was not included in the sessions. Therefore, the sessions consisted of Level 2, Level 3, and Level 4 activities as demonstrated in Table 2. There were two sessions for Sublevel 2a: AB Pattern fixer and duplicator (i.e., sessions 1 and 2), two sessions for Sublevel 2b: AB Pattern extender (i.e., sessions 3 and 4), two sessions for Sublevel 2c: ABB & ABC Pattern fixer, duplicator, and extender (i.e., sessions 5 and 6), two sessions for Level 3: Pattern generalizer (i.e., sessions 7 and 8), and four sessions for Level 4: Unit Patterner (i.e., sessions 9, 10, 11, and 12).

Each instruction session included in one or two related patterning activities with at least two examples. For example, as demonstrated in Table 5, in session 2, there are two activities (i.e., *Activity 2.1. Where Is My Friend?* and *Activity 2.2: Where Is My Twin?)* including two examples for each (i.e., Ex 2.1.A. and Ex 2.1.B for Activity 2.1 and Ex 2.2.A. and Ex 2.2.B for Activity 2.2). Moreover, manual materials such as geometric shapes, unifix cubes, vehicles, animals, colored tokens, chips, fruits, and vegetables were benefited during the instructions.

Table 5

An example for instruction plan

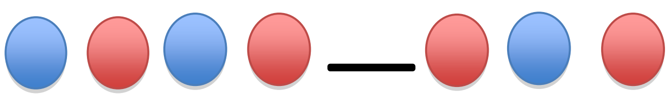
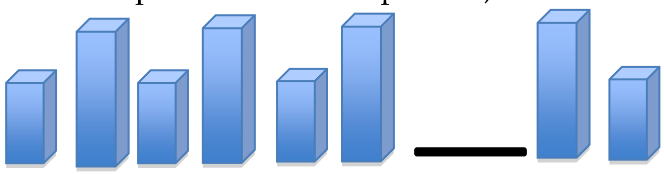
Levels	Sessions	Activities
2a (AB Pattern Fixer and Duplicator)	2	***<u>Activity 2.1. Where Is My Friend?</u>*** Start with a brief introduction that makes child aware of the activity and motivate him/her as telling 'Today we will play a game with different shapes and colors. In this game, they are looking for their friends. Would you like to help them?' **Ex 2.1.A:** *Show children the geometric repeating pattern below and encourage them to describe it with you (e.g., chant together blue, red, blue, red, blue, red..)*  Then, point to the blank in the pattern and say, "This What color is missing here?" Encourage the child to fix the pattern.

Table 5 (cont'd)

Ex 2.1.B: Show children a cube pattern strip (e.g., small, big; small, big; small, big; .. at least three complete units of the pattern).



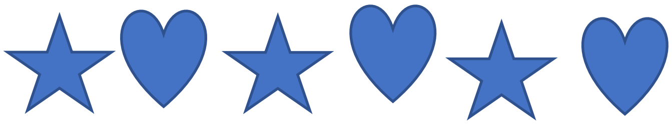
Then, point to the blank in the pattern and say, "This
where a shape 'fell off'." Ask children what shape they need to fix the pattern and wait for their response.

Activity 2.2: Where Is My Twin?
The goal is for a child to duplicates AB patterns.

Ex 2.2.A: *Show children the geometric repeating pattern below and encourage them to describe it with you (e.g., chant together circle, square, circle-square, circle, square. . . for the three complete units of the pattern).*

Then, ask the child to copy the pattern with same materials.

Ex 2.2.B: *Show children the repeating pattern below and encourage them to describe it with you (e.g., chant together star, heart, star-heart, star,heart. . . for the three complete units of the pattern).*



Then, ask the child to copy the pattern with same materials.

3.2.2.3 Descriptions of the Testing Tasks and Scoring Protocol for Modified HLT

The testing materials involved in two tasks. The primary task was identifying the core unit of the patterns and the secondary task was pattern extension. For both tasks, children were provided a box of interlocking blocks that contains enough blocks (4 to 6 of each color) to permit extending a pattern or representing the core unit of the pattern. Testing was started by extension tasks and children were, in turn, shown an AAB, ABCC, and ABCD patterns constructed of interlocking blocks.

Before starting to the testing tasks, two brief introduction tasks to the pattern were given. First, the explanation of the pattern was told as ***"A repeating pattern involves a regular sequence, like day and then night, then day and night again."*** then it was asked: ***"It's day now, what comes next? After night comes what?".***

Second, the child was shown (a) 8 White, (b) 6 White and 2 Red, and (c) White-Red-White-Red-White-Red interlocking blocks and asked: ***"Which of these do you think is a repeating pattern?"*** If needed, the explanation was made as: ***"Only this one*** [point to W-R-W-R-W-R-W-R] ***is a repeating pattern because it involves a regular sequence—white, then red, then white again, then red again, white, red, white, red."***

Task 1: Extension

For the extension tasks, a practice trial involving an AB pattern was introduced with instructions: ***"In the Keep Going Game, I'll show you a***

pattern using interlocking blocks like this [the child was shown the White-Red-White-Red-White-Red example]. ***Use these cubes*** [tester pointed to the box] ***to make the pattern "keep going—to make the pattern longer."*** If the child did not respond or had difficulty, the researcher helped by adding a white and then a red cube and encourage the child to make the pattern longer. If a child adds only one white and one red, said**:** ***"Can you keep going—to make the pattern longer?"*****.** A correct response (1 point) entailed extending the pattern two full core units of the pattern without errors (using only complete examples of the core). Partial credit (0.5 points) was granted if the child produces at least one full core unit of the pattern and the part of another. An incorrect response was scored as 0.

Task 2: Core Identification

For the core identification task, children were shown the same patterns in the same order as the extension task and instructed: *"Use these cubes* [the tester pointed to the box] *to see what part of the pattern* [a tester draw her finger along the length of the interlocking cubes forming the pattern] *keeps repeating."* If need be, ask the child, "*What is the smallest part of the pattern that happens again, and again, and again to make the pattern?"* Responses were considered completely correct (1 point) if the child represented the core with interlocking blocks or incorrect (0 points).

3.2.3 Research Cycle 3: Evaluation of the Modified Hypothetical Learning Trajectory (HLT)

In order to evaluate the effectiveness of the modified Hypothetical Learning Trajectories (HLTs), two research questions were determined and a randomized pretest-posttest-control group experimental study was designed. The pretest was administered before the training sessions and the delayed posttest was applied two weeks after the last training session.

3.2.3.1 Interventions in Research Cycle 3

Two intervention groups, namely the gradual HLT approach and the condensed non-HLT approach were formed, and participants were randomly assigned to an intervention. The sequenced instruction plans described above designed for the Hypothetical Learning Trajectory (HLT) based intervention (i.e., the gradual HLT approach) while an unordered training was designed for the active control group (i.e., the condensed non-HLT approach). These two approaches had four commonalities and three key differences. As presented in Table 6, both built on using physical characteristics to describe the elements of a pattern (e.g., labeling a ●■●■●■ pattern a "circle-square-circle-square-circle-square"). Moreover, both then used letters to label (all of) the elements of a pattern (e.g., labeling a ●■●■●■ pattern "ABABAB"). Both also used "AND" to describe the physical and letter labels of pattern elements to implicitly underscore the core (e.g., labeling a ●■●■●■ circle-square AND circle-square AND circle-square AND"). Finally, both used letters to identify the core and as a shorthand label a pattern (e.g., labelling a ●■●■●■ an "AB pattern"). On the other hand, Levels 2a to 2c were followed in a fixed order for the gradual LT approach (i.e., AB patterns were used exclusively in Sessions 1 to 4 and the more advanced ABB and ABC patterns were not introduced until Sessions 5 & 6). In the condensed non-LT approach, AB patterns were used to introduce an activity, but ABB and ABC patterns were introduced in Session 2. Also, the transition to using letters to describe (all of) the elements of a pattern and implicitly underscoring the core by using "AND" in physical and letter descriptions of all of the elements occurred in Level 3 (pattern generalizer level) immediately before Level 4, which involved explicitly identifying the core). This transition phase occurred immediately—in Session 1—for the condensed non-LT approach. Perhaps most importantly, the use of letters to identify the core of repeating patterns was delayed until Sessions 9 to 12 in the gradual LT approach, but introduced relatively early in the condensed non-LT approach.

Table 6

Differences and similarities between the Interventions

	Intervention 1: Gradual HLT Approach					Intervention 2: Compressed non-HLT Approach				
HLT Levels (adapted from Sarama & Clements, 2009)	Session	Physical labels → elements	Letters → elements	Use of "AND"	Letters → core	Session	Physical labels → elements	Letters → elements	Use of "AND"	Letters → core
2a. AB Pattern fixer & duplicator	1	X				1	X	X	X	
	2	X				2	X	X	X	
2b. AB Extender	3	X				3	X	X	X	X
	4	X				4	X	X	X	X
2c ABB fixer, duplicator & extender	5	X				5	X	X	X	X
2c ABC fixer, duplicator & extender	6	X				6	X	X	X	X
3. Pattern generalizer	7	X	X	X		7	X	X	X	X
	8	X	X	X		8	X	X	X	X
	9	X	X	X	X	9	X		X	X
4. Core unit	10	X	X	X	X	10	X		X	X
	11				X	11				X
	12				X	12				X

Using **physical characteristics** to label the *elements* of repeating pattern (e.g., ●■●■●■): "Circle, square, circle, square, circle, square."
Using **letter**s to label the *elements* of repeating pattern (e.g., ●■●■●■): "ABABAB."
Using **"AND"** to implicitly underscore the *core* of repeating pattern (e.g., ●■●■●■): "Circle, square AND circle, square AND circle, square."
Using **letter**s to label the *core* of repeating pattern (e.g., ●■●■●■): AB

The basic characteristics of the interventions were outlined in Table 6. Based on these similarities and differences, separate lesson plans were prepared in detail for each intervention. That is, twelve instruction plans were formed for each intervention, and the researcher implemented the lesson plans as considering these essential points. As exemplified in Table 5, although children in both groups were first taught an AB fixing activity (e.g., a circle-square pattern), children in non-HLT group were asked to extend the given pattern and duplicate the same pattern with letters, even in session 1 (the children in HLT group, also had this training but not in session 1 rather in session 7). Moreover, in session 1, children in non-HLT group were introduced the use of AND, an implicit way to connect the core unit of the pattern, while they were describing the pattern (e.g., *Our pattern goes circle-square, AND circle-square, AND circle-square*) (see Table 7).

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Table 7

Sample lesson plans from HLT and non-HLT intervention groups

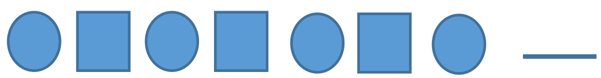
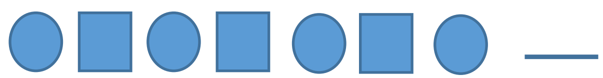
	Intervention 1 (HLT Group)	Intervention 2 (non-HLT Group)
Session 1	***Activity 1.1. What's Missing?*** The aim of this game is to fill in missing element of a repeating AB pattern. **Ex 1.1.A.** Show children the geometric repeating pattern below and encourage them to describe it with you (e.g., chant together: *circle, square, circle, square, circle, square. . .* for three complete core units of the pattern).  Then, point to the blank in the pattern and say, "*This where a shape 'fell off'*." Encourage the child to fix the pattern by saying: "*Would you fix the pattern?*" ***Hint***: While pointing to each element in turn, say, "Our pattern goes circle-square, circle-square, circle-square, what should come next?	***Activity 1.2. What's Missing?***[a] The aim of this game is to fill in missing element of a repeating AB pattern **and then extend the pattern. Another aim is to introduce letters to label (abstractly) the elements of pattern**. **Ex 1.2.A.** Show children the geometric repeating pattern below and encourage them to describe it with you (e.g., chant together *circle-square AND circle-square AND circle-square. . .* for three complete core units of the pattern). **Emphasize the 'AND'. (The idea of a core is implicitly introduced by labeling the elements of a pattern in core chunks such as circle-square, AND circle-square, AND circle-square. . . while emphasizing the 'AND'.)**  Then, point to the blank in the pattern and say, "*This where a shape 'fell off'*." Encourage the child to fix the pattern by saying: "*Would you fix the pattern?*" ***Hint***: While pointing to each element in turn, say, "Our pattern goes circle-square **AND** circle-square, **AND** circle-square, **AND** what should come next? ***Hint 2***: We started with a circle and a square come next **AND** a circle

Table 7 (cont'd)

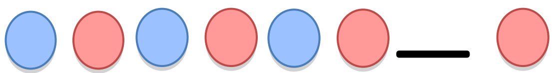
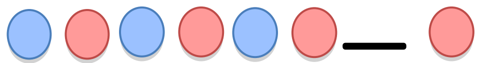
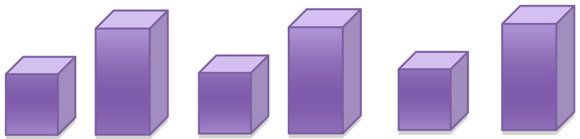
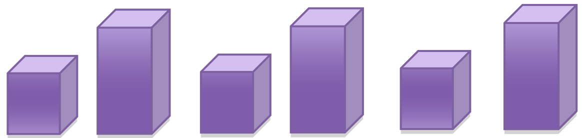
Hint 2: We started with a circle and a square come next a circle followed by a square again, a circle followed by a square again, so do you think a circle or square will be next? ***Give away***: If all else fails, say: "*Circle-square, circle-square, circle-square, so circle comes next.*	followed by a square again, **AND** a circle followed by a square again, so do you think a circle or square will be next? ***Give away***: If all else fails, say: "*Circle-square **AND** circle-square **AND** circle-square, so circle comes next.* After fixing the pattern, ask the child to EXTEND the pattern by saying: "*What should come next*?" **Finally, give the child plastic letters A, B, and C and ask the child to use letters to duplicate the pattern.** ***Prompt*: Say: "Let's make this same pattern but with letters."** ***Hint*: Say, "Which of these letters can we use instead of the circle?"** ***Hint 2*: Say, "Which should we call A the circle or the square?" Which should we call B then?** ***Give away*: If all else fails say, "Let's use A in place of the circle and B in place of the square."** **Summarize the labels the elements of the pattern: "So we can call this pattern with small then large blocks an A-B AND A-B, AND A-B pattern.**
Ex 1.1.B. Repeat the process with the color pattern below (e.g., chant together *red, blue, red, blue, red, blue circles*…). Say, "*What color is missing here*?" 	**Ex 1.2.B.** Repeat the process with the color pattern below (e.g., chant together *blue-red, AND blue-red, AND blue-red circles*). **Then repeat the process with letters then AB AND AB AND AB)**. Say, "*What color is missing here*?" 

Table 7 (cont'd)

	Activity 1.2. Can You Copy Me? The goal is for a child to duplicates AB patterns. ***Ex 1.2.A.*** Show children a strip of cubes (e.g., small, big; small, big; small, big; ..).  Ask the child to describe (e.g., "big, small, big, small, big, small"). Help as needed. Summarize the pattern: "*So our pattern is small, big, small, big, small, big, small, big*." Then, ask the child to copy the pattern with same materials but of different colors. ***Ex 1.2.B.*** Put out another AB pattern and repeat the process with the exception of saying, "This time I'm going to make it harder for you by hiding the pattern" and then hide the pattern under a cover.	***Activity 1.1. Can You Copy Me?***[a] The goals are for a child are to duplicate AB patterns **and use AND to (implicitly) connect cores**. ***Ex 1.1.A.*** Show children a strip of cubes (e.g., small, big; small, big; small, big; ..).  Ask the child to describe (e.g., "big-small **AND** big-small **AND** big, small"). Help as needed. Summarize the pattern: "*So our pattern is small, big, **AND** small, big, **AND** small, big, **AND** small, big*." Then, ask the child to copy the pattern with same materials but of different colors.

[a] For Intervention 2, What's Missing? was actually the second activity and Can You Copy Me? was the first activity. The activities are presented in table out of order so that a reader might more easily compare and contrast them to comparable activities in Intervention 1. Can You Copy Me? wa presented first in Intervention 2 to introduce the use of AND, and What's Missing? was presented second to introduce the use of letters to label th elements of a pattern. In this way two instructional goals were introduced separately, the easier (using AND) first and the more challenging (trans the elements of a pattern into letters) second.

Note. How Intervention 2 differed from Intervention 1 is indicated by **red bold** type.

3.2.3.2 Participants Involved in Research Cycle 3

Participants were from three classes in a university preschool serving the faculty, staff, and students of a university and the working-class community of a medium-size Mid-western city in the United States. Parental consent forms were received for 26 students of the 58 sent out. One child refused to participate and was not pretested. Four children were excluded from the study because they were essentially untestable at pretest due to a lack attentiveness. One Intervention 1 student did not most of the training because of a prolonged family vacation. One non-HLT student refused to continue after two training sessions. A total of 19 four-year olds completed the study (see Table 8).

Table 8
Demographic information of the participants

		f	%
Gender	Female	12	63.16
	Male	7	36.84
Age	3 years old	7	36.84
	4 years old	12	63.16
Race	Caucasian	7	35
	Asian-American	9	45
	Latina/o	4	20
Economic Status	Free Lunch	4	21.05
	Regular	15	78.95

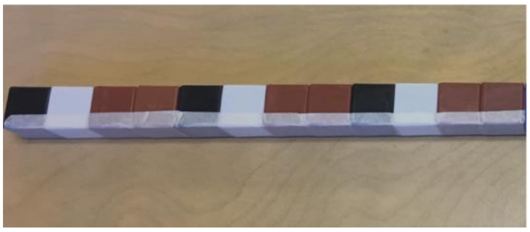
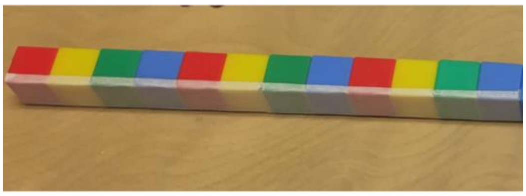
As presented in Table 10, while 12 children were female, 7 children were male. More than half of the children were four years old (63.16%).

Most of the participants were Asian-American (45%), then Caucasian (35%) and Latina/o (20%), respectively. Lastly, in terms of economic status, only four children had free lunch that can be one of the indicators for low income.

3.2.3.3 Testing Materials Used in Research Cycle 3

Three types of patterns were used in testing sessions and none of these patterns were a part of the interventions and, thus, expected to serve to gauge transfer. Each example of a pattern included at least three complete core units, that is, consist of 12 elements (see Table 9).

Table 9
Model AAB, ABCC, and ABCD patterns used in each task of the pretest and posttest

Pattern Type	Model
AAB	
ABCC	
ABCD	

3.2.3.4 Research Questions Formed in Research Cycle 3

Two research questions were determined to address the main issues in research cycle three as follows.

1) Is there a significant difference between HLT-based instruction and non-HLT instruction regarding children's pattern extension and core identification skills?
2) Is there a significant difference between the extension scores and the core identification scores considering the age of children?

3.2.3.5 Analysis Used in Research Cycle 3

To answer the research questions an independent-samples t-test was used. Moreover, the assumptions were checked and met before conducting t-test. In addition to checking for statistical significance, the effect size was checked, where applicable, for the statistical magnitude of the effect and practical significance (Lipsey et al., 2012).

3.2.3.6 Results Found in Research Cycle 3

3.2.3.6.1 RQ1: Is there a significant difference between the HLT-based instruction and non-HLT instruction regarding children's pattern extension and core identification skills?

As Table 10 indicates, the pretest-posttest gains by the gradual HLT intervention for the core-identification task (+1.944) were somewhat greater than those by compressed non-HLT (+1.600). That is, the former had a slightly more beneficial effect on the target level goal of core identification than did the compressed non-HLT intervention but not a significant or substantial one (t[17]=.481, 2-tailed *p*=.637). Further, Cohen's effect size value (d=.22) suggested low practical significance (Moreover, Hedges' g value was found as 0.22). The same was true for extension transfer (+1.555 versus +1.300; t[17]=.021, 2-tailed *p*=.98). Further, Cohen's effect size value (d=.01) suggested very low practical significance (Hedges' g value was .01).

Table 10
Results of paired samples t-test (pretest-posttest gains) for each intervention group

Groups	Mean Difference Gain	S.D.	Std. Error Mean	95% Confidence Interval of Difference		*t*	df	Sig. (two-tailed)	η^2
				Lower	Upper				
Core Identification Task									
Gradual HLT	-1.94	.95	.31672	-2.67479	-1.21410	-6.139	8	.000	0.82
Compressed non-HLT	-1.60	1.37	.43333	-2.58027	-0.61973	-3.692	9	.005	0.60
Extension Task									
Gradual HLT	-1.55	1.04	.34805	-2.35817	-0.75294	-4.469	8	.002	0.71
Compressed non-HLT	-1.30	1.15	.36667	-2.12946	-0.47054	-3.545	9	.006	0.58

Gradual HLT-based training does not appear necessary for helping all children become core identifiers but may be beneficial (i.e., is less confusing and more meaningful) for some children than compressed non-HLT. That is, although some children in the compressed non-HLT appeared to thrive with the challenge of learning a number of new ideas more or less simultaneously, some seemed overwhelmed. It may not be coincidental that only child who refused further participation (after two training sessions) was in the compressed non-HLT condition.

3.2.3.6.2 RQ2: Is there a significant difference between the extension scores and the core identification scores considering the age of children?

Three results indicate that age is a key factor in whether children might benefit from patterning instruction. For the most part, 4-year-olds, but not 3-year-olds, benefitted from the extension (Level 2) and core identification (Level 4) training. Whereas only one of six 3-year-olds who could improve had success on a majority of the trials for the Extension task at posttest (> 2 of 3 points), eight of ten such 4-year-olds benefitted from patterning instruction (p=.025, one-tailed Fisher Exact 2x2 Test). Similarly, only two of seven 3-year olds had success on a majority of the trials for the Core ID task at posttest (> 2 of 3 points), ten of twelve 4-year olds benefitted from patterning instruction (p=.030, one-tailed Fisher Exact 2x2 Test). The four children who were untestable at pretest (and unlikely to benefit from the patterning instruction) were all 3-year-olds. The one child who quit after two training sessions was a 3-year-old.

3.2.3.7 Conclusions from Research Cycle 3

As demonstrated by transfer to core identification and extension tasks with the novel (unpracticed) and developmentally challenging repeating patterns, participants in both the gradual HLT and compressed non-HLT interventions, particularly those 4-years of age, benefitted significantly and substantially from the targeted patterning instruction. The experiment revealed that patterning instruction based on a HLT had some benefits. Specifically, the gradual HLT-based training was somewhat more beneficial for some children than compressed non-HLT training. Clearly, though, a gradual HLT was not necessary for helping all children become core identifiers. That is, the present results indicate that one method may not suit all children. For example, although some children in the compressed non-HLT appeared to thrive with the challenge of learning a number of new ideas more or less simultaneously, some seemed overwhelmed. It may not be coincidental that the only child who refused further training (after two sessions) was in the compressed non-HLT condition.

Moreover, after the implementation of the training sessions, eight specific questions were prepared to qualitatively evaluate the modified version of proposed HLT on patterning (see Table 11).

Table 11

Evaluation questions for the modified HLT

#	**Questions***
1	What was confusing for children?
2	Why some of the children had difficulty during training and posttest?
3	Which children did Session 11 (S11) and Session 12 (S12) without help or with help?
4	Is it good to start earlier to core unit?
5	Which condition made children more prepared for S11 and S12?
6	Which lesson plans were good, which needs to be changed?
7	Who benefited from Intervention 1 (I1) and Intervention 2 (I2)?
8	What can be advised for the field study?

For this purpose, field notes were taken and the observations were made. The basis of the qualitative analysis was the extensive notes taken on the participants' reaction to each lesson and progress. Based on these notes, the evaluation questions were answered in the following part.

1- *What was confusing for children?*

Counting core was confusing for the children because they counted the elements of the pattern. Also, the statement of 'smallest part of the pattern' was confusing because they gave just one element for this question.

2- ***Why some of the children had difficulty during training and posttest?***

Intervention 2 (I2) tasks had something new such as introducing letters earlier and core identification which was different from the proposed regular LT. Moreover, because of the nature of Intervention 2, the tasks took much more time. Therefore, for some of the children in I2, the tasks became difficult and confusing. So, some children were disoriented easily.

3- ***Which children did S11 and S12 without help or with help?***

<u>*In Intervention 1,*</u>

Four children *(i.e.,* SS#12, SS#24, SS#13, and SS#34) did without help.

Two children (i.e., SS#31 and SS#26) did with little help.

Three children (i.e., SS#33, SS#312, SS#35 did with help.

Those children who could do the tasks without help in S11 and S12 were also good at pretest intro part (except SS#24. She couldn't do intro part and pretest). Moreover, they could almost do other sessions without help. On the other hand, other children showed parallel progression with their pretest and intro performance (except SS#33. She could do intro part on the pretest. However, then her performance decreased gradually).

<u>*In Intervention 2:*</u>

Five children (i.e., SS#22, SS#16, SS#11, SS#32, and SS#15 did without help.

Two children (i.e., SS#25 and SS#39) did with little help.

Three children (i.e., SS#38, SS#13, and SS#23) did with help.

Those children who could do the tasks without help in S11 and S12 were also good at pretest intro part (except SS#16. He couldn't do any of pretest tasks and intro part. However, he showed gradual progress during the training). Moreover, these children could almost do other sessions without help. On the other hand, other children showed parallel progression with their pretest and intro performance (except SS#23. She could do intro part on the pretest. However, she couldn't in S11 and S12).

4- ***Is it good to start earlier to core unit?***

For most of the children, definitely yes. Even, some children in I1 would be better if they are in I2.

5- ***Which condition made children more prepared for S11 and S12?***

According to the results, it seems that I2 made children more prepared for S11 and S12.

6- ***Which lesson plans were good, which needs to be changed?***

In Intervention 1, S10 and S8 took a long time. It was divided even for good children. On the other hand, in Intervention 2, S2 should definitely be divided. Moreover, it is starting with ABB and ABC directly; it can be better to continue with AB one more session.

7- ***Who benefited from Intervention 1 (I1) and Intervention 2 (I2)?***

From I1: SS#12, SS#312, SS#24, SS#31, and SS#34. In total, 4 children. These children showed regular progress during the training. Moreover, when compared to the pretest scores, they got higher scores on posttest tasks.

From I2: SS#22, SS#16, SS#11, SS#25, SS#32, and SS#23. In total, 6 children. These children showed progress during the intervention sessions. They showed big achievement on posttest tasks when compared to the pretest scores.

8) What can be advised for the field study?

- For counting core task, 'to take apart the core' is so helpful and easy for children. They can take apart and count them. I showed them how to make a core for pattern train. I made them to watch me. Then, we count the cores and they created more cores easily.
- The activity including cups was extremely enjoyable and good for most children. They could even guess the next two elements! This activity can be included to prepare patterning skills such as extension, fixing, and core identification skills.
- Children didn't have clear/obvious difficulty to understand and accomplish the tasks related to ABB type pattern. It can be said that both ABB and ABC pattern were clearly different than AB pattern. But, ABB was not a type of pattern that can be more difficult from the ABC pattern. Moreover, the AAB pattern type was the easiest task on posttest. And, just the ABCC pattern seems the most difficult task on posttest.

3.2.3.8 Lessons Learned from Research Cycle 3

The study's main practical and scientific benefit may be suggested revisions about when specific patterning skills are taught.

- Most 4-year, but not 3-year, olds, may benefit from extension (Level 2) and core identification (Level 4) training.

- Both the gradual HLT and compressed non-HLT participants exhibited significantly and, as measured by effect size, a substantial pretest-posttest improvement on both tasks.

- Although logically an aspect of Level 3 (translating a pattern into a different format), children quickly learned to translate patterns into letters (e.g., translating green ◎•◎•◎• into the plastic alphabet letters: ABABAB). Therefore, using letters to label the elements of a pattern is a distinct form of translating patterns that can be introduced to children early in the trajectory—in Level 2.

- In contrast, children struggled mightily with translating patterns into different materials (e.g., translating the circle-square-circle-square-circle-square pattern above into triangles-hexagon-triangle-hexagon-triangle-hexagon or—in a few cases—even a red circle-square repeating pattern; cf. Fyfe et al., 2015).

- More scientific data are needed to have insights on young children's patterning skills

3.2.4 Research Cycle 4: Revision of the Modified Hypothetical Learning Trajectory (HLT)

3.2.4.1 Description of the Revisions Made on the Modified HLT

When all findings and critical implications were taken into account, some revisions were thought as necessary on the modified hypothetical learning trajectory (HLT) proposed by Baroody, Yilmaz, Clements, & Sarama (2019). More specifically, as presented in Table 12, in Level 2, the training activities started with describing the elements of repeating patterns with physical characteristics and then with letters (starting from the second session of Level 2b). Then, in Level 3, children will reproduce the given pattern in different materials. Moreover, the word “AND” was used to implicitly underscore the repetition of a pattern’s core. Level 4 activities will focus on using letters to identify the core (the smallest part of a pattern).

Table 12

The changes made on the modified HLT (Baroody, Yilmaz, Clements, & Sarama, 2019)

	Modified HLT (adapted from Clements & Sarama, 2009)						Re-revised HLT (adapted from Baroody, et al., 2019)					
HLT Levels	S#	Physical labels → elements	Physical labels → core	Letters → elements	Use of "AND"	Letters → core	S#	Physical labels → elements	Physical labels → core	Letters → elements	Use of "AND"	Letters → core
1. Intuitive Patterner		*Not instructed in the training*						*Not instructed in the training*				
2a. AB Pattern fixer & duplicator	1	X					1	X				
	2	X					2	X				
2b. AB Extender	3	X					3	X				
	4	X					4	X		X		
2c ABB fixer, duplicator & extender	5	X					5	X		X		
2c ABC fixer, duplicator & extender	6	X					6	X		X		
3. Pattern generalizer	7	X		X	X		7	X		X	X	
	8	X		X	X		8	X		X	X	
							9	X		X	X	
4. Core unit	9	X	X	X	X	X	10		X	X		X
	10	X	X	X	X	X	11		X	X		X
	11					X	12					X
	12					X	**13**					X
							14					X
5. Numeric Patterner		*Not included in the study*						*Not included in the study*				

Note: Text in green implies inserts while text in red shows deletion

3.2.4.2 Description of the Instruction Plans used for Revised HLT

Fourteen instruction sessions were designed for patterning training. Level 1: Intuitive Patterner, was not needed in training. Therefore, the sessions started with Level 2, Level 3, and Level 4 activities, as demonstrated in Table 14. There were two sessions for Sublevel 2a: AB Pattern fixer and duplicator (i.e., sessions 1 and 2), two sessions for Sublevel 2b: AB Pattern extender (i.e., sessions 3 and 4), two sessions for Sublevel 2c: ABB & ABC Pattern fixer, duplicator, and extender (i.e., sessions 5 and 6. three sessions for Level 3: Pattern generalizer (i.e., sessions 7, 8, and 9), and five sessions for Level 4: Unit Patterner (i.e., sessions 10, 11, 12, 13, and 14). Moreover, each instruction session included in one or two patterning activities designed by manual and/or computer-supported activities with at least two examples. For example, as demonstrated in Table 13, in session 2, there are two activities (i.e., *Activity 2.1. Where Is My Friend?* and *Activity 2.2: Where Is My Twin?)* including two examples for each (i.e., Ex 2.1.A and Ex 2.1.B for Activity 2.1 and Ex 2.2.A: Twin Shapes (Computer-Supported Activity): AB with shapes and Ex 2.2.B: Singing Birds (Computer-Supported Activity) for Activity 2.2) (see Table 13).

Table 13

An Example for Instruction Plan

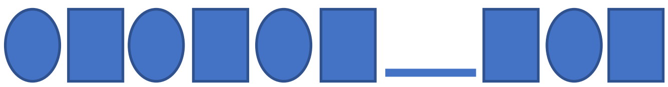
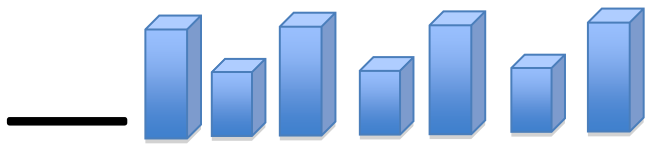
Levels	Sessions	Activities
2a (AB Pattern Fixer and Duplicator)	2	***Activity 2.1. Where Is My Friend?*** Start with a brief introduction that makes child aware of the activity and motivate him/her as telling ***'Today we will play a game with different shapes and colors. In this game, they are looking for their friends. Would you like to help them?'*** ***Ex 2.1.A:*** *Show children the geometric shapes repeating pattern below and encourage them to describe it to you. If need be, chant together circle-square, circle-square, circle-square,.. .*  Then, point to the blank in the pattern and say, ***"What Shape is missing here?"*** ***Prompt: "Which shape goes here?"*** ***Hint:*** "***If we follow the repeating pattern, which goes here—a circle or square?***" ***Give away: If we follow the repeating pattern, a square goes here"*** ***Ex 2.1.B:*** Show children a cube pattern strip (e.g., small, big; small, big; small, big; .. at least three complete units of the pattern).  Then, point to the blank in the pattern and say, ***"This where a shape 'fell off'."*** ***Prompt: "What comes here?"*** ***Hint:*** "***If we follow the repeating pattern, which comes here—a big or small one?***" ***Give away: If we follow the repeating pattern, a small one goes here"***

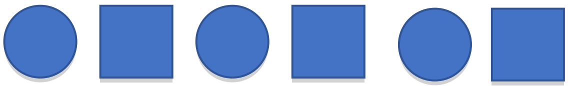
Table 13 (cont'd)

Activity 2.2: Where Is My Twin?

Goal: To duplicate AB patterns.

 ***Ex 2.2.A: Twin Shapes (Computer-Supported Activity): AB with shapes***

Show children the virtual geometric repeating pattern for AB and encourage them to describe it to you. If the child needs help, chant together: (e.g., circle, square; circle-square; circle, square..) for the three complete units of the pattern.



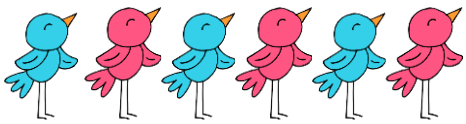
And say, ***"This time, I'm going to make it harder for you by hiding the pattern"*** and then hide the pattern under a cover.

If this proves too hard, uncover the pattern and let the child examine it and then cover it again. If a second look does not help, just uncover the pattern and let the child copy the visible pattern.

Then, ask the child to copy the pattern with **same color-print materials** (i.e., provide concrete materials to copy the pattern model).

 ***Ex 2.2.B: Singing Birds (Computer-Supported Activity)***

Show children the virtual repeating pattern of AB with singing birds and encourage them to describe it to you. If the child needs help, chant together: (e.g., blue bird, pink bird; blue bird, pink bird; blue bird, pink bird; .. for the three complete units of the pattern).



And say, ***"This time, I'm going to make it harder for you by hiding the pattern"*** and then hide the pattern. If this proves too hard, uncover the pattern and let the child examine it and then cover it again. If a second look does not help, just uncover the pattern and let the child copy the visible pattern.

Then, ask the child to copy the pattern with **same color-print materials** (i.e. provide concrete materials to copy the pattern model).

In the activities, the manual materials included in the examples such as geometric shapes, unifix cubes, vehicles, animals, colored tokens, chips, fruits, and vegetables (see Figure 12) while virtual materials and concrete color-print materials created the computer-supported activities (see Figure 13) during the instructions. In total, there were fourteen activities designed by computer-supported activities, while twenty-three activities trained by manual materials.

Figure 12: A sample of the activity using manual materials

Figure 13: A sample of computer-supported activity

3.2.4.3 Description of the Eye-Tracking Materials utilized for Revised HLT

For eye-tracking, computer-supported materials were used and children's responses and cognitive behaviors were followed by Tobii X2-60 eye tracker. As mentioned before, there were fourteen activities designed by computer-supported materials. The tasks and the related goals were displayed in Table 14.

Table 14

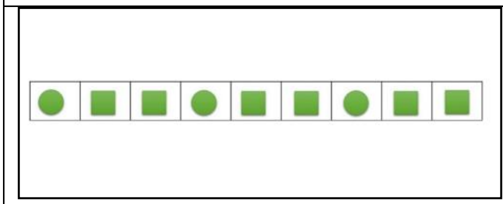
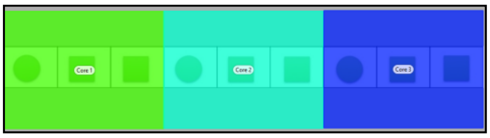
Overall Tasks and Goals used in Eye Tracking Methodology

Task #	Task Name	Goals
1-2	Activity 2.2 A-B	To fix an AB pattern
3-4	Activity 3.2 A-B	To extend an AB pattern
5	Activity 5.1	To fix an ABB pattern
6	Activity 6.1	To fix an ABC pattern
7	Activity 6.2	To fix an ABC pattern
8	Activity 8.1	To translate the pattern
9-10	Activity 9.1 B-C	To translate the pattern
11	Activity 13.1	To identify the core unit
12	Activity 13.2	To identify the core unit
13	Activity 14.1	To identify the core unit
14	Activity 14.2	To identify the core unit

For each patterning task, a specific protocol was prepared and applied. Moreover, in order to quantitatively analyze the eye-tracking data, the Areas of Interest (AOIs) were defined as two or more areas for each activity. For example, as illustrated in Table 15, for the activity 13.2.A, three AOIs were created which were seen to the only researcher. In other words, the participants saw the task for each activity as in its general view.

Table 15

Sample task with and without AOIs

<table>
<tr><th>Activity 13.2 A without AOI[1]</th><th>Activity 13.2 A with AOIs[2]</th></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Notes:
[1]The image seen to child
[2] The image not seen to child but to the researcher</td></tr>
</table>

3.2.4.4 Description of the Testing Tasks and Scoring Protocol used for Revised HLT

The testing tasks were adapted from The Research-Based Early Maths Assessment (REMA) patterning items developed by Clements, Sarama, and Liu (2008). The pretest and posttest involved three tasks. The first task was pattern extension, the second task was identifying the core unit of the patterns, and the third task was the abstraction of the given pattern (i.e., translation). For extension and core identification tasks, children were provided a box of interlocking blocks that contains enough blocks (4 to 6 of each color) to permit extending a pattern or representing the core unit of the pattern. For translation task, children were provided geometric shapes that consist of enough shapes (4 to 6 of each shape of circle, square, triangle, and rectangle) (see Figure 14).

Figure 14: Tasking tasks used in the study

Before starting to the testing tasks in the pretest, two brief introduction tasks to the pattern were given. First, the explanation of the pattern was told as ***"A repeating pattern involves a regular sequence, like day and then night, then day and night again."*** then it was asked: ***"It's day now, what comes next? After night comes what?".*** A series of "day and night" pattern was shown the child and waited for the response of the next element.

Second, the child was shown (a) 8 Blue, (b) 6 Blue and 2 Red, and (c) Blue-Red- Blue-Red- Blue-Red interlocking blocks (see Figure 15) and asked: ***"Which of these do you think is a repeating pattern?"*** If needed, the explanation was made as: *"Only this one* [point to B-R-B-R-B-R-B-R] *is a repeating pattern because it involves a regular sequence—white, then red, then white again, then red again, white, red, white, red."*

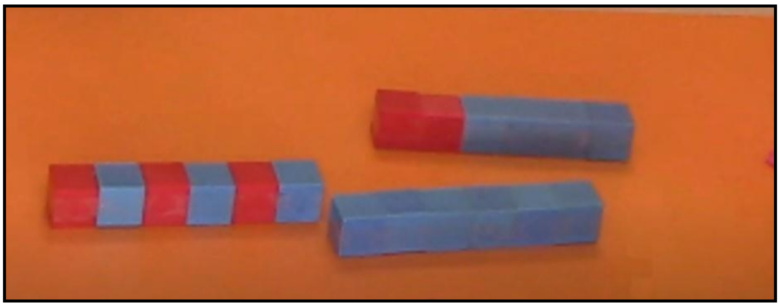


Figure 15: The trail tasks used in the pretest

Task 1: Extension

For the extension tasks, a practice trial involving an AB pattern was introduced with instructions: *"In the Keep Going Game, I'll show you a pattern using interlocking blocks like this* [the child was shown the Blue-Red- Blue-Red- Blue-Red]. *Use these cubes* [tester pointed to the box] *to make the pattern "keep going—to make the pattern longer."* If the child did not respond or had difficulty, the researcher helped by adding a blue and then a red cube and encourage the child to make the pattern longer. If a child adds only one blue and one red, said: *"Can you keep going—to make the pattern longer?"*. After the trial task, the patterns AAB, ABCC, and ABCD were asked to extend, in turn. No feedback or comments were provided to children during the testing. A correct response (6 points) entailed extending the pattern two full core units of the pattern without errors (using only complete examples of the core). Partial credit (from 1 to 5 points) was granted if the child produces at least one full core unit of the pattern and the part of another. An incorrect response was scored as 0.

Task 2: Core Identification

For the core identification task, a practice trial involving the AB pattern was introduced with instructions: *"Use these cubes* [the tester pointed to the box] *to see what part of the pattern* [a tester draw her finger along the length of the interlocking cubes forming the pattern] *keeps repeating."* If need be, ask the child, *"What is the smallest part of the pattern that happens again, and again, and again to make the pattern?"*. If the child did not respond or had difficulty, the researcher helped by saying *"In this pattern a blue-and-red part keeps repeating"*. Then, the children were shown the AAB, ABCC, and ABCD patterns, in turn, to find the core unit of each pattern. No feedback or comments were provided to children during the testing. Responses were considered correct (6 points) if the child represented the core with interlocking blocks or incorrect (0 points). No partial credit was applied for the core identification task.

Task 3: Translation Task

For the translation task, a practice trial involving the AB pattern were introduced with instructions: *"Use these shapes* [the tester pointed to the geometric shapes] *to make this same pattern but using different materials* [a tester draws her finger over the interlocking cubes forming the pattern] If need be, say: *"Let's use a circle in place of the blue cube, then a triangle in place of the red cube."* Then, the children were shown the AAB, ABCC, and ABCD patterns, in turn, to find the core unit of each pattern. No feedback or comments were provided to children during the testing. A correct response (6 points) entailed extending the pattern two full core units of the pattern without errors (using only complete examples of the core). Partial credit (from 1 to 5 points) was granted if the child produces at least one full core unit of the pattern and the part of another. An incorrect response was scored as 0.

The posttest was implemented two weeks after the last instruction session. Same measurement and same procedure were used as same as in the pretest detailed above; however, the introduction tasks and the practice trial involving an AB pattern were not introduced with instructions at the beginning.

3.2.5 Research Cycle 5: Evaluation of the Revised Hypothetical Learning Trajectory (HLT)

This last research cycle, which was produced by the previous iteration cycles, serves as the main study for this dissertation. In other words, the findings and the discussions of this dissertate will be presented based on research cycle 5. Therefore, the following sections will explain all the details about it.

In order to evaluate the revised version of Hypothetical Learning Trajectory (HLT), a randomized pretest-posttest-control experimental study was designed. A pretest served to ensure participants in the study were below Level 4 on at least two of the three core-identification trials (n=48) and to establish baseline patterning knowledge. Participants were randomly assigned within the classroom to one of the three conditions. Two weeks after the last intervention session, a patterning posttest was administered. The posttest tasks involved pattern types not used in the training, and, thus, helped the transfer of learning. Moreover, in order to understand underlying cognitive processes regarding to patterning skills, eye-tracking methodology was employed. The related procedure was presented in detail below.

3.2.5.1 Interventions in Research Cycle 5

As presented in Table 16, there were three training conditions to compare the efficacy of core-identification instruction based on a HLT, with non-HLT instruction using the same activities, and business-as-usual (BAU).

- Intervention 1 (experimental intervention): Gradual, HLT-based core-identification instruction
- Intervention 2 (active control): Non-HLT-based core-identification involving the same activities as Intervention 1 but integrated without regard to developmental level (integrated non-HLT).
- BAU (passive control): Regular classroom instruction, which did not provide instruction on core identification or other aspects of patterning.

Table 16
Intervention groups formed in the present study

Intervention Name	Intervention Group	Nature
Intervention #1: Gradual, HLT-based	Experimental Intervention Group	Follows the Level 2, then Level 3, and finally Level 4 progression specified by the LT WITH a transition between uses using ABSTRACT LABELS.
Intervention #2: Integrated, non- HLT	Active Control Group	Levels 2 and 3 (1 or 2 lessons each) are very brief preludes to Level 4 using ABSTRACT LABELS.
Intervention #3: Business-As Usual (BAU)	Passive Control Group	No patterning instruction with repeating patterns)

[1]Modification: Use letters to label elements of a pattern moved from Level 3 to Level 2.
[a] The transition between the two uses of letters would entail asking a child to label the elements and then identify the core—the smallest part that repeats.
[b] The transition between the two uses of physical characteristics would entail asking a child to label the elements and then identify the core—the smallest part that repeats.

As presented in Table 17, the sequenced instruction sessions were organized for the Hypothetical Learning Trajectory (HLT) (i.e., Intervention 1: Gradual HLT Approach) while an unordered training was put together as an active control group (i.e., Intervention 2: Integrated non-HLT Approach). These two approaches completely used the same activities and materials but in a different order. For example, both built on using physical characteristics to describe the elements of a pattern (e.g., labelling a ●■●■●■ pattern a "circle-square-circle-square-circle-square"). Both Intervention 1 and 2 focused on AB, ABB, and ABC patterns. Both started with labeling the elements of repeating patterns with physical characteristics and then with letters (e.g., labeling a ●■●■●■ pattern "Circle-square, circle-square, circle-square" and then "ABABAB"). Both interventions used "AND" to implicitly underscore the core of repeating pattern (e.g., labeling a ●■●■●■ "Circle, square, AND circle, square, AND circle, square"), and using letters to label the core of repeating pattern (e.g., labeling a ●■●■●■ as an "AB pattern"). For both interventions, the transition between using letters to label the elements of a pattern and to identify the core of a pattern entailed asking a child to first label the elements with letters and then identify the core—the smallest part that repeats—using letters. However, in Intervention 2 (I2), the use of letters to identify the elements of the core was also introduced immediately in Session 1 while it was presented in Session 4 in Intervention 1 (I1). Moreover, the use of letters to identify the core of repeating patterns was delayed until Session 10 in the gradual HLT approach but presented relatively early (i.e., in Session 3) in the integrated non-HLT approach. The use of "AND" to describe the physical and letter labels of pattern elements to implicitly underscore the core (e.g., labeling a ●■●■●■ circle-square AND circle-square AND circle-square AND") was given in Session 4, which was placed in Session 7 in I1. This situation was similar for the pattern types, too. For example, Levels 2a to 2c were followed in a fixed order for the gradual HLT approach (i.e., AB patterns were used exclusively in Sessions 1 to 4 and the more advanced ABB and ABC patterns were not introduced until Sessions 5 & 6). In the integrated non-HLT approach, AB patterns were used to introduce an activity, but ABB pattern was introduced in Session 2.

The business-as-usual (BAU) intervention group did not get patterning instruction rather had regular classroom instruction. Ministry of Education in Turkey has a Turkish Early Childhood Education Program to help public school early childhood teachers to plan their instruction. The program is formed as progressive, holistic, and eclectic, as well as embedded in cognitive development, linguistic development, social-emotional development, and motor development domains (MoNE, 2013). Under the cognitive domain, there are some objectives and indicators that can be related to mathematical thinking. For example, children are expected to have some skills such as comparing, matching, and grouping the objects, problem-solving, and building cause and effect relationships. Moreover, there one objective and four indicators related to pattern in the program as stating, "Child creates a pattern with objects by looking at the model; Tells the rule in the pattern consisting of up to three elements; Tells the missing element in a pattern and completes it; Creates a pattern with objects" (MoNE, 2013, p.21). For the instruction of the patterns, the program explains a brief guideline starting to define the pattern and how to extend a given pattern. However, no instruction about advance patterning skills such as translation and core identification were given in the program as well as no examples of instruction that can be utilized from the technology were mentioned in the program.

Table 17

Key Differences and Similarities between the Intervention Groups

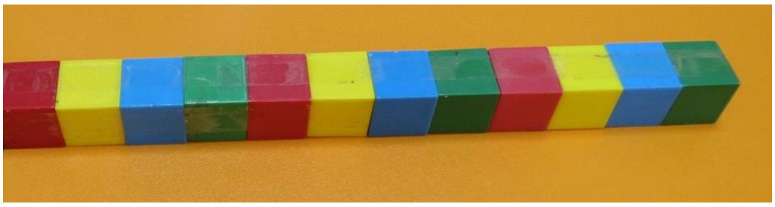
HLT Levels	S #	Intervention 1: Gradual HLT Approach — Physical Labels/ Elements	Physical Labels/ Core	Use of "AND"	Letters / Element	Letters / Core	S# (Equivalent I-1 Sessions)	Intervention 2: Integrated non-HLT Approach — Physical Labels/ Elements	Physical Labels/ Core	Use of "AND"	Letters / Element	Letters / Core
2a. AB fixer & duplicator	1	X					1 (4)	X			X	
	2	X					2 (6)	X			X	
2b. AB Extender	3	X					3 (13)					X
	4	X			X		4 (9)	X		X	X	
2c ABB fixer, duplicator & extender	5	X			X		5 (1)	X				
2c ABC fixer, duplicator & extender	6	X			X		6 (10)		X	X		X
3. Pattern generalizer	7	X		X	X		7 (8)	X		X	X	
	8	X		X	X		8 (3)	X				
	9	X		X	X		9 (14)					X
4. Core unit	10		X	X		X	10 (7)	X		X	X	
	11		X	X		X	11 (2)	X				
	12					X	12 (11)		X	X		X
	13					X	13 (5)	X			X	
	14					X	14 (12)					X

Using **physical characteristics** to label the *elements* of repeating pattern (e.g., ●■●■●■): "Circle, square, circle, square, circle, square."
Using **letter**s to label the *elements* of repeating pattern (e.g., ●■●■●■): "ABABAB."
Using **"AND"** to implicitly underscore the *core* of repeating pattern (e.g., ●■●■●■): "Circle, square AND circle, square AND circle, square."
Using **letter**s to label the *core* of repeating pattern (e.g., ●■●■●■): AB

3.2.5.2 Testing Materials Used in Research Cycle 5

Three types of patterns were used in testing sessions and none of these patterns were a part of the interventions and, thus, expected to serve to gauge transfer. Each example of a pattern included at least three complete core units, that is, consist of 12 elements (see Table 18).

Table 18
Model AAB, ABCC, and ABCD Task of the Pretest and Posttest in Research Cycle 5

Pattern Type	Model
AAB	
ABCC	
ABCD	

Pretest and posttest were conducted to measure patterning skills (i.e., extension, core identification, and translation) for AAB, ABCC, and ABCD patterns. Moreover, children were asked to perform the patterning skills such as fixing, duplicating, extending, translation, and core identification for three types of pattern structures, namely AB, ABB, ABC pattern. The former measurements were not included in the eye-tracking part but the latter.

The testing tasks were adapted from The Research-Based Early Maths Assessment (REMA) patterning items developed by Clements, Sarama, and Liu (2008). REMA is a theoretically-based instrument developed to measure young children's mathematical skills including various topics such as counting, numbers, geometry, patterning, and measurement considering developmental levels. The items of the instrument were developed by conducting three pilot study and qualitative observations. For the content validity of the instrument, experts panel was arranged and required suggestions were applied. Moreover, Rasch model was applied to refine and validate the instrument as well as to establish the construct validity. After conducting item difficulty analysis and reliability analysis, interrater reliability value was found 98% while the range for coefficient alpha reliabilities was between .89 to .71. In addition, concurrent validity of the total test score was examined and found as .86. In the end, considering all the procedures and the findings, it can be concluded that REMA is a proper, valid, and reliable instrument to measure early mathematical skills of young children aged 4 and 5 (Clements et al., 2008). Therefore, REMA patterning items were utilized for the testing tasks of the present study.

3.2.5.3 Research Questions Formed in Research Cycle 5

In order to evaluate the effectiveness of the revised Hypothetical Learning Trajectories (HLT) and to understand the cognitive behaviors on patterning, two research questions were formed as follows.

1) Does instruction in which Learning Trajectories (LT) levels are taught consecutively (e.g., presenting children at level n- instructional tasks from level n+1, then n+2, and so forth) result in greater learning than instruction that uses the same activities without regard to developmental order or business-as-usual instruction?

  1a) Is there a significant difference between the children's pattern extension scores considering the intervention groups (i.e., HLT group, integrated-HLT group, and business as usual group)?

  1b) Is there a significant difference between the children's translation scores considering the intervention groups (i.e., HLT group, integrated-HLT group, and business as usual group)?

  1c) Is there a significant difference between the children's core identification scores considering the intervention groups (i.e., HLT group, integrated-HLT group, and business as usual group)?

2) How do children establish their patterning skills?

  2a) How do children establish patterning extension skill?

  2b) How do children establish patterning translation skill?

  2c) How do children establish patterning core identification skill?

3.2.5.4 Procedures Followed in Research Cycle 5

3.2.5.4.1 Procedure for Experimental Study in Research Cycle 5

The experimental study was designed as a randomized pretest-posttest control group study. As exemplified in Table 19 below, according to Fraenkel, Wallen, and Hyun (2012, p. 272), the Randomized Pretest-Posttest Control Group Design is explained as a design in which the participants are randomly assigned (see the letter R) to the treatment (see the letter X) and control groups (see the letter C). Moreover, both groups have a test before the training and a test after the training (see the letter O).

Table 19

Randomized Pretest-Posttest Control Group Design

Treatment group	R	O	X	O
Control group	R	O	C	O

Based on the outline offered by Fraenkel and colleagues (2012), the researcher designed the experimental setup as presented in Table 20. Before the implementation of the training sessions the pretest was applied, and the posttest was implemented two weeks after the last instruction session. Same measurement and same protocol were used as same as in the pretest.

Table 20
Design of the Experimental Study in Research Cycle 5

PRETEST **(O)** Extension Core-identification Translation		**TRAINING** (Fourteen training sessions of patterning training from Levels 2 to 4)	**DELAYED POSTTEST** **(O)** Extension Core-identification Translation
		Treatment Group **(X)**	
All participants	All participants → Random assignment **(R)**	Active Control Group **(X)**	All participants
		Passive Control Group (Non-patterning group) **(C)**	

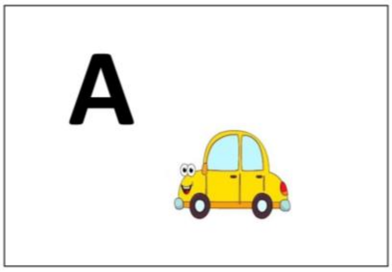
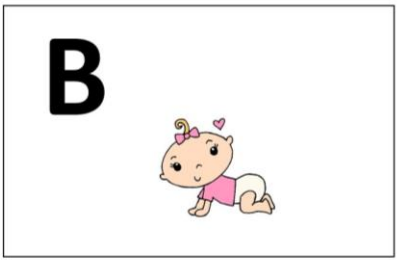
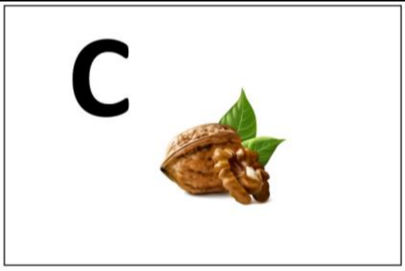
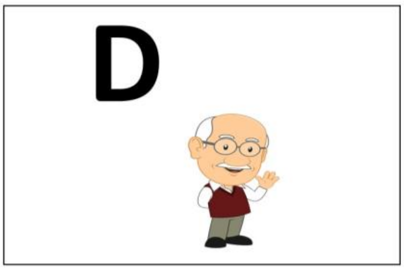
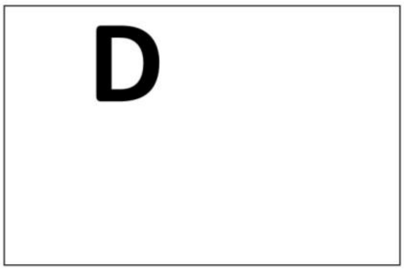
The sessions for the experimental study occurred in the quiet room near to the child's classroom. The training sessions included fourteen lesson sessions designed for patterning instruction. Each instruction session included one or two patterning activities designed by manual and/or computer-supported activities with at least two examples.

The training sessions were scheduled in regular preschool hours either between 10 am and 12 am or/and from 3 pm to 5 pm in the quiet project room close to the child's classroom. There were fourteen training sessions and each of them was applied to each child individually. Before starting to a training session, each child was asked and received their approval. Moreover, the children were informed about the tasks to be done in the session.

Before implementing the experimental study, a pilot study was conducted Turkish children since the previous research was applied to American children. In this way, it was examined whether Turkish children aged three to five were ready or not to implement the patterning study. The lesson plans were translated into Turkish language and consulted to two experts who are professors in education faculty, competent in both English and Turkish languages and have experience in early mathematics. In the pilot study, the instruction plans based on modified HLT and non-HLT groups, and the testing tasks were applied to five children in the same preschool. The findings revealed that Turkish children (aged between 46 to 66 months) are also ready for patterning. Although they knew about geometric shapes, they did not know the letters because of their school policy. Therefore, children were first instructed about letter recognition. For this purpose, the researcher prepared the materials in a tablet computer to introduce the letters. Four letters (A, B, C, and D) were presented in two versions: with the corresponded picture and then without a picture, in turn. In the first version, the researcher pointed the picture and said: *"See, this is a car [in Turkish, "Araba"] that starts with letter A. So, could you say the name of this letter?"* (the researcher points out the next slide without picture). Moreover, switches were made between the previous or next slide when needed. The same procedure was followed for the rest of the letters. This method worked as we practiced with children during the training. In total, eight slides were prepared, as demonstrated in Table 21.

Table 21

Demonstration of the slides about letters

Letters	Slide #1	Slide #2
A		
B		
C		
D		

Note: The corresponded pictures were chosen considering the Turkish language. In other words, a car means "Araba", a baby means "Bebek", a walnut means "Ceviz", and a grandfather means "Dede" in Turkish.

3.2.5.4.1.1 Participants Involved in Experimental Study in Research Cycle 5

Parental consent was obtained for a total of 64 children from 6 classes in 2 typical urban middle-class public preschools serving families from low to mid-high socio-economic status. Two state-run preschools, located in a metropolis city in Turkey, had been conveniently selected. Five children were uncooperative and not tested. One Business-As-Usual (BAU) child and one HLT-based child refused to continue after the pretest. Four HLT-based and five non-HLT-based children refused to continue after one to four (n=3) training sessions. A total of 48 preschoolers completed the IRB-reviewed and -approved study. See Table 22 for a description of the participants by conditions.

Table 22

Characteristics of the Participants in Research Cycle 5

		HLT-Based Group	Integrated Non-HLT Group	Business-as-Usual Group
Age	Old 3s and young 4s (46 to 53 months)	9	8	7
	Old 4s and young 5s (54 to 66 months)	6	7	11
	Mean (SD)	53 months (4.33)	52 months (4.29)	54 months (3.55)
Gender	Number of girls/boys	5/10	8/7	4/14

3.2.5.4.1.2 Analysis for Experimental Study in Research Cycle 5

The obtained data from experimental research were analyzed using inferential statistics. For the main research question examining the effectiveness of the revised HLT among the intervention groups, analysis of covariance (ANCOVA) was conducted. While one-way between-groups analysis of variances (ANOVA) was used to answer the first sub-research question related to patterning extension skills and third sub-research question regarding patterning core-identification skills, an analysis of covariance (ANCOVA) was conducted for the second sub-research question about patterning translation skills (Tabachnick & Fidell, 2013). According to The Institute of Education Science (IES) What Works Clearinghouse (WWC) guidelines (IES, 2014), "Effects of 0.25 standard deviations or larger are considered to be substan- tively important . . . even though they may not reach statistical significance in a given study" (p. 23). Therefore, Given the importance of reporting effect size (Lipsey et al., 2012), the efficacy was also evaluatedin this study.

3.2.5.4.2 Procedure for Eye-Tracking Study in Research Cycle 5

The eye-tracking study was designed as a within-subject study in which children's eye movements were examined considering some specific eye-tracking metrics. Before conducting the main eye-tracking recordings, a revised application form was constructed and applied to METU Human Research Ethics Committee because, in the first application, eye tracking methodology was not included. After all the documents were reviewed and approved, the parental consent form was revised accordingly. Then, one more time, the parental consents were taken for all children participated.

The sessions for the eye-tracking study occurred in the quiet room near to the child's classroom. The eye-tracking sessions, as other sessions, were scheduled in regular school hours either between 10 am and 12 am or/and from 3 pm to 5 pm in the quiet project room close to the child's classroom. Eye-tracking sessions were also applied to each child individually. Before starting the eye-tracking, each child was explained about the process. For example, children were told about calibration steps and the importance of their position. Moreover, in each session, the children were informed about the tasks and their requirements as well as not to change their posture much and not to look around during eye-tracking recordings.

Moreover, a pilot study was conducted for eye-tracking data collection. This pilot study consisted of three purposes:

1) To get familiar with the equipment, the use of the eye tracker (e.g., calibration, setup, recording, etc.)
2) To understand children's reactions
3) To manage the time and place for the implementation.

3.2.5.4.2.1 Participants involved in Eye-Tracking Study in Research Cycle 5

Children who participated in the eye-tracking study were the same as the children involved in HLT-based and Integrated Non-HLT-based intervention. That is, 30 children (13 girls and 17 boys) with a mean age of 52.5 months (SD = 4.31, range: 46–66 months) from 6 kindergarten classrooms in 2 public schools were included in the study.

3.2.5.4.2.2 Apparatus and preparation for Eye-Tracking Study in Research Cycle 5

Tobii X2-60 Eye Tracker with a 60 Hz sampling rate and freedom of head movement 50 x 36 cm (20 x 14") (Width x Height) at the distance of 70 cm was used. Before starting to use the Tobii X2–60 Eye Tracker, the accompanying devices needed to meet some prerequisites as recommended in Tobii User Manual (2014).

For example,

- The computer should be compatible with the software that you are going to use (Tobii Studio or other eye-tracking software).
- The screen used for presenting the stimuli should have proper size and form factor to be used with the eye-tracker that you have (e.g., PC monitors up to app. 25").
- Need to be used either Windows 7 or Windows 8 as an operating system.
- The firewall(s) on the computer need to allow access for eye-tracking software (Tobii User Manual, 2014, p.5).

All recommended prerequisites above were provided to start using the Tobii X2-60 eye tracker containing a mounting bracket, external processing unit, power supply, USB Ethernet adapter, Ethernet cable, and PSU cable.

3.2.5.4.2.3 Setting for Eye-Tracking Data in Research Cycle 5

Tobii User's Manual (2014) recommends some different setups for using Tobii eye-trackers. Since the participants of this study were children, one of the dissertation committee members, a professor at Computer Education and Instructional Technologies (CEIT) department, recommended the researcher to use both primary (screen size: 19") and secondary screen (screen size: 15") at the same time (see Figure 16). Therefore, the researcher designed this setup to make children focus on the primary screen presenting essential stimuli.

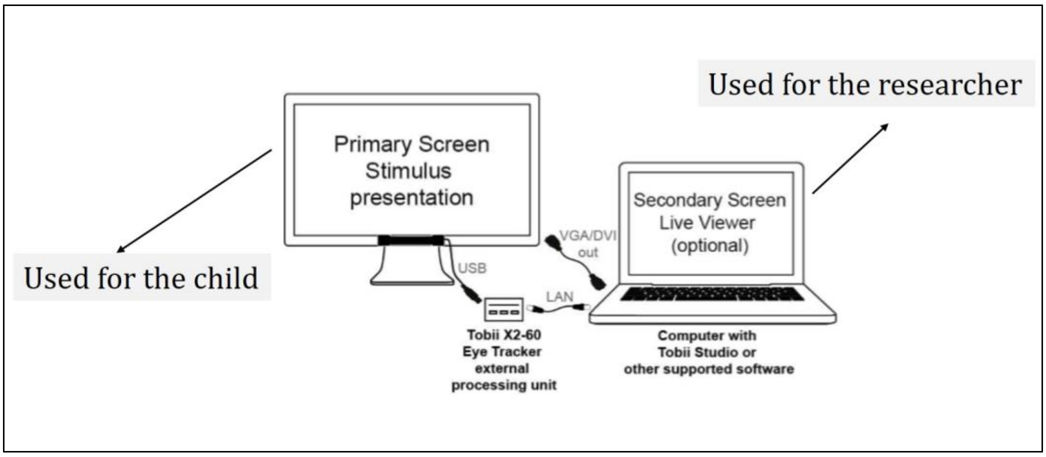


Figure 16. Illustration of setup used in the study (The picture was adapted from Tobii User's Manual, 2014, p. 22)

To ensure a successful eye-tracking record, a suitable location was chosen for eye-tracking setup. Moreover, direct sunlight was avoided by closing curtains and direct lamplight was prevented by turning off the causing ones. Based on these considerations, the eye-tracking setup was arranged as shown in Figure 17.

Figure 17. The demonstration of the real setup for the present study

3.2.5.4.2.4 Calibration Process for Eye-Tracking Data in Research Cycle 5

The calibration process was completed in four steps as follows:

1. Informing children about the calibration and the tasks that children would accomplish
2. Informing children about the importance of the position during calibration
3. Monitoring children's postures and distance to the eye-tracker to make sure that their eyes were detected. If needed, children's chair

moved forward or backward to ensure the optimal distance between the child and the eye tracker (i.e., app. 60–65 cm (Tobii User Manual, 2014)) It was tried to keep the same distance among the children as displayed in Figure 18.

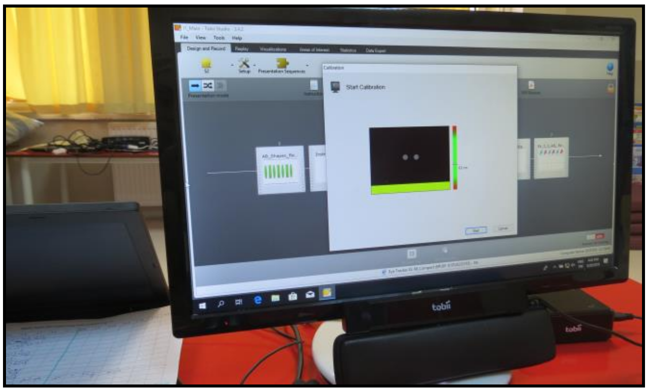


Figure 18. The illustration of the distance arrangement in the study

4. Starting the calibration process and checking it to see whether there was any point needed to recalibrate. If so, calibrate again or continue with the main tasks. Figure 19 showed an optimal calibration process applied to each child.

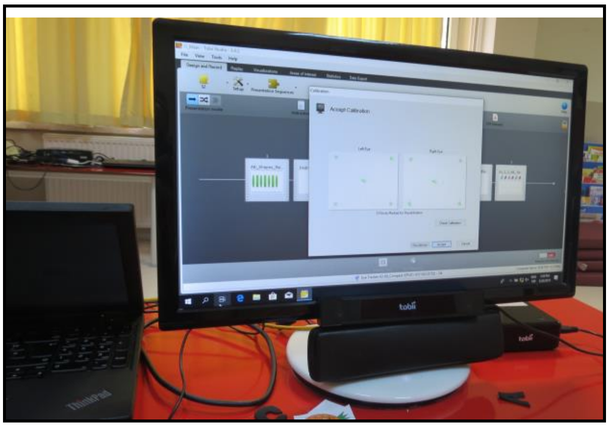


Figure 19. The illustration of the calibration applied in the study

3.2.5.4.2.5 Analysis of Eye-Tracking Data in Research Cycle 5

For this study, children's demographic data (i.e., age and gender), patterning pretest and posttest scores, and eye-tracking data were analyzed by using both descriptive statistics and inferential statistics. Specifically, for the eye-tracking data, gaze plots, heat maps, and the Areas of Interest (AOIs) with related metrics were examined and reported. AOIs were created to calculate the eye-tracking measures, including fixation duration, the sum of the fixation duration, and visit duration.

3.3. Ethical Issues

In any research study, every researcher should have an important responsibility to ensure that participants of the study are protected from physiological and physical harm. There are three essential issues in this situation, such as protecting the participant from harm, ensuring the confidentially of the data and avoid the deception of subjects (Frankel & Wallen, 2006). All stages of the present study were reviewed and approved by the UIUC Institutional Review Board (IRB), METU Human Research Ethics Committee, and the MoNE Ethics Committee. The deception was not used in the testing.

The parents were informed, and the consent forms were given to fill; therefore, nobody participated unwillingly or by force to the study. In addition to parental consent, positive assent was obtained from a child for every testing and training session. Moreover, children were given the choice to drop or continue at any time.

To ensure willing participation, the researcher conducted two familiarization sessions—one in a child's classroom and one alone with the child in the project room. Moreover, the testing and training were done in the context of a game so as to be engaging to children (as well as educational). The researcher was enthusiastic and made every effort to make children feel comfortable.

The testing and training of the study presented a minimal risk. That is, the probability and magnitude of harm or discomfort were not greater than those ordinarily encountered in an educational (instructional or testing). Indeed, the risks involved in the research were negligible relative to the potential benefits involved. The participants benefited from the testing/training by providing them opportunities to engage in mathematical thinking and learning (to develop mathematical proficiency) they might not otherwise have had.

3.4 Validity and Reliability Issues

According to Fraenkel, Wallen, and Hyun (2012), internal validity refers that "any relationship observed between two or more variables should be unambiguous as to what it means rather than being due to something else" (Fraenkel et al., 2012, p. 166). Therefore, it is crucial that the researches ensure the possible threats were controlled, eliminated, or minimized. Moreover, it is believed that an experimental study is "one of the most powerful research methodologies that researchers can use" (Fraenkel, Wallen, & Hyun, 2012, p. 265). Indeed, True Experiment Designs or Randomized Controlled Trials is believed to give high-quality information for cause-effect relationship because it generally controls the extraneous variables by having random assignment and control group (Cash, Stanković, & Štorga, 2016; Fraenkel et al., 2012). In this study, true experimental research was utilized and the participants were randomly assigned to three conditions in which one of those was a control group. According to Fraenkel et al., (2012), the random assignment has an essential and powerful role in forming the groups as much as equivalent, which can control the possible internal validity threats. Indeed, randomization is offered one of the ways to handle the effects of the potential variables such as subject characteristics, maturation, and statistical regression. However, some internal validity threats such as instrumentation, mortality, data collector characteristics, data collector bias, location, and testing may still exist (Fraenkel et al., 2012). Therefore, these possible threats were tried to handle and controlled by taking precautions and making some modifications for this study.

To begin with instrumentation (i.e., data collection tool), it means that poor data collection tools can be a threat for the validity of the study. Therefore, both valid and reliable measurements are needed to be used (Fraenkel et al., 2012). In this study, the testing tasks were adapted from the Research-Based Early Maths Assessment (REMA) items developed by Clements, Sarama, and Liu (2008). The REMA items have high reliability and validity values. With the help of the expert in early mathematics education and one of the developers of the original REMA tasks, minor changes were applied to the REMA patterning items. The reliability of the adapted tasks was not statistically examined however, these adapted items were also evaluated by the same experts, and after getting their approval, the tasks were used in the present study. Moreover, in order to score the answers of the participants, one more independent scorer was employed. A scoring sheet was used to record the answers of the participants. Participants were randomly chosen. Both the researcher and the independent coder scored the answers independently. Then they gathered and compared the scores using a scoring worksheet. In the end, 91% agreement was made on total testing scores. Moreover, when examined for each patterning task, 83% agreement was made on extension task scores, 100% on core task scores, and 93% on transition task scores. These values are higher than the cut off value of 80% (Fraenkel et al., 2012). Therefore, it is assumed that instrumentation threat was controlled.

Mortality means the loss of the participants. In long-term studies, it is sometimes unavoidable to prevent dropouts. Since the present study followed the ethical considerations, the researcher did her best to keep the participants until the end of the research but did not force any children. Therefore, in this study, while some participants did not want to continue after a few sessions, some withdrawal the study at the beginning of the study. To control mortality threat, it is recommended to explain the reason for the loss to show it did not happen intentionally but incidentally (Fraenkel et al., 2012). Therefore, the detailed explanation of dropouts was mentioned in the method section of the present study. Moreover, the number of losses was seen as similar in each group. Thus, it is assumed that the mortality threat was not a problem for this study.

Data Collector Characteristics refers to any characteristics such as gender, age, ethnicity, other related attributes of the data collector that may affect the obtained data (Fraenkel et al., 2012). In this study, all treatment and control group participants were treated and tested by the same researcher. Therefore, it is assumed that the data collector characteristics threat was controlled in the study.

Data Collector Bias means that "data collector(s) or scorer(s) may unconsciously distort the data in such a way as to make certain outcomes" (Fraenkel et al., 2012, p. 170). To handle this threat, it is advised to standardize all procedures and not to inform any groups whether they are a treatment or control group. In this study, the researcher prepared all the session plans in advance and used the same activities for all participants. Moreover, the researcher used the pre-prepared standardized rubrics related to each session. Besides, a scoring sheet and scoring protocol were used to score the children's answers and another coder has also scored the answers. Furthermore, the researcher did not say anything and did not explain to any individual which group was a treatment or control group. Thus, data collector bias was not seen as a threat to this study.

Location threat means the place where the data were collected, and the treatment was given. To control this threat, it is advised to keep the location the same for all groups (Fraenkel et al., 2012). In this study, the data were collected from all treatment and control group participants in the same room close to the children's classroom in the kindergarten. Moreover, the same materials were used, and the same procedures were followed for each group. Thus, no location threat was seen in the study.

Testing threat refers to alert the participant by conducting a pretest, and it is usually common in single-group designs (Fraenkel et al., 2012). In this study, there were three groups including a control group. Moreover, the period between the pretest and posttest was not so close to each other. Therefore, it is assumed that testing was not a threat to this study.

External validity means the generalization of the research findings from sample to population (Fraenkel et al., 2012). Since this study used nonrandom sample, it can be a threat for generalizability. However, Fraenkel et al., (2012) recommend researchers to describe the characteristics of the sample regarding their age, gender, ethnicity, and socioeconomic status in detail so that interested others could make some conclusion from the research findings. Therefore, the detailed information about sample characteristics were presented and explained in this study.

3.5 Limitations

The limitations of this study can be explained in six issues. In other words, the present study is limited to (1) Research model which was designed as randomized experiment study based on design based research, (2) the participants who were normally developing four- and five-year-old preschool children, (3) the data collection measures which were adapted from REMA items (Clements, Sarama, & Liu, 2008), (4) the eye-tracking apparatus, Tobii X2-60 eye tracker, which was used for the collection of the eye-tracking data, (5) the domain of mathematical patterning skills, and (6) the type of the patterns (i.e., repeating patterns).

CHAPTER 4

RESULTS

In this chapter, the findings of the last research cycle of the study (i.e., The evaluation of the revised HLTs) are presented in detail. The effectiveness and the underlying cognitive mechanisms of early patterning skills are presented by addressing the following research questions. As explained beforehand, three analysis methods were conducted to answer the research questions of this study namely, descriptive statistical techniques, ANOVA, and ANCOVA. Moreover, preliminary analyses were conducted to ensure the required assumptions for ANOVA and ANCOVA.

1) Does instruction in which Learning Trajectories (LT) levels are taught consecutively (e.g., presenting children at level n- instructional tasks from level n+1, then n+2, and so forth) result in greater learning than instruction that uses the same activities without regard to developmental order or business-as-usual instruction?

1a) Is there a significant difference between the children's pattern extension scores considering the intervention groups (i.e., LT group, integrated-LT group, and business as usual group)?

1b) Is there a significant difference between the children's translation scores considering the intervention groups (i.e., LT group, integrated-LT group, and business as usual group)?

1c) Is there a significant difference between the children's core identification scores considering the intervention groups (i.e., LT group, integrated-LT group, and business as usual group)?

2) How do children establish their patterning skills?

2a) How do children establish patterning extension skill?

2b) How do children establish patterning translation skill?

2c) How do children establish patterning core identification skill?

4.1 RQ1: Does instruction in which Learning Trajectories (LT) levels are taught consecutively (e.g., presenting children at level n- instructional tasks from level n+1, then n+2, and so forth) result in greater learning than instruction that uses the same activities without regard to developmental order or business-as-usual instruction?

For this research question, analysis of covariance (ANCOVA), was conducted to increase the power of *F* test for the main effect of intervention by removing the covariance from the error (Tabachnick & Fidell, 2013). ANCOVA seems similar to ANOVA; however, it is an *"extension of analysis of variance in which main effects and interactions of IVs are assessed after DV scores are adjusted for differences associated with one or more covariates (CVs), variables that are measured before the DV and are correlated with it"* (Tabachnick & Fidell, 2013, p.197). In other words, the effect of the Independent Variables (IVs) (i.e., intervention types) on the Dependent Variables (DVs) (i.e. posttest scores) are examined after controlling the Covariate Variables (CVs) (i.e., pretest scores). In this study, there were three intervention groups. A pretest was conducted before the interventions and therefore considered to be related to the posttest scores. Therefore, ANCOVA was determined as the appropriate statistic. However, before conducting ANCOVA the required assumptions were checked. According to Tabachnick and Fidell (2013), there are some specific assumptions for ANCOVA, which are unequal sample sizes, outliers, multicollinearity, normality, homogeneity of variance, linearity, homogeneity of regression. After ensuring these assumptions, the results of the ANCOVA were presented in the following sections.

4.1.1 The Assumptions of the ANCOVA

Unequal n and Missing Data:

SPSS provides a descriptive statistics table to screen the dependent variable (DV) and covariate (CV) for three intervention groups. As it is seen from the table, there is the unequal number of sample sizes for the groups. This situation is meaningful and resulted from the willingness/unwillingness of the participants to continue or drop the study at any time. Indeed, five children from HLT group and non-HLT group and one child from non-patterning group did not want to continue to the study.

Normality:

Normal is defined as “a symmetrical, bell-shaped curve, which has the greatest frequency of scores in the middle with smaller frequencies towards the extremes” (Gravetter & Wallnau 2004, p. 48). For the assessment of the normality, Kolmogorov-Smirnova values and histogram graphs were examined (Pallant, 2007). As it is seen in Table 23, the results of the Kolmogorov-Smirnov statistic reveal a non-significant result (i.e., the sig. value for Kolmogorov-Smirnov statistic is higher than .05 for each group), which assures the normality assumption.

Table 23
Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Groups	Statistic	df	Sig.	Statistic	df	Sig.
Post_Total	Int1	.129	15	.200*	.973	15	.901
	Int2	.201	15	.107	.945	15	.445
	Int3	.151	18	.200*	.902	18	.062

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

In the present study, except for one group (Post_Core) the distribution of scores appears normal (see Appendix A). Therefore, it can be said that the distribution of the scores can be assumed as "normal".

Linearity:

SPSS gives a plot graph to screen the general distribution of scores for each of the intervention groups. As can be seen in Figure 20, a clearly linear (straight-line) relationship appears for each group. Therefore, the assumption of linearity was not violated. Moreover, in the graph, the R squared values presented to show the strength of the relationship between the dependent variable (i.e., post_total) and the covariate (i.e., pre_Total).

In this study, it can be interpreted that these two variables are strongly correlated. In other words, for the HLT-group (i.e., Int1) 53.4 percent of the variance in scores at posttest are explained by the scores at pretest, while it is 12.1 percent for non-HLT group (i.e., Int2) and 49.6 percent for non-patterning group (i.e., Int3) (see Figure 20).

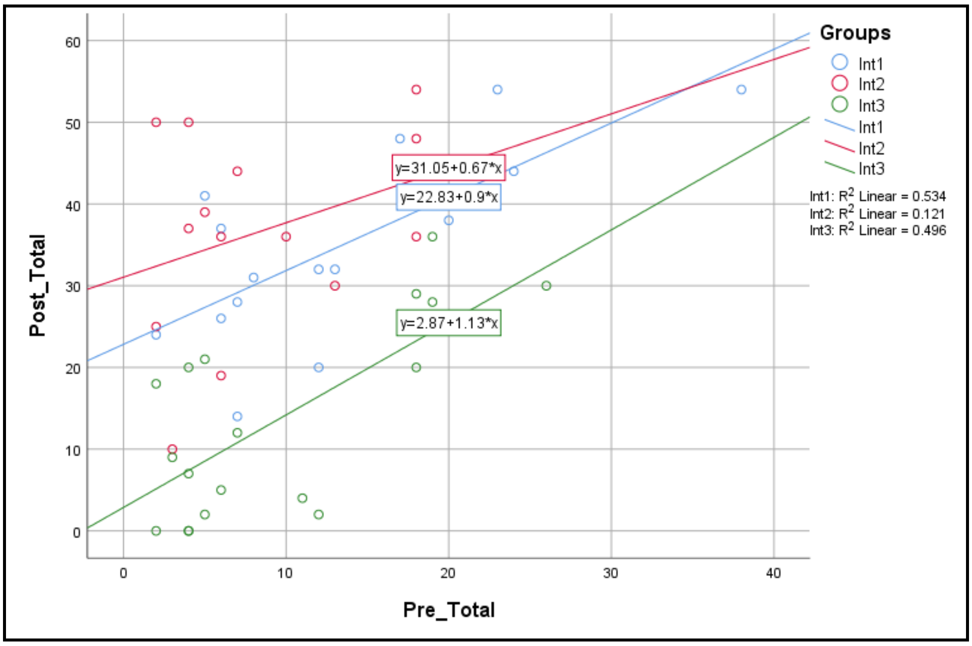


Figure 20. The variances of the pretest scores for intervention groups

Therefore, it seems appropriate to consider the pretest scores as the covariate variable and controlling it for the present study.

Multicollinearity and Singularity:

This is checked when there is more than one CV. In this study, there is only one covariate (i.e., pretest); therefore, this assumption was skipped.

Correlations among the covariates.

This is checked when there is more than one CV. In this study, there is only one covariate (i.e., pretest); therefore, this assumption was skipped.

Homogeneity of Variance:

SPSS gives a table of "Levene's Test of Equality of Error Variances" to examine the homogeneity of variances. According to Pallant (2007), the significance value (Sig.) for Levene's test should be greater than .05 to assure the homogeneity of variance assumption. As it is seen in Table 24, the significance value is .247 which is higher than the cut-off of .05 and shows that variances are equal. Therefore, the assumption of the equality of variance was not violated for this study.

Table 24

Levene's Test of Equality of Error Variances

Dependent Variable: Post_Total			
F	df1	df2	Sig.
1.443	2	45	.247

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Pre_Total + Groups

Homogeneity of Regression slopes:

This assumption was evaluated by establishing the interactions between effects and covariates through the ANCOVA. In other words, there should not be an interaction between covariates and the treatment groups. As it is displayed in Table 25, Tests of Between-Subjects Effects, the significance level of the interaction (i.e., Groups * Pre_Total) is found as .662 which is more than .05 the cut-off value. That is, the assumption of homogeneity of regression slopes was not violated.

Table 25

The Evaluation of the Homogeneity of Regression slopes

Dependent Variable: Post_Total

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8202.916[a]	5	1640.583	17.404	.000
Intercept	5729.906	1	5729.906	60.786	.000
Groups	2450.334	2	1225.167	12.997	.000
Pre_Total	2018.398	1	2018.398	21.412	.000
Groups * Pre_Total	78.548	2	39.274	.417	.662
Error	3959.063	42	94.263		
Total	48517.000	48			
Corrected Total	12161.979	47			

a. R Squared = .674 (Adjusted R Squared = .636)

In the end, as assuring all the assumptions, now the ANCOVA analysis can be performed to investigate the differences between the intervention groups.

4.1.2 Performing Analysis of Covariance (ANCOVA)

A one-way between-groups analysis of covariance (ANCOVA) was conducted to compare the effectiveness of three different interventions designed to improve children's repeating patterning skills. The independent variable was the type of intervention (HLT-based gradual, Non-HLT integrated group, and Non-Patterning Business as Usual group), and the dependent variable consisted of scores on the Patterning Posttest administered after two weeks the intervention was completed. Participants' scores on the pre-intervention administration of the Patterning Pretest were used as the covariate in this analysis. Preliminary checks were conducted to ensure that there was no violation of the assumptions of normality, linearity, homogeneity of variances, homogeneity of regression slopes, and reliable measurement of the covariate. As seen in Table 26, after controlling for pre-intervention scores, there was a significant difference between the three intervention groups on post-intervention scores on the Patterning Tasks [$F(2, 44)=28.05$, $p=.00$] with a very large effect size [partial eta squared=.56].

Table 26

The Effect of the Intervention groups after controlling pre-intervention scores

	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Contrast	5148.305	2	2574.153	28.052	.000	.560
Error	4037.611	44	91.764			

Note: The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

4.1.3 Post-Hoc Comparisons for ANCOVA

Even though, a significant difference was determined between the intervention groups, the difference in which group was still unknown. Therefore, to understand which intervention groups were different from the others, follow-up multiple comparisons using Bonferroni test was examined (see Table 27).

Table 27

Pairwise Comparisons of the Intervention Groups

Dependent Variable: Post_Total

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Int1	Int2	-6.235	3.588	.268	-15.165	2.694
	Int3	17.690*	3.424	.000	9.166	26.213
Int2	Int1	6.235	3.588	.268	-2.694	15.165
	Int3	23.925*	3.350	.000	15.587	32.263
Int3	Int1	-17.690*	3.424	.000	-26.213	-9.166
	Int2	-23.925*	3.350	.000	-32.263	-15.587

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Post-hoc comparisons indicated that the mean score for HLT-Intervention 1 (M= 34.87, SD= 11.87) and non-HLT-Intervention 2 (M= 37.00, SD= 12.15) were significantly different from non-Patterning-Intervention 3 (M= 13.50, SD= 11.95). Descriptive statistics were presented in Table 28.

Table 28

Descriptive Statistics of the Intervention Groups

Dependent Variable: Post_Total

Groups	Mean	Std. Deviation	N
Int1	34.87	11.868	15
Int2	37.00	12.148	15
Int3	13.50	11.952	18
Total	27.52	16.086	48

Moreover, the adjusted marginal means with 95% confidence interval were calculated. As displayed in Table 29, the highest scores were gained by the participants in Intervention 2 (mean= 38.44) than those in intervention 1 (mean=32.21), and Intervention 3 (mean=14.52).

Table 29

Confidence Interval Scores of the Intervention Groups

Dependent Variable: Post_Total

			95% Confidence Interval	
Groups	Mean	Std. Error	Lower Bound	Upper Bound
Int1	32.206[a]	2.527	27.113	37.298
Int2	38.441[a]	2.489	33.424	43.458
Int3	14.516[a]	2.267	9.949	19.084

a. Covariates appearing in the model are evaluated at the following values: Pre_Total = 10.48.

4.2. RQ 1a: Is there a significant difference between the children's pattern extension scores considering the intervention groups (i.e., LT group, integrated-LT group, and business-as-usual group)?

First of all, it was considered to conduct ANCOVA to see the differences in post extension scores between the intervention groups. However, it was seen that the correlations between covariates (i.e., pre-extension scores) and depended variables (i.e., post-extension scores) were too weak (see Figure 21). So, it is advised that there is no need to assign the pretest extension scores as a covariate and conduct ANCOVA (Pallant, 2007). Therefore, the pretest extension scores were not considered and the differences between the groups were examined focusing on the post-test scores.

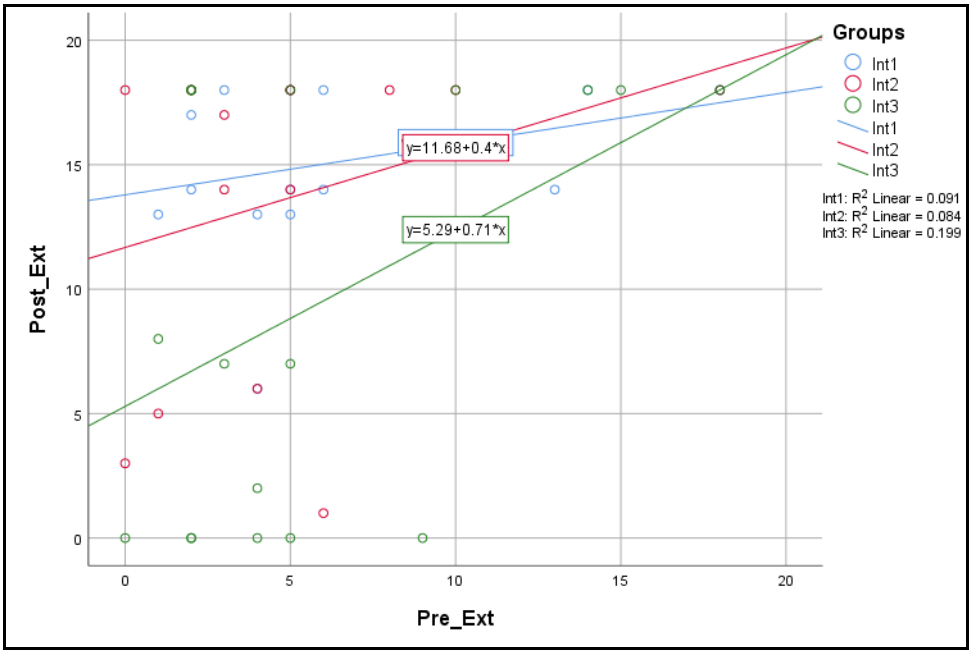


Figure 21. The correlation between extension pretest scores and extension posttest scores for each group

According to Pallant (2007), "in a one-way ANOVA design, each subject is treated in two or more different conditions" (p.223). Because of that reason, in order to compare the groups, one-way between-groups analysis of variances (ANOVA) was conducted for investigating Patterning Extension skill. Therefore, ANOVA, rather than ANCOVA, is seen as an appropriate test for the research question of *"Is there a difference in Extension scores for children those in HLT-group, non-HLT-group, and non-patterning group?"*. However, before conducting ANOVA, the essential assumptions were checked. According to Pallant (2007), there are five assumptions for ANOVA namely, Level of measurement, Random sampling, Independence of observations, Normal distribution, and Homogeneity of variance matrices. After ensuring these assumptions, the results of the ANOVA were presented in the following section.

4.2.1 The Assumptions of the ANOVA

Level of measurement

To be able to perform ANOVA, the dependent variable should be measured at the interval or ratio level, rather than discrete levels (Pallant, 2007). In this study, the testing tasks which used at pretest and posttest were scored in a continuous scale. Therefore, no violation seems for this assumption.

Random sampling

According to Pallant (2007), this assumption assumes that "the scores are obtained using a random sample from the population and this is often not the case in real-life research" (p.197). Indeed, even though the sample was not randomly chosen, the participants were randomly assigned to each intervention groups. Therefore, this assumption can be considered as assured.

Independence of observations

Pallant (2007) suggests that the observations or the collected data should be independent, otherwise that makes a serious violation. In other words, the participants should not be interacted and affected by each other during the assessment. Indeed, the participants in this study were tested one-on-one setting rather than in a group or within a classroom setting. So, it can be stated that this assumption was not violated.

Normal distribution

In general, it is advised to have a normally distributed scores on the dependent variable, though it is less common in social sciences (Pallant, 2007). For the assessment of the normality, Kolmogorov-Smirnova values and histogram graphs were examined (Pallant, 2007). The results of the Kolmogorov-Smirnov statistic reveal a non-significant result (i.e., the sig. value for Kolmogorov-Smirnov statistic is higher than .05 for each group), which assures the normality assumption.

Homogeneity of variance

According to Pallant (2007), the significance value (Sig.) for Levene's test should be greater than .05 to assure the homogeneity of variance assumption. SPSS gives a table of "Levene's Test of Equality of Error

Variances" to examine the homogeneity of variances. As it is seen in Table 30, the significance value is .00 which is lower than the cut-off of .05 and shows that variances are not equal. This may be because of the unequal group sizes are according to random loss of subjects in an experimental design. Therefore, the assumption of the equality of variance was violated and the output "Robust Tests of Equality of Means" was considered for this study. In other words, the Welch test was interpreted to detect the difference and Games-Howell test, rather than Tukey HSD, was used for Post-hoc analysis.

Table 30

Test of Homogeneity of Variances for Post-Extension scores

		Levene Statistic	df1	df2	Sig.
Post_Ext	Based on Mean	14.493	2	45	.000
	Based on Median	5.551	2	45	.007
	Based on Median and with adjusted df	5.551	2	28.441	.009
	Based on trimmed mean	13.162	2	45	.000

4.2.2 Performing Analysis of Variance (ANOVA) for Extension Skill

A one-way ANOVA was conducted to compare the effectiveness of three intervention groups (i.e., Int 1: HLT-Based Intervention, Int 1: non-HLT based Intervention, and Int 3: Business as Usual). A significant difference in extension post-intervention scores was found between the groups [$F(2,26.94) = 3.51$, $p = 0.04$] (see Table 31).

Table 31

Welch Test Results for Post-Extension scores

	Statistic[a]	df1	df2	Sig.
Welch	3.511	2	26.939	.044

a. Asymptotically F distributed.

Besides reaching statistical significance, the actual difference in mean scores between the groups was calculated using Eta squared and found as .13, which is almost a large effect. Post hoc comparisons using the Games-Howell test were carried out.

4.2.3 Post-Hoc for ANOVA

As seen in Table 32, it was found that there was a significant difference between Int 1 and Int 3 ($p = 0.035$) with children in Int 1 (M=15.07, SD= 3.33) having higher scores than those in Int 3 (M= 9.33, SD= 8.37).

Table 32

Post-hoc Analysis for Post-Extension scores

	(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Games-Howell	Int1	Int2	1.467	1.857	.713	-3.21	6.15
		Int3	5.733*	2.151	.035	.35	11.12
	Int2	Int1	-1.467	1.857	.713	-6.15	3.21
		Int3	4.267	2.569	.236	-2.06	10.59
	Int3	Int1	-5.733*	2.151	.035	-11.12	-.35
		Int2	-4.267	2.569	.236	-10.59	2.06

*. The mean difference is significant at the 0.05 level.

Although the mean scores of the extension skill were higher for the children in Int 2 (M=13.60, SD= 6.38) than Int 3 (M= 9.33, SD= 8.37), no significant difference was found between the intervention groups (see Table 33 for descriptive information and Figure 22 for the mean plots).

Table 33

Descriptive Statistics for Extension Post-test Scores

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Min.	Max.
Int1	15	15.07	3.327	.859	13.22	16.91	6	18
Int2	15	13.60	6.379	1.647	10.07	17.13	1	18
Int3	18	9.33	8.367	1.972	5.17	13.49	0	18
Total	48	12.46	6.860	.990	10.47	14.45	0	18

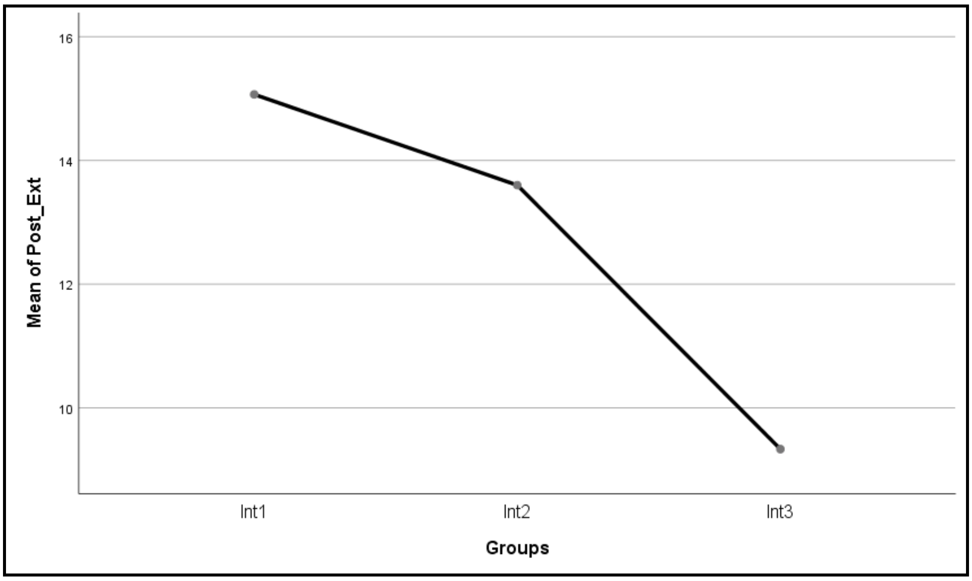


***Figure* 22.** Means plot of the extension posttest scores by the intervention groups

4.3 RQ 1b: ***Is there a significant difference between the children's translation scores considering the intervention groups (i.e., LT group, integrated-LT group, and business as usual group) while controlling for their translation pretest scores?***

In order to increase the power of the *F* test for the main effect of the intervention groups the covariance adjusted and the analysis of covariance (ANCOVA) was performed (Tabachnick & Fidell, 2013). ANCOVA is an *"extension of analysis of variance in which main effects and interactions of IVs are assessed after DV scores are adjusted for differences associated with one or more covariates (CVs), variables that are measured before the DV and are correlated with it"* (Tabachnick & Fidell, 2013, p.197). That is, the effect of the Independent Variables (IVs) (i.e., the intervention types) on the Dependent Variables (DVs) (i.e., post-translation scores) were investigated after controlling the

Covariate Variables (CVs) (i.e., pre-translation scores). In this study, a pretest had been conducted before the interventions were implemented and a posttest was used after two weeks of implementations. Therefore, performing ANCOVA was seen as an appropriate statistic. Before conducting ANCOVA, the essential assumptions were checked. According to Tabachnick and Fidell (2013), there are eight assumptions for ANCOVA, namely unequal sample sizes, outliers, reliability of covariates, normality, homogeneity of variance, multicollinearity, linearity, and homogeneity of regression.

4.3.1 The Assumptions of the ANCOVA

Unequal n and Missing Data:

SPSS provides a descriptive statistics table to screen the dependent variables and covariate variables for the three intervention groups as having an unequal number of sample sizes for the groups. This situation is meaningful and resulted from the willingness/unwillingness of the participants to continue or drop the study at any time. Indeed, five children from HLT group and non-HLT group and one child from non-patterning group did not want to continue to the study.

Normality:

Normal is defined as "a symmetrical, bell-shaped curve, which has the greatest frequency of scores in the middle with smaller frequencies towards the extremes" (Gravetter & Wallnau 2004, p. 48). For the assessment of the normality, Kolmogorov-Smirnova values and histogram graphs were examined (Pallant, 2007). The results of the Kolmogorov-Smirnov statistic reveal a non-significant result (i.e., the sig. value for Kolmogorov-Smirnov statistic is higher than .05 for each group), which assures the normality assumption.

Linearity:

SPSS gives a plot graph to screen the general distribution of scores for each of the intervention groups. As can be seen in Figure 23, a clearly linear (straight-line) relationship appears for each group. Therefore, the assumption of linearity was not violated. Moreover, in the graph, the R squared values presented to show the strength of the relationship between the dependent variable (i.e., post_trans) and the covariate variable (i.e., (pre_trans). In this study, it can be interpreted that these two variables are strongly correlated. In other words, for the HLT-group (i.e., Int1) 20 percent of the variance in scores at posttest are explained by the scores at pretest, while it is 32 percent for non-HLT group (i.e., Int2) and 50 percent for non-patterning group (i.e., Int3). Therefore, considering pretest scores as covariate variable and controlling it seems appropriate for the study.

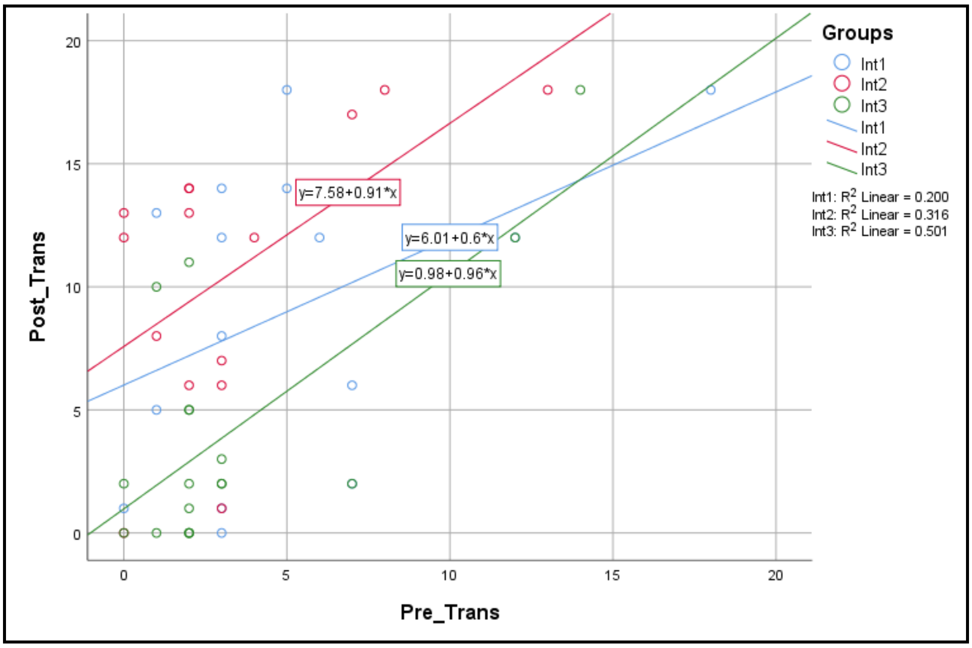


Figure 23. Plot graph for linearity

Multicollinearity and Singularity:

This is checked when there are more than one covariates. In this study, there is only one covariate (i.e., pretest); therefore, this assumption was skipped.

Correlations among the covariates:

This is checked when there are more than one covariates. In this study, there is only one covariates (i.e., pretest); therefore, this assumption was skipped.

Homogeneity of Variance:

SPSS gives a table of "Levene's Test of Equality of Error Variances" to examine the homogeneity of variances. According to Pallant (2007), the significance value (Sig.) for Levene's test should be greater than .05 to assure the homogeneity of variance assumption. As it is seen in Table 34, the significance value is .104 which is higher than the cut-off of .05 and shows that variances are equal. Therefore, the assumption of the equality of variance was not violated for this study.

Table 34

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Post_Trans

F	df1	df2	Sig.
2.385	2	45	.104

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Groups + Pre_Trans + Groups * Pre_Trans

Measurement of the covariate:

This assumption specifies that the covariate should be measured before the treatment or experimental manipulation begins.

Moreover, the covariate cannot be statistically significant between the groups. Therefore, to make sure that there are no significant differences between the pre-translation scores among the groups, a one-way ANOVA was conducted. As it was shown in Table 35, Sig value was found .37 which is higher than the cut-off value of .05 (Pallant, 2007). That is, the covariate (i.e., pre-translation scores) did not statistically differ among the intervention groups.

Table 35

ANOVA Test for the Covariate (Translation Pretest Score)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	33.413	2	16.706	1.031	.365
Within Groups	729.067	45	16.201		
Total	762.479	47			

Homogeneity of Regression slopes:

This assumption was evaluated by establishing the interactions between effects and covariates through the ANCOVA. In other words, there should not be an interaction between covariates and the treatment groups. As it is displayed in Table 36, the significance level of the interaction (i.e., Groups * Pre_Trans) is found as .641 which is more than .05 the cut-off value. That is, the assumption of homogeneity of regression slopes was not violated.

Table 36

Testing Interactions between Groups and Covariates for Translation Skills

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	859.258[a]	5	171.852	7.436	.000	.470
Intercept	553.378	1	553.378	23.944	.000	.363
Groups	211.462	2	105.731	4.575	.016	.179
Pre_Trans	465.024	1	465.024	20.121	.000	.324
Groups * Pre_Trans	20.764	2	10.382	.449	.641	.021
Error	970.659	42	23.111			
Total	4682.000	48				
Corrected Total	1829.917	47				

a. R Squared = .470 (Adjusted R Squared = .406)

In brief then, as assuring all the assumptions, now the ANCOVA analysis can be performed to investigate the differences between the intervention groups.

4.3.2 Performing Analysis of Covariance (ANCOVA) for Translation Skill

A one-way between-groups analysis of covariance (ANCOVA) was conducted to compare the effectiveness of three different interventions designed to improve children's patterning translation skills. The independent variable was the type of intervention (i.e., Int1: HLT-based gradual group, Int2: HLT integrated group, and Int 3: Business as Usual group), and the dependent variable consisted of scores on the Patterning Post-Translation tasks administered after two weeks the intervention was completed. Participants' scores on the pre-intervention administration of the Patterning Pre-Translation were used as the covariate in this analysis. Preliminary checks were conducted to ensure that there was no violation of the assumptions of normality, linearity, homogeneity of variances, homogeneity of regression slopes, and reliable measurement of the covariate. As seen in Table 37, after controlling for pre-intervention scores, there was a significant difference between the three intervention groups on post-intervention scores on the Patterning Translation Tasks [$F(2, 44)=7.58$, $p=.001$] with a very large effect size [partial eta squared=.26].

Table 37

Testing the Significance between Intervention Groups for Translation Skills

	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Contrast	341.573	2	170.787	7.580	.001	.256
Error	991.423	44	22.532			

Note: The F tests the effect of Groups. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Even though, a significant difference was determined between the intervention groups, the difference in which group was still unknown. Therefore, to understand which intervention groups were different from the others, a follow-up multiple comparisons using Bonferroni test was examined.

4.3.3 Post-Hoc for ANCOVA

As seen in Table 38, Post-hoc comparisons indicated that the mean score for Int 2 (*M*= 10.60, *SD*= 5.70) were significantly different from Int 3 (*M*= 4.17, *SD*= 5.18).

Table 38
Descriptives

	N	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Min	Max
Int1	15	9.07	6.204	1.602	5.63	12.50	0	18
Int2	15	10.60	5.705	1.473	7.44	13.76	0	18
Int3	18	4.17	5.182	1.221	1.59	6.74	0	18

Table 38
Post-hoc Comparisons for Translation skill

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference Lower Bound	95% Confidence Interval for Difference Upper Bound
Int1	Int2	-2.963	1.762	.299	-7.348	1.423
	Int3	3.471	1.689	.138	-.734	7.676
Int2	Int1	2.963	1.762	.299	-1.423	7.348
	Int3	6.433*	1.660	.001	2.303	10.564
Int3	Int1	-3.471	1.689	.138	-7.676	.734
	Int2	-6.433*	1.660	.001	-10.564	-2.303

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

As displayed in Table 39, the adjusted marginal means with 95% confidence interval showed that the highest scores were gained by the participants in Intervention 2 (mean= 11.05) than those in intervention 1 (mean=8.08), and Intervention 3 (mean=4.61).

Table 39

Adjusted Means with Interval Confidence for Translation Skills

			95% Confidence Interval	
Groups	Mean	Std. Error	Lower Bound	Upper Bound
Int1	8.084[a]	1.245	5.575	10.593
Int2	11.047[a]	1.230	8.569	13.525
Int3	4.613[a]	1.123	2.350	6.877

a. Covariates appearing in the model are evaluated at the following values: Pre_Trans = 3.90.

4.4 RQ Is there a significant difference between the children's core identification scores considering the intervention groups (i.e., LT group, integrated-LT group, and business as usual group)?

In the beginning, ANCOVA was considered to conduct to detect the differences in post-core scores between the intervention groups. However, the correlations between covariate (i.e., pre-core scores) and dependent variable (i.e., post-core scores) were too weak (see Figure 24). So, it is advised that it is not necessary to assign the pretest core scores as the covariate and perform the ANCOVA (Pallant, 2007). Therefore, the pretest core scores were not included and the differences between the groups were explored considering the post-core scores.

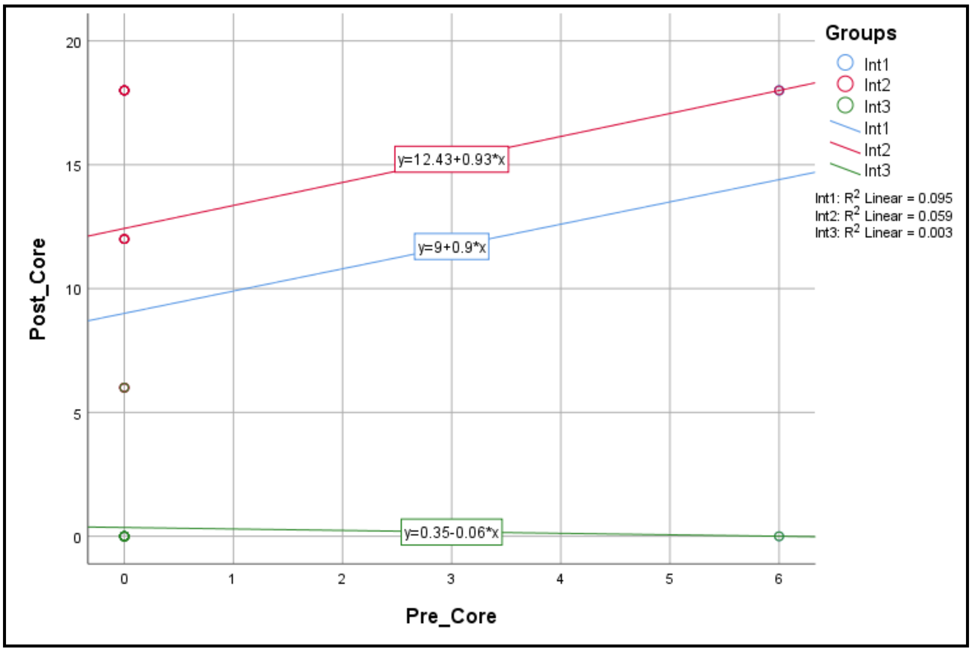


Figure 24. Correlations between covariate and dependent variable

In order to compare the groups, there are some tests, however, Pallant (2007) advised one-way between-groups analysis of variances (ANOVA) design because "each subject is treated in two or more different conditions" (p.223). Therefore, ANOVA, rather than ANCOVA, was seen as an appropriate test to investigate the Patterning Core Identification skill. In other words, for the research question of *"Is there a difference in Core Identification scores for children who are in HLT-group, non-HLT-group, and non-patterning group?".* Before performing ANOVA; however, the required assumptions namely, Level of measurement, Random sampling, Independence of observations, Normal distribution, and Homogeneity of variance were checked (Pallant, 2007). After meeting the assumptions, the

ANOVA was conducted and the results were presented in the following section.

4.4.1 The Assumptions of ANOVA

Level of measurement

To be able to perform ANOVA, the dependent variable should be measured at the interval or ratio level, rather than discrete levels (Pallant, 2007). In this study, the testing tasks which used at pretest and posttest were scored in a continuous scale. Therefore, no violation seems for this assumption.

Random sampling

According to Pallant (2007), this assumption assumes that "the scores are obtained using a random sample from the population and this is often not the case in real-life research" (p.197). Indeed, even though the sample was not randomly chosen, the participants were randomly assigned to each intervention groups. Therefore, this assumption can be considered as assured.

Independence of observations

Pallant (2007) suggests that the observations or the collected data should be independent, otherwise that makes a serious violation. In other words, the participants should not be interacted and affected by each other during the assessment. Indeed, the participants in this study were tested one-on-one setting rather than in a group or within a classroom setting. So, it can be stated that this assumption was not violated.

Normal distribution

In general, it is advised to have a normally distributed scores on the dependent variable, though it is less common in social sciences (Pallant, 2007). For the assessment of the normality, Kolmogorov-Smirnova values and histogram graphs were examined (Pallant, 2007). The results of the Kolmogorov-Smirnov statistic reveal a non-significant result (i.e., the sig. value for Kolmogorov-Smirnov statistic is higher than .05 for each group), which assures the normality assumption.

Homogeneity of variance

According to Pallant (2007), the significance value (Sig.) for Levene's test should be greater than .05 to assure the homogeneity of variance assumption. SPSS gives a table of "Levene's Test of Equality of Error Variances" to examine the homogeneity of variances (See Table 40).

Table 40

Test of Homogeneity of Variances for core-identification skills

		Levene Statistic	df1	df2	Sig.
Post_Core	Based on Mean	36.439	2	45	.000
	Based on Median	7.491	2	45	.002
	Based on Median and with adjusted df	7.491	2	19.285	.004
	Based on trimmed mean	36.978	2	45	.000

As it is seen in Table 40, the significance value is .00 which is lower than cut-the off of .05 and shows that variances are not equal. This may be because of the unequal group sizes are according to random loss of subjects in an experimental design. Therefore, the assumption of the equality of variance was violated and the output "Robust Tests of Equality of Means" was considered for this study. In other words, the Welch test was interpreted to detect the difference and Games-Howell test, rather than Tukey HSD, was used for Post-hoc analysis.

4.4.2 Performing Analysis of Variance (ANOVA) for Core Identification Skill

A one-way ANOVA was conducted to compare the effectiveness of three intervention groups (i.e., Int 1: HLT-Based Intervention, Int 1: non-HLT based Intervention, and Int 3: Business as Usual). A significant difference in core identification post-intervention scores was found between the groups [$F(2,19.91)= 40.04$, $p = 0.00$] (see Table 41).

Table 41

Welch Test Results for core-identification skills

	Statistic[a]	df1	df2	Sig.
Welch	40.040	2	19.911	.000

a. Asymptotically F distributed.

4.4.3 Post-Hoc for ANOVA

Besides reaching statistical significance, the actual difference in mean scores between the groups was calculated using Eta squared and found as .49, a very large effect. Post hoc comparisons using the Games-Howell test were carried out (see Table 42).

Table 42

Post-hoc Analysis for core-identification skills

	(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Games-Howell	Int1	Int2	-2.000	2.688	.740	-8.69	4.69
		Int3	10.467*	2.232	.001	4.66	16.28
	Int2	Int1	2.000	2.688	.740	-4.69	8.69
		Int3	12.467*	1.570	.000	8.40	16.54
	Int3	Int1	-10.467*	2.232	.001	-16.28	-4.66
		Int2	-12.467*	1.570	.000	-16.54	-8.40

*. The mean difference is significant at the 0.05 level.

As seen in Table 42, it was found that there was a significant difference between Int 1 and Int 3 (p = 0.001) with children in Int 1 (M=10.80, SD= 8.55) having higher scores than those in Int 3 (M= 0.33, SD= 1.41). A significant difference was also found between Int 2 and Int 3 (p = 0.000) with children in Int 2 (M= 12.80, SD= 5.94) having higher scores than those in Int 3 (M= 0.33, SD= 1.41). Although the mean scores of the core identification skill were higher for the children in Int 2 (M=12.80, SD= 5.94) than Int 1 (M= 10.80, SD= 8.55), no significant difference was found between the intervention groups (see Table 43 for descriptive information and Figure 25 for the mean plot).

Table 43

Descriptive Statistics for Core Identification Post-test Scores

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Min.	Max.
Int1	15	10.80	8.546	2.206	6.07	15.53	0	18
Int2	15	12.80	5.943	1.534	9.51	16.09	0	18
Int3	18	.33	1.414	.333	-.37	1.04	0	6
Total	48	7.50	8.069	1.165	5.16	9.84	0	18

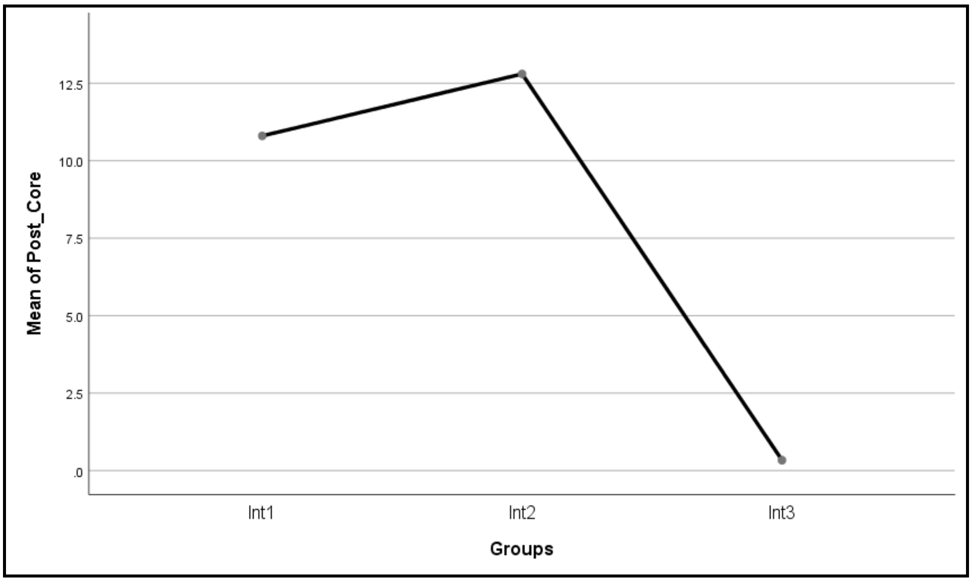


Figure 25. Means plot of the core identification posttest scores

4.5 RQ 2: How Do Children Establish Their Patterning Skills?

4.5.1 RQ 2a: How Do Children Establish Patterning Extension Skill?

For extension skill, two computer-supported examples were shown on AB, ABB, ABC type patterns. For this purpose, heat maps were created and fixation duration metric was calculated.

4.5.1.1 Extension of AB Pattern

As displayed in Figure 26 and Figure 27, the heat maps related to extension skill for AB pattern showed that children had some fixations overall the given pattern but mostly focused on the last core (i.e., core 3) to extend the pattern. It was the same for both examples. Accumulative values were used in order to display the heat maps. These behaviors were shown by the children in Intervention 1, the gradual HLT group, in Session 3 after being trained about fixing and duplicating skills but not about translating and core identification skills. For children in intervention 2, it was so easy that no eye-tracking data were available for the extension of the AB pattern.

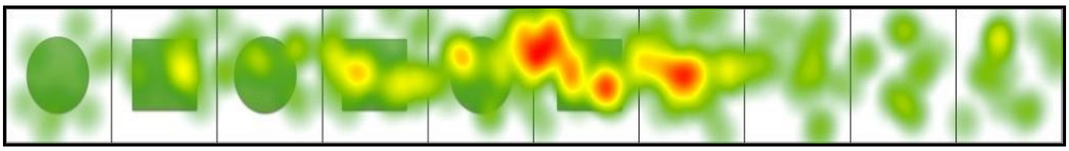


Figure 26. Extension of AB pattern (circle-square) in Intervention 1

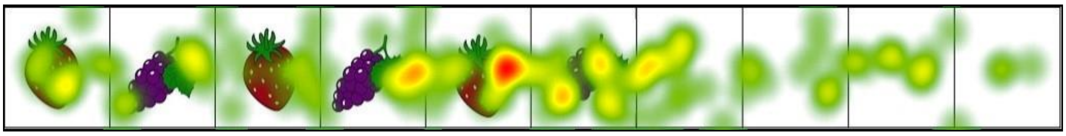


Figure 27. Extension of AB pattern (Strawberry - Grapes) in Intervention 1

In addition to the heat maps images, fixation durations supported the findings. For each example shown above, the Areas of Interest (AOIs) were created with the size of 205 X 210 px (width X height) and the fixation duration values were calculated for each core unit of the pattern. As shown in Table 44, the sum of the fixation duration for the Core 1 was found as 3.37 seconds (*M*= 0.16, *SD*= 0.09) while it was found as 9.54 seconds for Core 2 (*M*= 0.23, *SD*= 0.12) and 17.20 seconds for Core 3 (*M*= 0.22, *SD*= 0.14).

This was the same in the second example, too. In other words, as presented in Table 45, the sum of the fixation duration for Core 1 was calculated as 6.13 seconds (*M*= 0.27, *SD*= 0.18) while it was calculated 5.42 seconds for Core 2 (*M*= 0.19, *SD*= 0.12) and 10.66 seconds for Core 3 (*M*= 0.24, *SD*= 0.22) (see Table 2). These findings in both examples supported that children mostly focus on Core 3 (i.e., the last core) to extend an AB pattern.

Table 44

Fixation Duration Measures for the Extension of AB Pattern (Circle-square) in Intervention 1

	Core 1				Core 2				Core 3			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secon
Rec 10	6	0.14	0.83	0.04	4	0.29	1.17	0.16	6	0.20	1.18	0.17
Rec 01	1	0.08	0.08	-	1	0.13	0.13	-	4	0.16	0.63	0.15
Rec 03	-	-	-	-	4	0.25	0.98	0.09	2	0.12	0.25	0.04
Rec 09	-	-	-	-	2	0.11	0.22	0.01	-	-	-	-
Rec 04	2	0.14	0.28	0.01	3	0.16	0.48	0.07	6	0.23	1.37	0.16
Rec 02	6	0.26	1.57	0.10	5	0.30	1.48	0.11	5	0.37	1.87	0.17
Rec 05	1	0.07	0.07	-	2	0.38	0.75	0.20	1	0.20	0.20	-
Rec 08	1	0.12	0.12	-	7	0.24	1.70	0.13	10	0.25	2.52	0.06
Rec 11	1	0.07	0.07	-	2	0.12	0.25	0.06	2	0.09	0.18	0.01
Rec 12	-	-	-	-	-	-	-	-	3	0.33	0.98	0.13
Rec 06	3	0.12	0.35	0.05	7	0.22	1.55	0.13	28	0.22	6.06	0.15
Rec 07	-	-	-	-	5	0.16	0.82	0.05	11	0.18	1.95	0.10
All Recordings	21	0.16	3.37	0.09	42	0.23	9.54	0.12	78	0.22	17.20	0.14

Table 45

Fixation Duration Measures for the Extension of AB Pattern (Strawberry - Grapes) in Intervention 1

	Core 1				Core 2				Core 3			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secon
Rec 10	2	0.15	0.30	0.09	8	0.15	1.18	0.05	18	0.20	3.54	0.16
Rec 01	1	0.20	0.20	-	-	-	-	-	1	0.22	0.22	-
Rec 03	-	-	-	-	1	0.10	0.10	-	-	-	-	-
Rec 09	-	-	-	-	-	-	-	-	-	-	-	-
Rec 04	3	0.49	1.48	0.25	3	0.20	0.60	0.10	3	0.18	0.55	0.06
Rec 02	-	-	-	-	1	0.35	0.35	-	1	0.13	0.13	-
Rec 05	4	0.23	0.92	0.10	3	0.31	0.93	0.15	13	0.27	3.49	0.34
Rec 08	3	0.22	0.67	0.14	3	0.19	0.57	0.14	2	0.39	0.78	0.27
Rec 11	-	-	-	-	-	-	-	-	-	-	-	-
Rec 12	7	0.25	1.74	0.20	2	0.14	0.28	0.11	-	-	-	-
Rec 06	2	0.33	0.67	0.14	5	0.15	0.77	0.10	2	0.38	0.77	0.07
Rec 07	1	0.17	0.17	-	3	0.21	0.63	0.23	4	0.30	1.19	0.16
All Recordings	23	0.27	6.13	0.18	29	0.19	5.42	0.12	44	0.24	10.66	0.22

4.5.1.2 Extension of ABB Pattern

As displayed in Figure 28, the heat map related to extension skill for ABB pattern showed that children mostly skipped the first core and focused on the last core (i.e., Core 3) to extend the given ABB pattern. Accumulative values were used in order to display the heat maps. These behaviors were shown by the children in Intervention 1, the gradual HLT group, in Session 5 after being trained about fixing, duplicating, and extension skills. For children in intervention 2, it was so easy that no eye-tracking data were available for the extension of the ABB pattern.

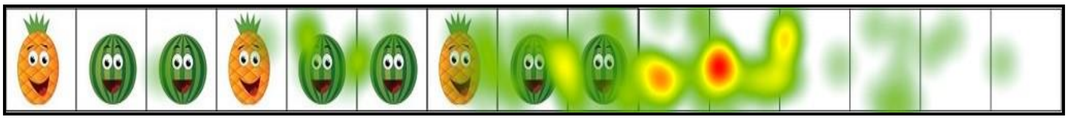


Figure 28. Heat map for the extension of ABB pattern

Besides the heat map image, fixation durations supported these findings. For the example shown above, the Areas of Interest (AOIs) were created with the size of 205 X 210 px (width X height) and the fixation duration values were calculated for each core unit of the pattern. That is, except from Rec 11, it was found that almost all of the children skipped the first core (i.e., Core 1). While the sum of the fixation duration was calculated as 2.14 seconds for Core 2 (M= 0.16, SD= 0.10), it was found as 10.28 seconds for Core 3 (M= 0.19, SD= 0.22) (see Table 46).

Table 46

Fixation Duration Measures for Extension of ABB Pattern in Intervention 1

	Core 1				Core 2				Core 3			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor
Rec 02	-	-	-	-	1	0.17	0.17	-	3	0.23	0.70	0.02
Rec 11	1	0.45	0.45	-	5	0.13	0.67	0.06	6	0.16	0.95	0.12
Rec 01	-	-	-	-	-	-	-	-	-	-	-	-
Rec 15	-	-	-	-	2	0.23	0.47	0.02	25	0.25	6.33	0.30
Rec 04	-	-	-	-	-	-	-	-	-	-	-	-
Rec 10	-	-	-	-	-	-	-	-	-	-	-	-
Rec 05	-	-	-	-	1	0.44	0.44	-	2	0.15	0.30	0.05
Rec 03	-	-	-	-	-	-	-	-	-	-	-	-
Rec 06	-	-	-	-	-	-	-	-	1	0.10	0.10	-
Rec 07	-	-	-	-	-	-	-	-	-	-	-	-
Rec 09	-	-	-	-	-	-	-	-	-	-	-	-
Rec 14	-	-	-	-	2	0.10	0.20	0.02	3	0.09	0.28	0.01
Rec 16	-	-	-	-	1	0.13	0.13	-	4	0.15	0.62	0.08
Rec 13	-	-	-	-	1	0.07	0.07	-	7	0.11	0.75	0.05
Rec 12	-	-	-	-	-	-	-	-	2	0.12	0.24	0.05
Rec 08	-	-	-	-	-	-	-	-	-	-	-	-
All Recordings	1	0.45	0.45	-	13	0.16	2.14	0.10	53	0.19	10.28	0.22

4.5.1.3 Extension of ABC Pattern

As displayed in Figure 29, the heat map related to extension skill for ABC pattern showed that children mostly focused on the last core (i.e., Core 3) to extend the given pattern. It was also seen that some fixations were seen at the beginning of the model pattern as well as the extension part. Accumulative values were used in order to display the heat maps. These behaviors were shown by the children in Intervention 1, the gradual HLT group, in Session 6 after being trained about fixing, duplicating, and extension of AB and ABB patterns.

Figure 29. The heat map for ABC extension in Intervention 1

For children in intervention 2 (i.e., integrated non-HLT group), although little findings were found, it can be said that the last core (i.e., Core 3) had the most fixation duration for the extension of ABC pattern which was asked in the Session 2 (see Figure 30).

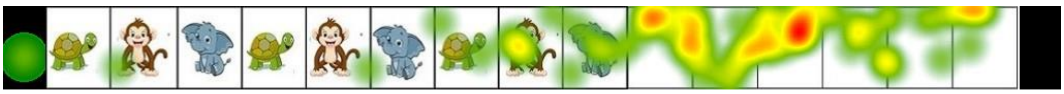


Figure 30. The heat map for ABC extension in Intervention 2

Besides the heat map image, fixation durations supported these findings. For the example shown above, the Areas of Interest (AOIs) were created with the size of 190 X 240 px (width X height) and the fixation duration values were calculated for each core unit of the pattern. When quantitative eye-tracking metrics were examined for ABC pattern, similar findings were found with the heat map shown above. In Intervention 1, the sum of the fixation duration was calculated as 2.21 seconds for Core 1 (M= 0.20, SD= 0.17), while it was found as 1.83 seconds for Core 2 (M= 0.23, SD= 0.15), 10.43 seconds for Core 3 (M= 0.23, SD= 0.24) (see Table 47).

On the other hand, in Intervention 2, the sum of the fixation duration was calculated as 0.17 seconds for Core 1 (M= 0.17), while it was found as 0.07 seconds for Core 2 (M= 0.07), 2.87 seconds for Core 3 (M= 0.22, SD= 0.24) (see Table 48).

Table 47

Fixation Duration Measures for the Extension of ABC Pattern in Intervention 1

	Core 1				Core 2				Core 3			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secon
Rec 06	-	-	-	-	1	0.15	0.15	-	1	0.10	0.10	-
Rec 09	-	-	-	-	-	-	-	-	-	-	-	-
Rec 07	2	0.18	0.37	0.09	1	0.18	0.18	-	1	0.08	0.08	-
Rec 01	2	0.38	0.75	0.41	-	-	-	-	4	0.15	0.58	0.09
Rec 03	-	-	-	-	-	-	-	-	-	-	-	-
Rec 02	4	0.19	0.77	0.10	2	0.19	0.38	0.01	13	0.29	3.77	0.35
Rec 04	-	-	-	-	-	-	-	-	-	-	-	-
Rec 08	1	0.15	0.15	-	-	-	-	-	3	0.11	0.33	0.03
Rec 05	2	0.08	0.17	0.00	4	0.28	1.12	0.21	15	0.30	4.56	0.22
Rec 10	-	-	-	-	-	-	-	-	9	0.11	1.00	0.06
All Recordings	11	0.20	2.21	0.17	8	0.23	1.83	0.15	46	0.23	10.43	0.24

Table 48

Fixation Duration Measures for the Extension of ABC Pattern in Intervention 2

	Core 1				Core 2				Core 3			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Seconc
Rec 01	-	-	-	-	-	-	-	-	-	-	-	-
Rec 04	-	-	-	-	-	-	-	-	4	0.11	0.45	0.07
Rec 02	-	-	-	-	-	-	-	-	-	-	-	-
Rec 03	1	0.17	0.17	-	1	0.07	0.07	-	9	0.27	2.42	0.28
All Recordings	1	0.17	0.17	-	1	0.07	0.07	-	13	0.22	2.87	0.24

4.5.2 *RQ 2b: How Do Children Establish Patterning Translation Skill?*

4.5.2.1 Translation of AB pattern into Different Materials

As displayed in Figure 31, the heat map related to translation skill for AB pattern had a different cognitive process than extension skill for AB pattern. That is, children's eye moved over all core units of the given pattern rather than focusing on the specific one. Accumulative values were used in order to display the heat map for the participants in Intervention 2 (i.e., integrated non-HLT group) Session 4 after being trained about fixing, extension, and core identification skills. Because of the non-availability of the eye-tracker, no eye-tracking data could be collected for the children in Intervention 1 (i.e., gradual HLT group).

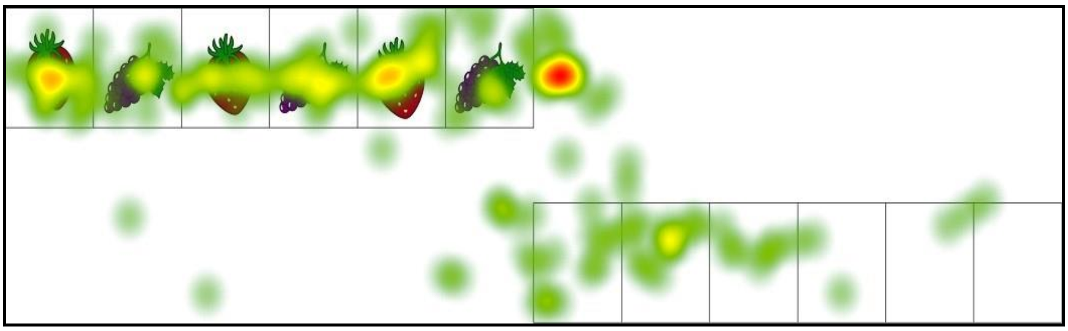


Figure 31. The heat map for AB translation in Intervention 2

Besides the heat map image, fixation durations supported these findings. The Areas of Interest (AOIs) were created with the size of 175 X 240 px (width X height) and the fixation duration values were calculated for each core unit of the pattern and similar findings were found with the heat map shown above. That is, the sum of the fixation duration was calculated as 9.89 seconds for Core 1 (*M*= 0.29, *SD*= 0.27), while it was found as 9.00 seconds for Core 2 (*M*= 0.28, *SD*= 0.25), and 6.62 seconds for Core 3 (*M*= 0.18, *SD*= 0.11) (see Table 49).

Table 49

Fixation Duration Measures for the Translation of AB Pattern in Intervention 2

	Core 1				Core 2				Core 3			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Seconc
Rec 05	7	0.13	0.90	0.04	4	0.15	0.62	0.13	3	0.16	0.47	0.11
Rec 02	1	0.22	0.22	-	1	0.18	0.18	-	1	0.07	0.07	-
Rec 03	11	0.38	4.13	0.33	10	0.30	3.00	0.31	8	0.21	1.69	0.12
Rec 01	8	0.24	1.90	0.14	8	0.19	1.55	0.12	15	0.16	2.45	0.10
Rec 04	5	0.33	1.63	0.25	6	0.37	2.25	0.22	5	0.21	1.05	0.11
Rec 06	2	0.55	1.10	0.66	3	0.47	1.40	0.42	4	0.22	0.89	0.15
All Recordings	34	0.29	9.89	0.27	32	0.28	9.00	0.25	36	0.18	6.62	0.11

4.5.2.2 Translation of ABB pattern into Different Materials

As demonstrated in Figure 32, the heat map related to translation skill for ABB pattern had a different cognitive process than extension skill for ABB pattern. That is, children's eye moved over the all core units of the given pattern but mostly on the second core (i.e., Core 2) and the first core (i.e., Core 1). Accumulative values were used in order to display the heat map for the participants in Intervention 2 (i.e., integrated non-HLT group) Session 4 after being trained about fixing, extension, and core identification skills. Because of the non-availability of the eye-tracker, no eye-tracking data could be collected for the children in Intervention 1 (i.e., gradual HLT group).

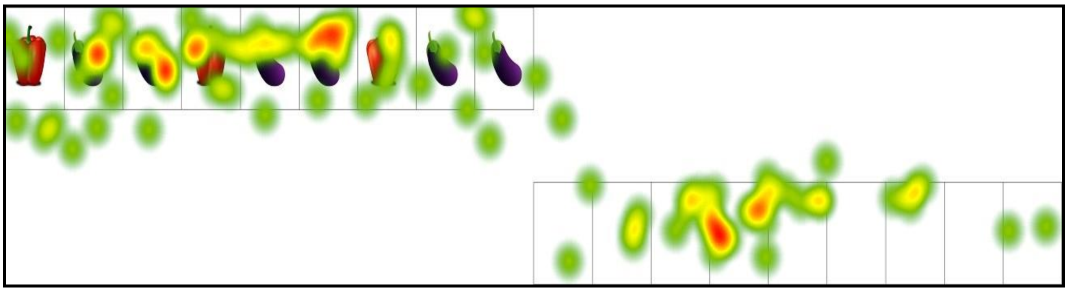


Figure 32. The heat map for ABB translation in Intervention 2

Besides the heat map image, fixation durations supported these findings. The Areas of Interest (AOIs) were created with the size of 215 X 240 px (width X height) and the fixation duration values were calculated for each core unit of the pattern. Quantitative eye-tracking metrics were explored for ABB pattern and similar findings were found with the heat map shown above. The sum of the fixation duration was calculated as 4.47

seconds for Core 1 (*M*= 0.19, *SD*= 0.14), while it was found as 5.29 seconds for Core 2 (*M*= 0.21, *SD*= 0.14), and 1.92 seconds for Core 3 (*M*= 0.14, *SD*= 0.12) (see Table 50).

Table 50

Fixation Duration Measures for the Translation of ABB Pattern in Intervention 2

	Core 1				Core 2				Core 3			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Second
Rec 05	12	0.15	1.75	0.08	6	0.21	1.27	0.13	5	0.18	0.89	0.18
Rec 02	-	-	-	-	-	-	-	-	1	0.01	0.01	-
Rec 03	-	-	-	-	-	-	-	-	4	0.10	0.42	0.02
Rec 01	3	0.15	0.45	0.07	7	0.14	0.95	0.06	1	0.07	0.07	-
Rec 04	-	-	-	-	-	-	-	-	-	-	-	-
Rec 06	9	0.25	2.27	0.21	12	0.26	3.07	0.16	3	0.18	0.54	0.05
All Recordings	24	0.19	4.47	0.14	25	0.21	5.29	0.14	14	0.14	1.92	0.12

4.5.2.3 Translation of ABC Pattern into Different Materials

As demonstrated in Figure 33, the heat map related to translation skill for ABC pattern had a different image than the translation skills for AB (i.e., Figure 31) and ABB pattern type (i.e., Figure 32). That is, children mostly focused on the task to be completed rather than the given pattern. It seemed that the third core had more interest in the ABC translation task. Accumulative values were used to display the heat map for the participants in Intervention 2 (i.e., integrated non-HLT group), Session 4 after being trained about fixing, extension, and core identification skills. Because of the non-availability of the eye-tracker, no eye-tracking data could be collected for the children in Intervention 1.

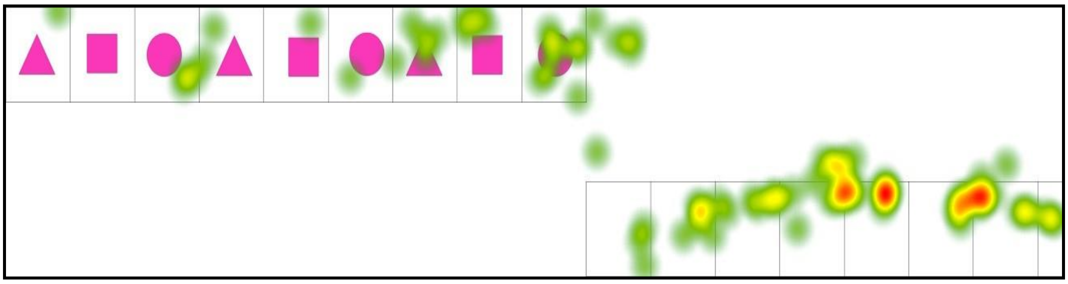


Figure 33. The heat map for ABC translation in Intervention 2

Besides the heat map image, fixation durations supported these findings. The Areas of Interest (AOIs) were created with the size of 240 X 200 px (width X height) and the fixation duration values were calculated for each core unit of the pattern. Quantitative eye-tracking metrics were explored for ABC pattern and similar findings were found with the heat map shown above. The sum of the fixation duration was calculated as 0.47 seconds for Core 1 (*M*= 0.12, *SD*= 0.05), while it was found as 1.20 seconds for Core 2 (*M*= 0.24, *SD*= 0.28), and 2.62 seconds for Core 3 (*M*= 0.15, *SD*= 0.09) (see Table 51).

Table 51

Fixation Duration Measures for the Translation of ABC Pattern in Intervention 2

	Core 1				Core 2				Core 3			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Seconc
Rec 05	3	0.10	0.30	0.04	3	0.35	1.05	0.33	13	0.15	1.97	0.10
Rec 02	-	-	-	-	-	-	-	-	-	-	-	-
Rec 03	-	-	-	-	-	-	-	-	-	-	-	-
Rec 01	-	-	-	-	-	-	-	-	-	-	-	-
Rec 04	1	0.17	0.17	-	2	0.08	0.15	0.01	4	0.16	0.65	0.07
Rec 06	-	-	-	-	-	-	-	-	-	-	-	-
All Recordings	4	0.12	0.47	0.05	5	0.24	1.20	0.28	17	0.15	2.62	0.09

4.5.3 *RQ 2c) How Do Children Establish Patterning Core Identification Skill?*

4.5.3.1 Core Identification of AB Pattern

Before children were asked to find the core unit of the AB pattern, they were shown three examples and asked to find the AB located in the bottom of the picture (i.e., orange-blue squares). As seen in Figure 34, children visited all the pattern types (i.e., AB, ABB, and ABC) to find the AB pattern.

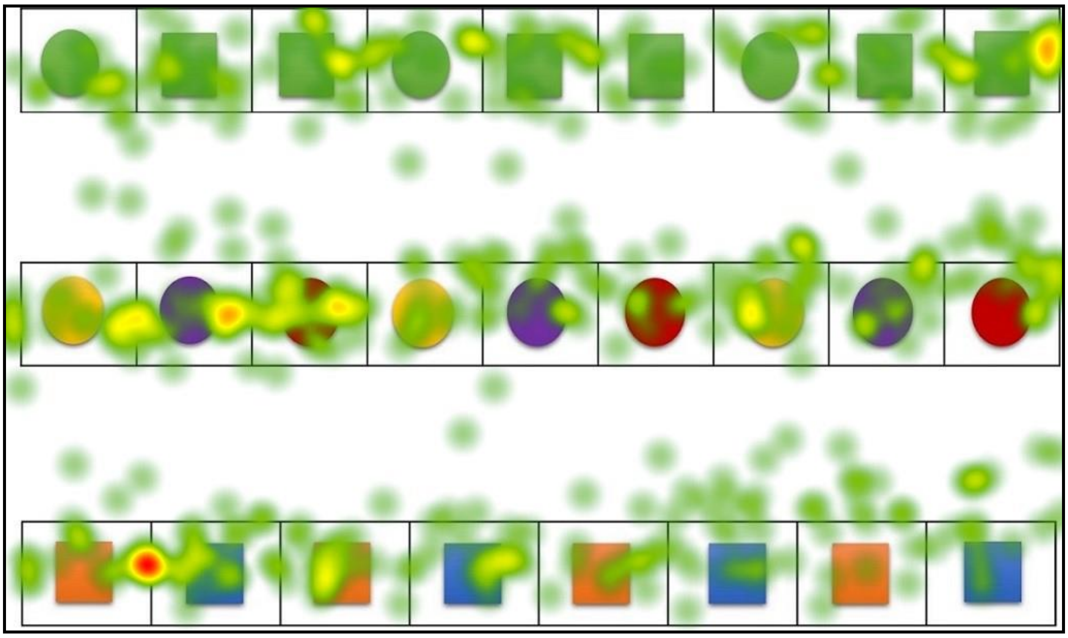


Figure 34. The heat map for choosing the AB pattern in Intervention 2

Besides the heat map, quantitative metrics supported these findings. The Areas of Interest (AOIs) were created with the size of 1020 X 180 px (width X height) and the visit duration values were calculated for each pattern type. As presented in Table 52, the sum of the visit duration of each pattern type was found as 56.73 seconds for AB pattern (*M*= 1.21, *SD*= 1.76), 51.83 seconds for ABB pattern (*M*= 1.02, *SD*= 1.88), and 59.66 seconds for ABC pattern (*M*= 0.83, *SD*= 1.06).

Table 52

Visit Duration Measures for Finding the AB Pattern in Intervention 2

	AB				ABB				ABC			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secon
Rec 06	11	2.76	30.41	3.03	12	2.02	24.19	3.24	10	1.42	14.17	1.39
Rec 01	4	0.95	3.80	0.76	2	0.55	1.10	0.36	2	0.33	0.65	0.34
Rec 04	2	0.23	0.45	0.22	2	0.59	1.18	0.72	2	0.59	1.19	0.18
Rec 05	-	-	-	-	-	-	-	-	1	0.33	0.33	-
Rec 02	14	0.82	11.50	0.83	10	0.80	7.95	1.20	15	0.49	7.33	0.62
Rec 03	-	-	-	-	-	-	-	-	2	2.50	5.00	1.76
Rec 07	1	2.19	2.19	-	2	0.54	1.08	0.55	4	1.01	4.03	0.69
Rec 10	8	0.64	5.13	0.34	8	1.02	8.15	1.95	10	0.76	7.59	0.80
Rec 09	3	0.66	1.99	0.74	12	0.59	7.05	0.46	19	0.81	15.44	1.32
Rec 08	-	-	-	-	1	0.08	0.08	-	1	0.23	0.23	-
Rec 11	4	0.32	1.27	0.17	2	0.53	1.05	0.13	6	0.62	3.71	0.74
All Recordings	47	1.21	56.73	1.76	51	1.02	51.83	1.88	72	0.83	59.66	1.06

However, it can be said that the AB pattern got more attention than the others. The fixation duration values supported these findings. The Areas of Interest (AOIs) were created with the size of 1020 X 180 px (width X height) and the fixation duration values were calculated for each pattern type. The mean of the fixation duration was calculated as 0.28 seconds for AB pattern (*SD*= 0.22), while it was found as 0.23 seconds for ABB (*SD*= 0.15), 0.24 seconds for ABC pattern (*SD*= 0.18) (see Table 53).

Table 53

Fixation Duration Measures for Finding the AB Pattern in Intervention 2

	AB				ABB				ABC			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secon
Rec 06	64	0.35	22.46	0.29	55	0.25	13.98	0.20	37	0.31	11.61	0.24
Rec 01	13	0.17	2.27	0.10	5	0.19	0.95	0.12	3	0.21	0.62	0.11
Rec 04	2	0.23	0.45	0.22	4	0.23	0.91	0.11	6	0.14	0.85	0.12
Rec 05	-	-	-	-	-	-	-	-	1	0.33	0.33	-
Rec 02	36	0.25	8.84	0.14	24	0.22	5.36	0.09	24	0.21	5.09	0.11
Rec 03	-	-	-	-	-	-	-	-	7	0.09	0.60	0.03
Rec 07	3	0.18	0.53	0.08	4	0.25	1.02	0.11	13	0.27	3.52	0.09
Rec 10	17	0.27	4.58	0.13	17	0.20	3.37	0.14	22	0.22	4.81	0.08
Rec 09	10	0.18	1.79	0.08	30	0.19	5.72	0.10	58	0.22	12.94	0.21
Rec 08	-	-	-	-	1	0.08	0.08	-	1	0.23	0.23	-
Rec 11	4	0.32	1.27	0.17	2	0.53	1.05	0.13	12	0.28	3.36	0.15
All Recordings	149	0.28	42.20	0.22	142	0.23	32.42	0.15	184	0.24	43.96	0.18

For children in intervention 2 (i.e., integrated non-HLT group), the eye-tracking data revealed more extensive results. The core identification task was asked in Session 3 before the translation tasks but after the fixing, duplication, and extension tasks. It can be said that all core units were visited by children (see Figure 35).

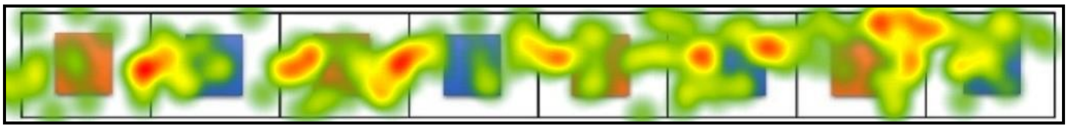


Figure 35. The heat map for AB core identification in Intervention 2

Besides the heat map image, fixation durations supported these findings. The Areas of Interest (AOIs) were created with the size of 250 X 250 px (width X height) and the fixation duration values were calculated for each core unit of the pattern. The sum of the fixation duration was calculated as 12.32 seconds for Core 1 (M= 0.34, SD= 0.28), while it was found as 15.33 seconds for Core 2 (M= 0.29, SD= 0.26), 13.05 seconds for Core 3 (M= 0.24, SD= 0.15), and 15.10 seconds for Core 4 (M= 0.27, SD= 0.23) (see Table 54). That is, although the fixation durations seemed close to each other, the most fixations were seen on the second core, fourth core, third core, and first core, respectively (see Table 54).

Table 54

Fixation Duration Measures for Core Identification of the AB Pattern in Intervention 2

	Core1				Core2				Core3				Core4			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secon
Rec 06	13	0.49	6.36	0.40	9	0.44	3.98	0.28	16	0.38	6.07	0.17	11	0.50	5.50	0.26
Rec 01	-	-	-	-	-	-	-	-	1	0.25	0.25	-	1	0.17	0.17	-
Rec 04	1	0.13	0.13	-	4	0.18	0.73	0.11	3	0.13	0.39	0.05	11	0.18	1.97	0.17
Rec 05	-	-	-	-	-	-	-	-	1	0.01	0.01	-	-	-	-	-
Rec 02	1	0.33	0.33	-	3	0.22	0.67	0.07	2	0.24	0.48	0.20	-	-	-	-
Rec 03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rec 07	6	0.22	1.33	0.13	6	0.64	3.83	0.44	1	0.19	0.19	-	5	0.16	0.79	0.12
Rec 10	13	0.29	3.81	0.13	9	0.29	2.63	0.16	8	0.23	1.86	0.11	3	0.60	1.80	0.35
Rec 09	1	0.27	0.27	-	16	0.16	2.49	0.08	16	0.17	2.71	0.07	23	0.20	4.61	0.13
Rec 08	-	-	-	-	1	0.28	0.28	-	1	0.06	0.06	-	-	-	-	-
Rec 11	1	0.08	0.08	-	5	0.14	0.70	0.05	6	0.18	1.05	0.11	2	0.13	0.27	0.05
All Recordings	36	0.34	12.32	0.28	53	0.29	15.33	0.26	55	0.24	13.05	0.15	56	0.27	15.10	0.23

The same examples were shown again and children were asked to find the ABB pattern which is at the top of the picture (i.e., circle, square, square) (see Figure 36). It seems that children had difficulty to find ABB pattern, rather mostly focused on ABC pattern in the given examples.

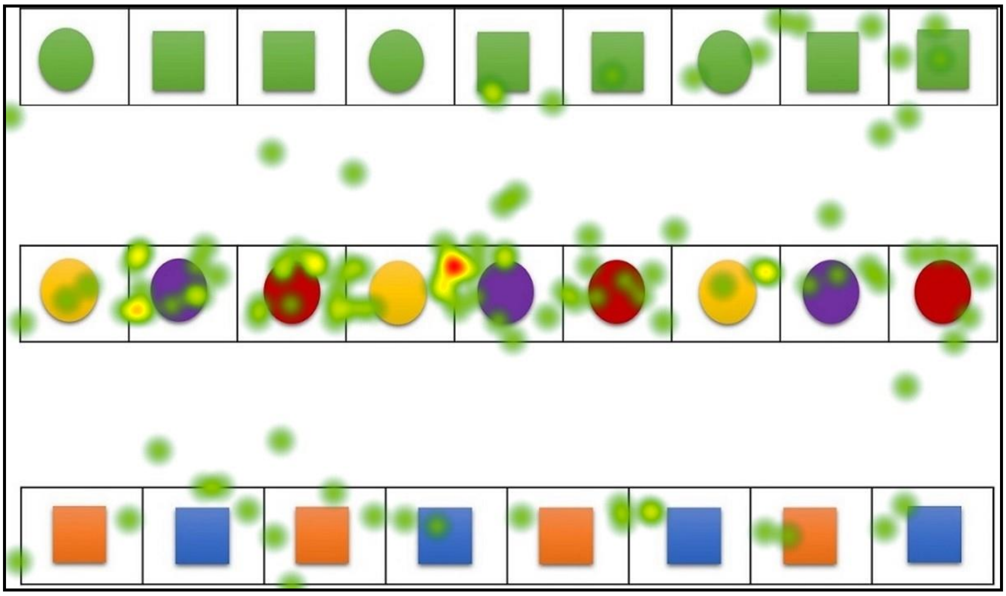


Figure 36. The heat map for finding the ABB pattern in Intervention 2

Besides the heat map, quantitative metrics supported these findings. The Areas of Interest (AOIs) were created with the size of 1020 X 180 px (width X height) and fixation durations were calculated for each pattern type. As presented in Table 55, the sum of the fixation duration of each pattern type was found as 5.77 seconds for AB pattern (M= 0.26, SD= 0.17), 2.27 seconds for ABB pattern (M= 0.14, SD= 0.09), and 17.65 seconds for ABC pattern (M= 0.22, SD= 0.20).

Table 55

Fixation Duration Measures for Finding the ABB Pattern in Intervention 2

Recordings	AB				ABB				ABC			
	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Seconc
Rec 06	10	0.24	2.40	0.17	4	0.18	0.73	0.11	24	0.31	7.51	0.27
Rec 01	-	-	-	-	1	0.10	0.10	-	15	0.19	2.87	0.15
Rec 04	2	0.16	0.32	0.06	1	0.07	0.07	-	1	0.07	0.07	-
Rec 05	-	-	-	-	-	-	-	-	1	0.13	0.13	-
Rec 02	2	0.47	0.95	0.32	-	-	-	-	14	0.10	1.45	0.03
Rec 03	-	-	-	-	-	-	-	-	-	-	-	-
Rec 07	-	-	-	-	-	-	-	-	2	0.10	0.20	0.02
Rec 10	-	-	-	-	1	0.36	0.36	-	3	0.22	0.66	0.05
Rec 09	2	0.17	0.35	0.08	8	0.12	0.93	0.05	12	0.25	2.98	0.18
Rec 08	-	-	-	-	-	-	-	-	2	0.07	0.14	0.06
Rec 11	6	0.29	1.75	0.17	1	0.08	0.08	-	6	0.28	1.65	0.27
All Recordings	22	0.26	5.77	0.17	16	0.14	2.27	0.09	80	0.22	17.65	0.20

When they are asked to find the core unit of ABB pattern, it can be said that all core units were visited by the children (see Figure 37).

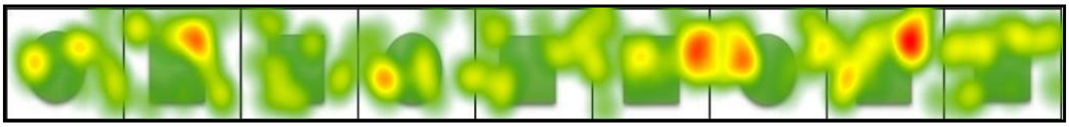


Figure 37. The heat map for ABB core identification in Intervention 2

For the example shown above (i.e., in Figure 37), the Areas of Interest (AOIs) were created with the size of 340 X 250 px (width X height) and the fixation duration values were calculated for each core unit of the pattern. The sum of the fixation duration was calculated as 12.37 seconds for Core 1 (M= 0.23, SD= 0.18), while it was found as 18.62 seconds for Core 2 (M= 0.27, SD= 0.26), and 17.39 seconds for Core 3 (M= 0.23, SD= 0.14) (see Table 56). That is, although the fixation durations seemed close to each other, the most fixations were seen on the second core, third core, and first core, respectively to find an ABB core unit (see Table 56).

Table 56

Fixation Duration Measures for Core Identification of the ABB Pattern in Intervention 2

	Core 1				Core 2				Core 3			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Second
Rec 06	16	0.27	4.28	0.20	10	0.53	5.28	0.52	7	0.29	2.02	0.14
Rec 01	2	0.22	0.43	0.19	2	0.19	0.38	0.13	1	0.12	0.12	-
Rec 04	5	0.10	0.50	0.04	5	0.20	0.98	0.09	4	0.26	1.03	0.20
Rec 05	-	-	-	-	1	0.00	0.00	-	-	-	-	-
Rec 02	4	0.22	0.90	0.18	6	0.25	1.53	0.15	6	0.20	1.20	0.13
Rec 03	-	-	-	-	-	-	-	-	-	-	-	-
Rec 07	-	-	-	-	7	0.22	1.52	0.12	13	0.18	2.28	0.07
Rec 10	9	0.34	3.05	0.11	6	0.34	2.04	0.21	6	0.29	1.72	0.13
Rec 09	7	0.29	2.00	0.29	28	0.21	5.78	0.13	36	0.24	8.73	0.17
Rec 08	2	0.12	0.24	0.11	4	0.27	1.10	0.21	2	0.14	0.28	0.01
Rec 11	8	0.12	0.97	0.08	-	-	-	-	-	-	-	-
All Recordings	53	0.23	12.37	0.18	69	0.27	18.62	0.26	75	0.23	17.39	0.14

Lastly, the same examples were shown again and children were asked to find the ABC pattern which is in the middle of the picture (i.e., yellow, purple, and red circles) (see Figure 38). It seems that children did not have so much difficulty to find the ABC pattern because most fixations were seen on the ABC pattern.

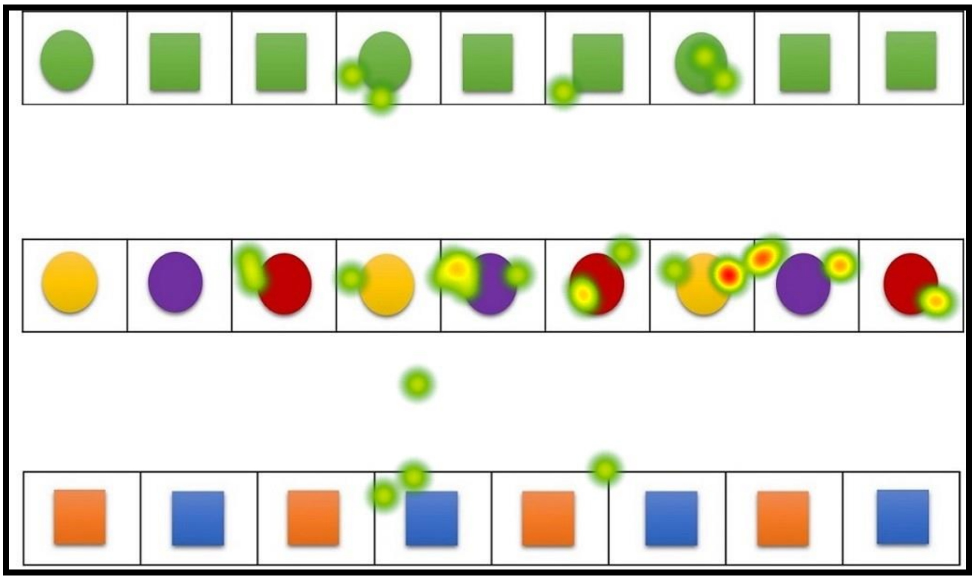


Figure 38. The heat map for finding the ABC pattern in Intervention 2

Besides the heat map, quantitative metrics supported these findings. The Areas of Interest (AOIs) were created with the size of 1024 X 180 px (width X height) and fixation durations were calculated for each pattern type. As presented in Table 57, the sum of the fixation duration of each pattern type was found as 0.57 seconds for AB pattern (M= 0.19, SD= 0.11), 0.70 seconds for ABB pattern (M= 0.14, SD= 0.07), and 3.58 seconds for ABC pattern (M= 0.16, SD= 0.09).

Table 57

Fixation Duration Measures for Finding the ABC Pattern in Intervention 2

	AB				ABB				ABC			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secon
Rec 06	-	-	-	-	2	0.07	0.15	0.01	1	0.23	0.23	-
Rec 01	-	-	-	-	-	-	-	-	8	0.14	1.10	0.10
Rec 04	1	0.13	0.13	-	-	-	-	-	1	0.22	0.22	-
Rec 05	-	-	-	-	-	-	-	-	1	0.12	0.12	-
Rec 02	-	-	-	-	-	-	-	-	-	-	-	-
Rec 03	-	-	-	-	-	-	-	-	-	-	-	-
Rec 07	-	-	-	-	-	-	-	-	-	-	-	-
Rec 10	-	-	-	-	-	-	-	-	-	-	-	-
Rec 09	2	0.22	0.43	0.14	3	0.18	0.55	0.06	12	0.16	1.91	0.10
Rec 08	-	-	-	-	-	-	-	-	-	-	-	-
Rec 11	-	-	-	-	-	-	-	-	-	-	-	-
All Recordings	3	0.19	0.57	0.11	5	0.14	0.70	0.07	23	0.16	3.58	0.09

When they are asked to find the core unit of ABC pattern, it can be said that all core units were visited by the children (see Figure 39).

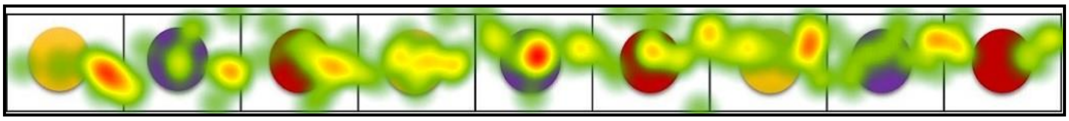


Figure 39. The heat map for ABC core identification in Intervention 2

For the example shown above (i.e., in Figure 39), the Areas of Interest (AOIs) were created with the size of 340 X 250 px (width X height) and the fixation duration values were calculated for each core unit of the pattern. The sum of the fixation duration was calculated as 9.32 seconds for Core 1 (M= 0.20, SD= 0.16), while it was found as 14.10 seconds for Core 2 (M= 0.25, SD= 0.21), and 10.75 seconds for Core 3 (M= 0.21, SD= 0.16) (see Table 58). In can be resulted that the most fixations were seen on the second core, third core, and first core, respectively to find an ABC core unit.

Table 58

Fixation Duration Measures for Core Identification of the ABC Pattern in Intervention 2

	Core 1				Core 2				Core 3			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secon
Rec 06	13	0.19	2.50	0.06	11	0.32	3.47	0.25	9	0.14	1.30	0.12
Rec 01	6	0.14	0.83	0.09	1	0.08	0.08	-	-	-	-	-
Rec 04	-	-	-	-	-	-	-	-	-	-	-	-
Rec 05	-	-	-	-	1	0.25	0.25	-	-	-	-	-
Rec 02	1	0.07	0.07	-	2	0.09	0.18	0.01	-	-	-	-
Rec 03	-	-	-	-	-	-	-	-	-	-	-	-
Rec 07	4	0.15	0.58	0.07	5	0.15	0.77	0.13	4	0.31	1.23	0.24
Rec 10	3	0.25	0.76	0.20	13	0.30	3.87	0.22	13	0.20	2.59	0.13
Rec 09	20	0.23	4.57	0.21	20	0.23	4.61	0.19	24	0.23	5.62	0.18
Rec 08	-	-	-	-	4	0.22	0.87	0.30	-	-	-	-
Rec 11	-	-	-	-	-	-	-	-	-	-	-	-
All Recordings	47	0.20	9.32	0.16	57	0.25	14.10	0.21	50	0.21	10.75	0.16

A second example of AB, ABB, and ABC pattern was shown to children to choose the specific pattern and to find the related core unit of that pattern. For example, children were presented three examples AB, ABB, and ABC pattern in a different order and first asked to find the AB pattern. The example for choosing an AB pattern (i.e., heart, smiley face) located in the middle of the screen revealed similar findings as the most attention was given to the AB pattern (see Figure 40).

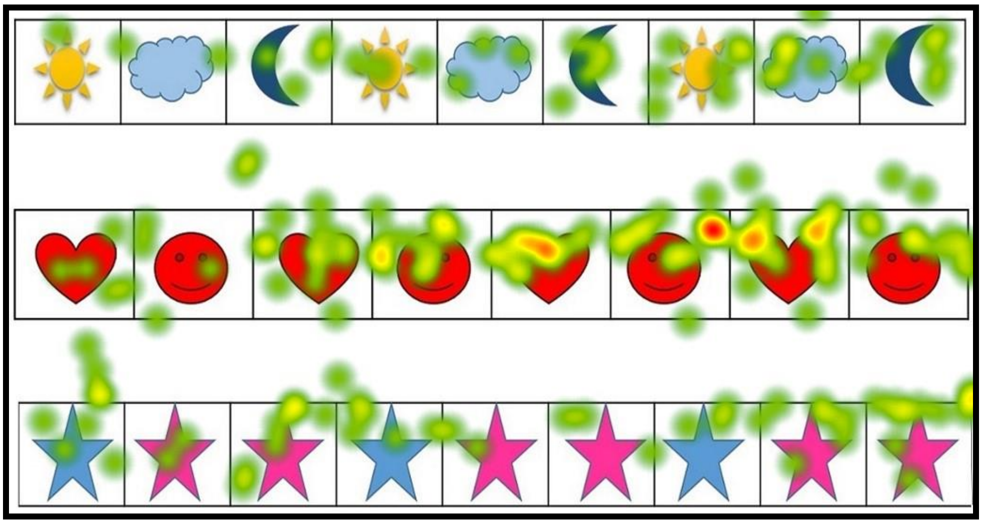


Figure 40. The second example of heat map for finding the of AB pattern in Intervention 2

Besides the heat map, quantitative metrics supported these findings. The Areas of Interest (AOIs) were created with the size of 1024 X 160 px (width X height) and fixation durations were calculated for each pattern type. As presented in Table 59, the sum of the fixation duration of each pattern type was found as 16.86 seconds for AB pattern (M= 0.18, SD= 0.11), 7.47 seconds for ABB pattern (M= 0.16, SD= 0.09), and 10.04 seconds for ABC pattern (M= 0.26, SD= 0.14).

Table 59

Fixation Duration Measures for Finding the Second Example of AB Pattern (Intervention 2)

	AB				ABB				ABC			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor
Rec 06	9	0.14	1.30	0.06	3	0.19	0.57	0.13	2	0.35	0.70	0.26
Rec 01	6	0.16	0.97	0.11	6	0.14	0.87	0.09	2	0.27	0.53	0.02
Rec 04	-	-	-	-	-	-	-	-	-	-	-	-
Rec 05	1	0.00	0.00	-	-	-	-	-	-	-	-	-
Rec 02	9	0.11	0.98	0.05	-	-	-	-	-	-	-	-
Rec 03	-	-	-	-	-	-	-	-	-	-	-	-
Rec 07	14	0.15	2.06	0.10	4	0.08	0.32	0.02	5	0.18	0.89	0.08
Rec 10	37	0.23	8.61	0.12	14	0.20	2.83	0.11	21	0.28	5.95	0.17
Rec 09	15	0.18	2.67	0.08	16	0.17	2.65	0.08	8	0.25	1.97	0.06
Rec 08	-	-	-	-	-	-	-	-	-	-	-	-
Rec 11	3	0.09	0.27	0.03	3	0.08	0.23	0.02	-	-	-	-
All Recordings	94	0.18	16.86	0.11	46	0.16	7.47	0.09	38	0.26	10.04	0.14

When children were asked to find the core unit of AB pattern, they mostly focused on the first core of the pattern (see Figure 41).

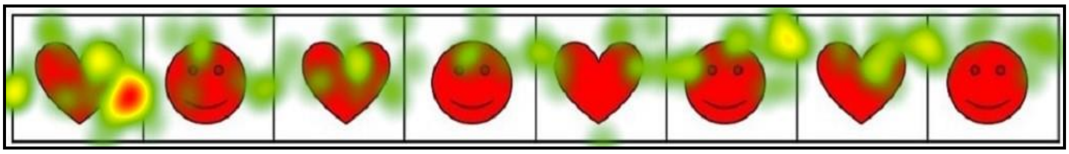


Figure 41. The second example of the heat map for AB core identification in Intervention 2

Besides the heat map image, fixation durations supported these findings. For the example shown above (i.e., in Figure 41), the Areas of Interest (AOIs) were created with the size of 250 X 250 px (width X height) and the fixation duration values were calculated for each core unit of the pattern. The sum of the fixation duration was calculated as 9.32 seconds for Core 1 (*M*= 0.21, *SD*= 0.15), while it was found as 3.73 seconds for Core 2 (*M*= 0.19, *SD*= 0.15), 6.97 seconds for Core 3 (*M*= 0.24, *SD*= 0.23), and 6.43 seconds for Core 4 (*M*= 0.23, *SD*= 0.15) (see Table 60). That is, although the fixation durations seemed close to each other, the most fixations were seen on the first core, third core, fourth core, and second core, respectively.

Table 60

Fixation Duration Measures for Core Identification of the AB Pattern in Intervention 2 (the Second Set of Example)

	Core 1				Core 2				Core 3				Core 4			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Second
Rec 06	13	0.19	2.42	0.14	2	0.29	0.58	0.25	-	-	-	-	-	-	-	-
Rec 01	-	-	-	-	-	-	-	-	5	0.11	0.55	0.05	-	-	-	-
Rec 04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rec 05	-	-	-	-	1	0.01	0.01	-	-	-	-	-	-	-	-	-
Rec 02	-	-	-	-	-	-	-	-	1	0.50	0.50	-	1	0.12	0.12	-
Rec 03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rec 07	-	-	-	-	2	0.14	0.28	0.03	-	-	-	-	3	0.20	0.60	0.23
Rec 10	5	0.42	2.10	0.15	6	0.30	1.82	0.16	11	0.32	3.52	0.34	15	0.25	3.76	0.14
Rec 09	14	0.22	3.15	0.16	2	0.08	0.17	0.02	12	0.20	2.40	0.10	9	0.22	1.95	0.16
Rec 08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rec 11	13	0.13	1.65	0.08	7	0.12	0.87	0.06	-	-	-	-	-	-	-	-
All Recordings	45	0.21	9.32	0.15	20	0.19	3.73	0.15	29	0.24	6.97	0.23	28	0.23	6.43	0.15

The same examples were shown again and children were asked to find the ABB pattern which is at the bottom of the picture (i.e., blue, pink, pink stars) (see Figure 42). It seems that children had difficulty to find ABB pattern, rather mostly focused on ABC pattern in the given examples.

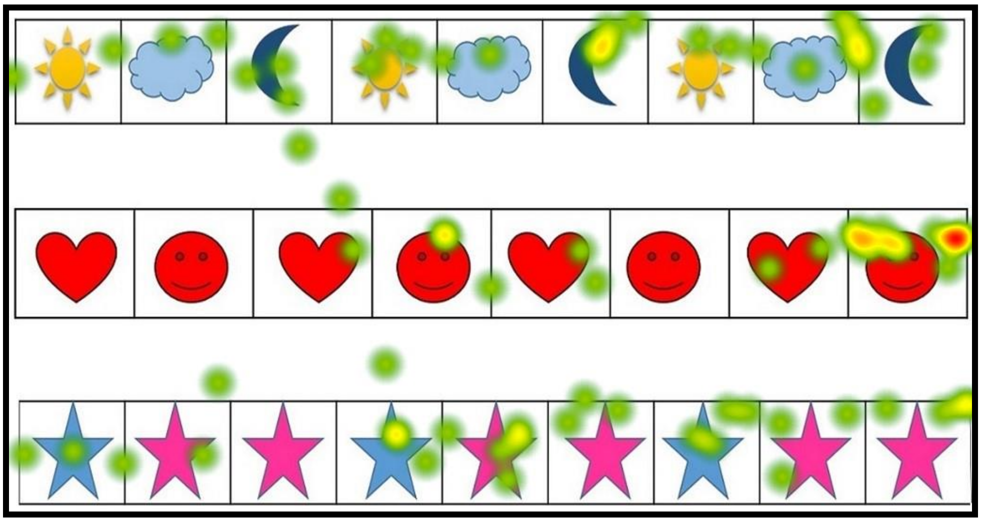


Figure 42. The second set of example of heat map for finding the of ABB pattern in Intervention 2

Besides the heat map, quantitative metrics supported these findings. The Areas of Interest (AOIs) were created with the size of 1024 X 160 px (width X height) and fixation durations were calculated for each pattern type. As presented in Table 61, the sum of the fixation duration of each pattern type was found as 4.84 seconds for AB pattern (M= 0.22, SD= 0.18), 6.44 seconds for ABB pattern (M= 0.24, SD= 0.12), and 7.24 seconds for ABC pattern (M= 0.24, SD= 0.11).

Table 61

Fixation Duration Measures for Finding the Second Set of Example of ABB Pattern (Intervention 2)

	AB				ABB				ABC			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Second
Rec 06	1	0.15	0.15	-	9	0.26	2.32	0.14	2	0.26	0.52	0.11
Rec 01	-	-	-	-	-	-	-	-	-	-	-	-
Rec 04	-	-	-	-	-	-	-	-	-	-	-	-
Rec 05	1	0.24	0.24	-	-	-	-	-	-	-	-	-
Rec 02	-	-	-	-	-	-	-	-	-	-	-	-
Rec 03	-	-	-	-	-	-	-	-	-	-	-	-
Rec 07	4	0.32	1.28	0.35	-	-	-	-	2	0.24	0.48	0.01
Rec 10	-	-	-	-	10	0.25	2.52	0.12	16	0.29	4.62	0.11
Rec 09	15	0.21	3.12	0.13	8	0.20	1.60	0.11	10	0.16	1.62	0.07
Rec 08	1	0.05	0.05	-	-	-	-	-	-	-	-	-
Rec 11	-	-	-	-	-	-	-	-	-	-	-	-
All Recordings	22	0.22	4.84	0.18	27	0.24	6.44	0.12	30	0.24	7.24	0.11

When children were asked to find the core unit of ABB pattern, their fixations were spread throughout the core units of the pattern (see Figure 43).

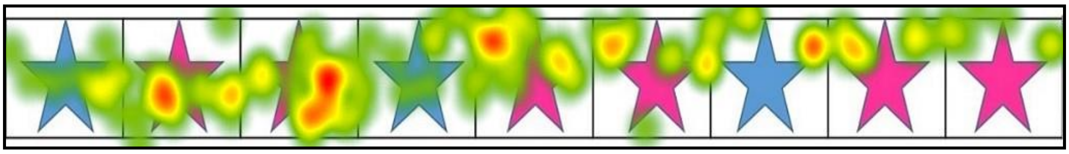


Figure 43. The second set of example of the heat map for ABB core identification in Intervention 2

Besides the heat map image, fixation durations supported these findings. For the example shown above (i.e., in Figure 43), the Areas of Interest (AOIs) were created with the size of 340 X 250 px (width X height) and the fixation duration values were calculated for each core unit of the pattern. The sum of the fixation duration was calculated as 8.30 seconds for Core 1 (M= 0.17, SD= 0.12), while it was found as 7.92 seconds for Core 2 (M= 0.19, SD= 0.12), and 8.44 seconds for Core 3 (M= 0.24, SD= 0.13), (see Table 62). That is, although the fixation durations seemed close to each other, the most fixations were seen on the third core, first core, and second core, respectively.

Table 62

Fixation Duration Measures for Core Identification of the ABB Pattern in Intervention 2 (the Second Set of Example)

	Core 1				Core 2				Core 3			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Seconds
Rec 06	20	0.21	4.22	0.16	2	0.22	0.44	0.08	-	-	-	-
Rec 01	1	0.07	0.07	-	-	-	-	-	-	-	-	-
Rec 04	3	0.14	0.43	0.04	6	0.15	0.88	0.10	2	0.18	0.37	0.00
Rec 05	-	-	-	-	2	0.02	0.03	0.02	-	-	-	-
Rec 02	2	0.13	0.25	0.08	1	0.07	0.07	-	9	0.24	2.15	0.13
Rec 03	-	-	-	-	-	-	-	-	-	-	-	-
Rec 07	-	-	-	-	-	-	-	-	-	-	-	-
Rec 10	10	0.11	1.12	0.04	18	0.24	4.30	0.14	13	0.30	3.95	0.12
Rec 09	12	0.16	1.97	0.06	12	0.16	1.95	0.06	11	0.18	1.97	0.11
Rec 08	-	-	-	-	1	0.25	0.25	-	-	-	-	-
Rec 11	2	0.12	0.25	0.04	-	-	-	-	-	-	-	-
All Recordings	50	0.17	8.30	0.12	42	0.19	7.92	0.12	35	0.24	8.44	0.13

Finally, the same example was shown for choosing ABC pattern (i.e., sun, cloud, moon) which was located at the top of the screen (see Figure 44). It seems that children did not have so much difficulty to find an ABC pattern because most fixations were seen on the ABC pattern.

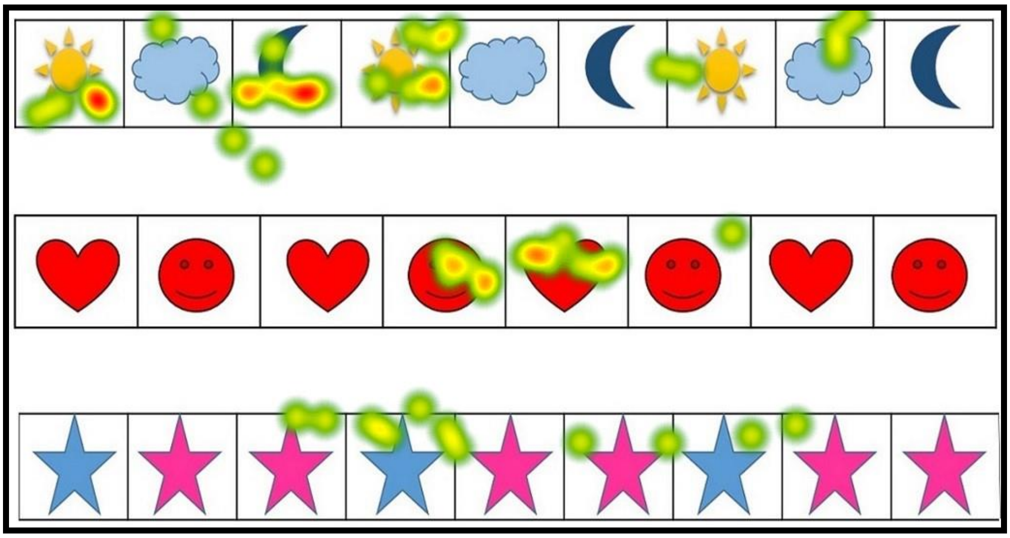


Figure 44. The second example of heat map for finding the of ABC pattern in Intervention 2

Besides the heat map, quantitative metrics supported these findings. The Areas of Interest (AOIs) were created with the size of 1024 X 160 px (width X height) and fixation durations were calculated for each pattern type. As presented in Table 63, the sum of the fixation duration of each pattern type was found as 1.91 seconds for AB pattern (M= 0.15, SD= 0.08), 1.52 seconds for ABB pattern (M= 0.14, SD= 0.04), and 5.79 seconds for ABC pattern (M= 0.20, SD= 0.14).

Table 63

Fixation Duration Measures for Finding the Second Example of ABC Pattern (Intervention 2)

	AB				ABB				ABC			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secon
Rec 06	2	0.15	0.30	0.09	2	0.10	0.20	0.00	7	0.25	1.75	0.16
Rec 01	-	-	-	-	-	-	-	-	-	-	-	-
Rec 04	-	-	-	-	-	-	-	-	1	0.09	0.09	-
Rec 05	2	0.16	0.31	0.13	-	-	-	-	-	-	-	-
Rec 02	-	-	-	-	-	-	-	-	-	-	-	-
Rec 03	-	-	-	-	-	-	-	-	-	-	-	-
Rec 07	-	-	-	-	-	-	-	-	-	-	-	-
Rec 10	-	-	-	-	2	0.14	0.28	0.06	4	0.15	0.60	0.06
Rec 09	7	0.16	1.09	0.08	7	0.15	1.03	0.04	17	0.20	3.35	0.15
Rec 08	2	0.11	0.22	0.02	-	-	-	-	-	-	-	-
Rec 11	-	-	-	-	-	-	-	-	-	-	-	-
All Recordings	13	0.15	1.91	0.08	11	0.14	1.52	0.04	29	0.20	5.79	0.14

When they are asked to find the core unit of the ABC pattern, it can be said that all core units were visited by the children but mostly focused on the first core of the pattern (see Figure 45).

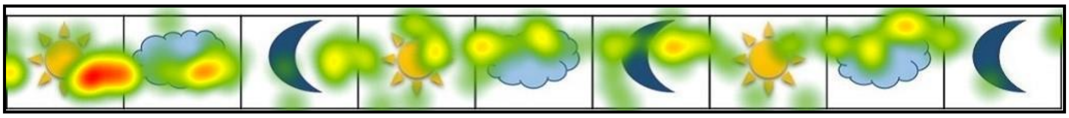


Figure 45. The second example of the heat map for ABC core identification in Intervention 2

Moreover, for the example shown above (i.e., in Figure 45), the Areas of Interest (AOIs) were created with the size of 340 X 250 px (width X height) and the fixation duration values were calculated for each core unit of the pattern. The sum of the fixation duration was calculated as 13.94 seconds for Core 1 (M= 0.27, SD= 0.16), while it was found as 11.28 seconds for Core 2 (M= 0.25, SD= 0.17), and 5.90 seconds for Core 3 (M= 0.19, SD= 0.14) (see Table 66). In can be resulted that the most fixations were seen on the first core, second core, and third core, respectively to find an ABC core unit.

Table 66

Fixation Duration Measures for Core Identification of the ABC Pattern in Intervention 2 (the Second Set of Example)

	Core 1				Core 2				Core 3			
Recordings	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secor	N (Count)	Mean (.Secor	Sum (.Secor	Stdev (.Secon
Rec 06	34	0.28	9.55	0.15	8	0.25	2.02	0.15	2	0.09	0.18	0.01
Rec 01	1	0.07	0.07	-	-	-	-	-	-	-	-	-
Rec 04	-	-	-	-	-	-	-	-	-	-	-	-
Rec 05	-	-	-	-	1	0.32	0.32	-	-	-	-	-
Rec 02	-	-	-	-	2	0.07	0.15	0.01	-	-	-	-
Rec 03	-	-	-	-	-	-	-	-	-	-	-	-
Rec 07	-	-	-	-	1	0.10	0.10	-	6	0.12	0.74	0.06
Rec 10	5	0.38	1.90	0.24	6	0.27	1.62	0.14	1	0.09	0.09	-
Rec 09	12	0.20	2.42	0.08	28	0.25	7.07	0.18	22	0.22	4.89	0.15
Rec 08	-	-	-	-	-	-	-	-	-	-	-	-
Rec 11	-	-	-	-	-	-	-	-	-	-	-	-
All Recordings	52	0.27	13.94	0.16	46	0.25	11.28	0.17	31	0.19	5.90	0.14

In order to get more information on how children accomplish the core identification task, the gaze plot belonging to a participant (i.e., Rec 6) was examined in detail. This participant represents a child who had no idea about core identification at first but achieved the task in the second example. Therefore, giving the gaze path of this participant would be meaningful to understand related cognitive mechanisms. For example, as displayed in Figure 46, when a child was asked to find the AB pattern in the given examples, Rec 06 started scanning the patterns from the top of the screen. After visiting the ABB pattern for a while, s/he jumped to the AB pattern. However, s/he did not focus so much on AB pattern, rather jumped to ABC and then again ABB pattern. Therefore, s/he could not find the correct one among the patterns.

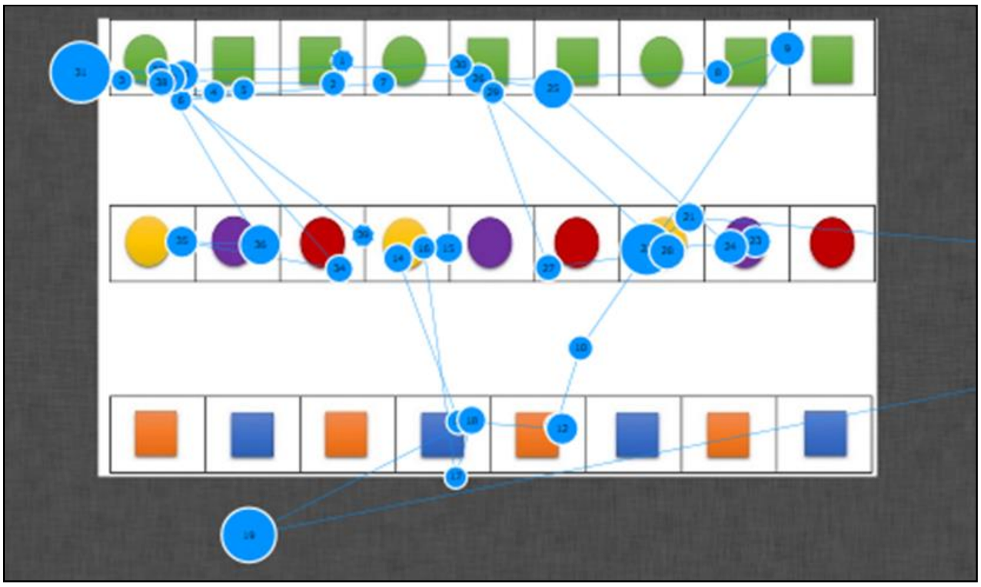


Figure 46. The gaze plot belonging to Rec 06 to find the AB pattern

However, after realizing the incorrect examples with the feedback of the researcher, s/he finally found the AB pattern, correctly. The gaze plot and heat map for finding the correct AB pattern was presented in Figure 47 and Figure 48, below.

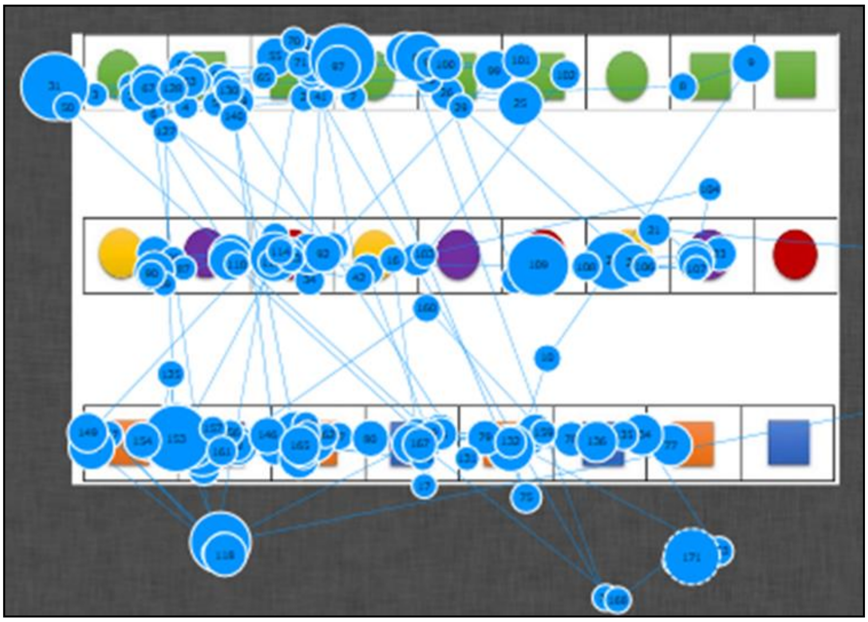


Figure 47. The gaze plot belonging to Rec 06 to find AB pattern with help

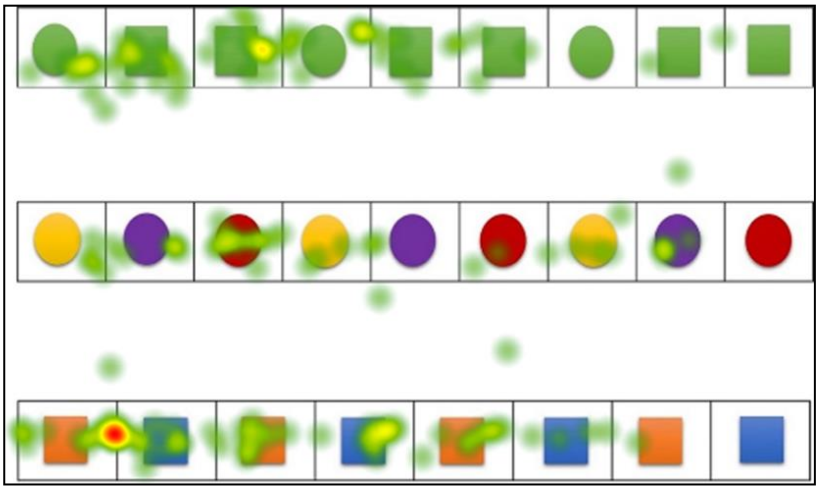


Figure 48. Heat map plot belonging to Rec 06 to find AB pattern with help

Later then, the child was asked to find the core unit of the AB pattern. As displayed in the gaze plot (see Figure 49), starting from the middle of the pattern, the child then moved to the end of the pattern, and then again to the middle, and then to the beginning of the pattern as looking at the whole pattern for many times. This shows that the child had difficulty to find the core unit of the AB pattern. The heat map also supported these findings (see Figure 50).

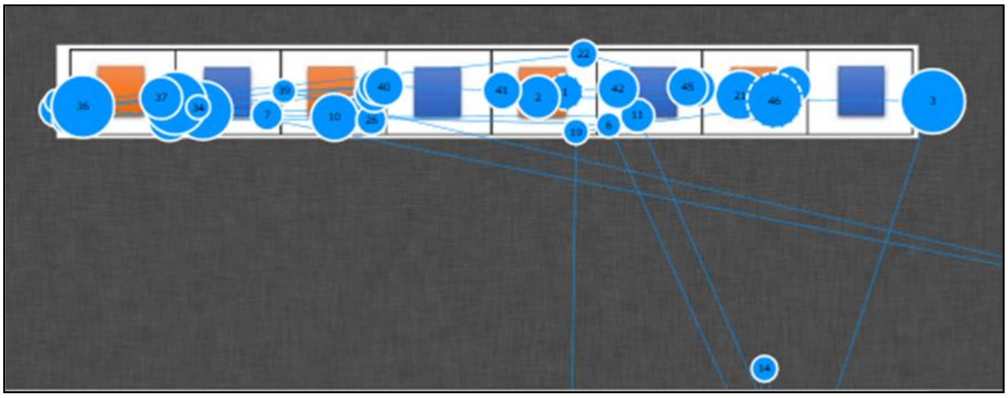


Figure 49. The gaze plot belonging to Rec 06 to find AB core unit with help

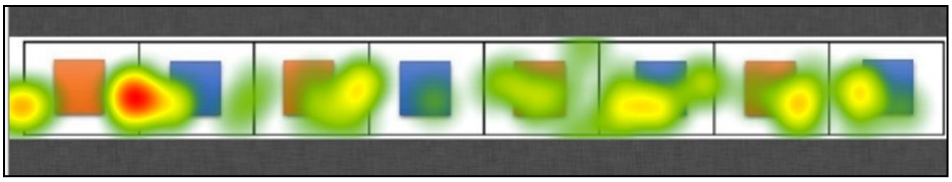


Figure 50. The gaze plot belonging to Rec 06 to find AB core unit with help

Similarly, when the child was shown the same examples and asked to find the ABB pattern, s/he started scanning the patterns from the middle of the screen (see Figure 51). Even though s/he visited AB and ABB pattern for a short time, s/he mostly focused on the ABC pattern and could not find the correct one among the patterns.

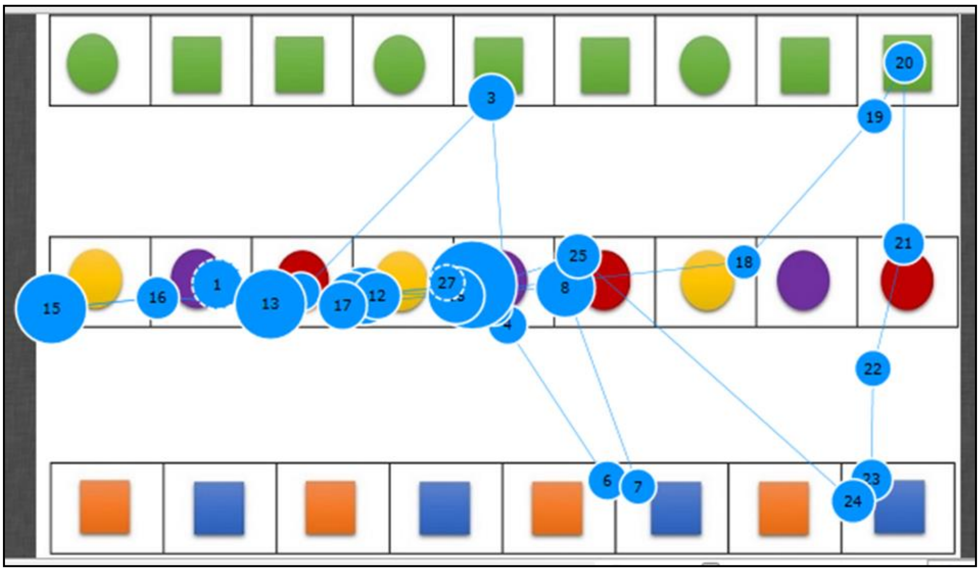


Figure 51. The gaze plot belonging to Rec 06 to find the ABB pattern

However, after realizing the incorrect examples with the feedback of the researcher, s/he finally found the ABB pattern, correctly. The gaze plot (see Figure 52) and heat map (see Figure 53) for finding the correct ABB pattern was presented as follow.

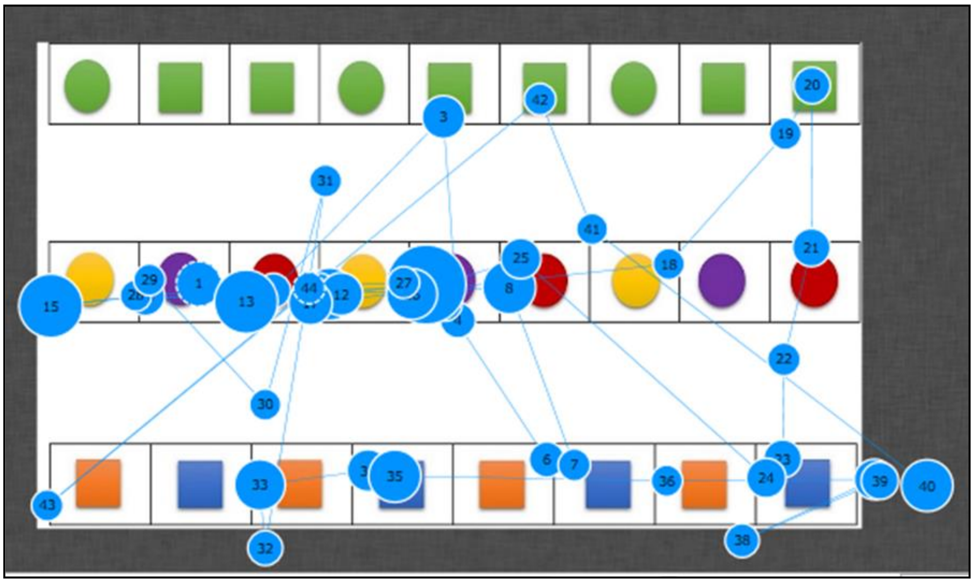


Figure 52. The gaze plot belonging to Rec 06 to find ABB pattern with help

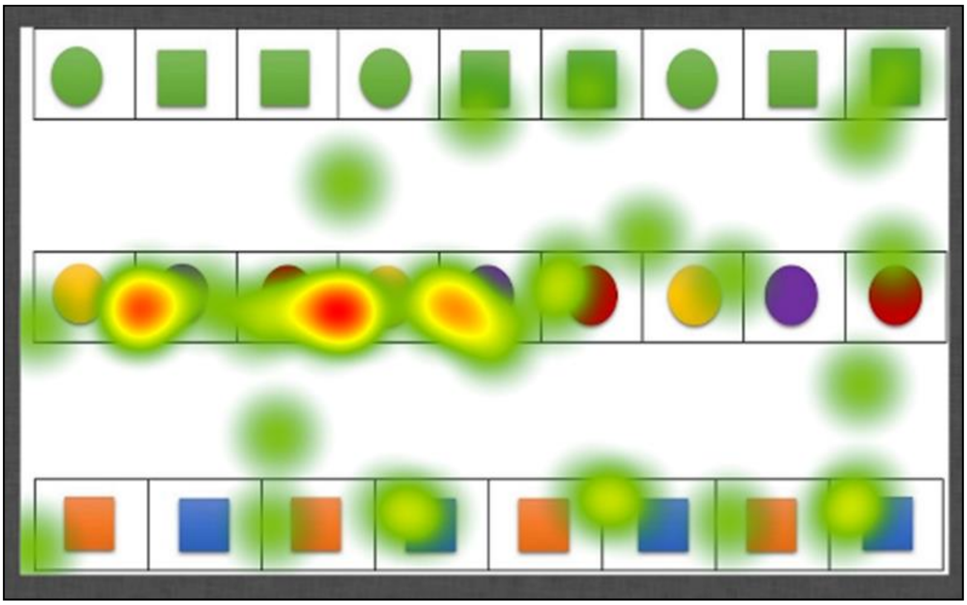


Figure 53. Heat map belonging to Rec 06 to find ABB pattern with help

Later then, the child was asked to find the core unit of the ABB pattern. As displayed in Figure 54, the child had difficulty to find the core as looking at the whole pattern for many times. The heat map also supported these findings (see Figure 55).

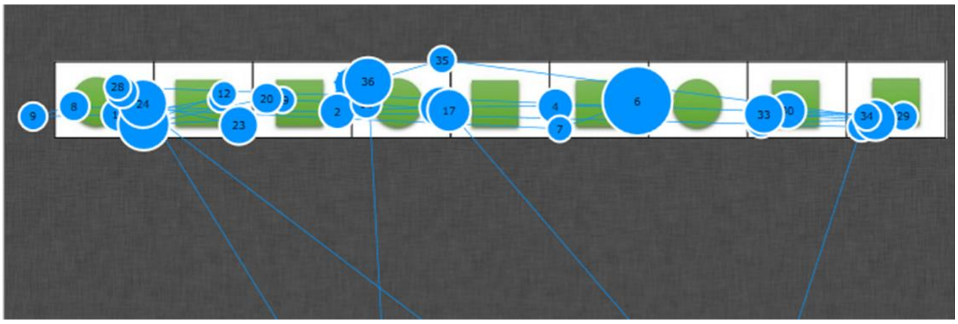


Figure 54. The gaze plot belonging to Rec 06 to find ABB core unit with help

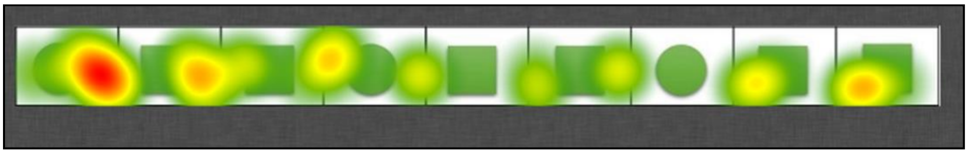


Figure 55. The heat map belonging to Rec 06 to find ABB core unit with help

Lastly, when the child was shown the same examples and asked to find ABC pattern, s/he started to look at the correct one as stating "because this one is left for ABC pattern". Indeed, the gaze plot (see Figure 56) and the heat map (see Figure 57) supported this finding.

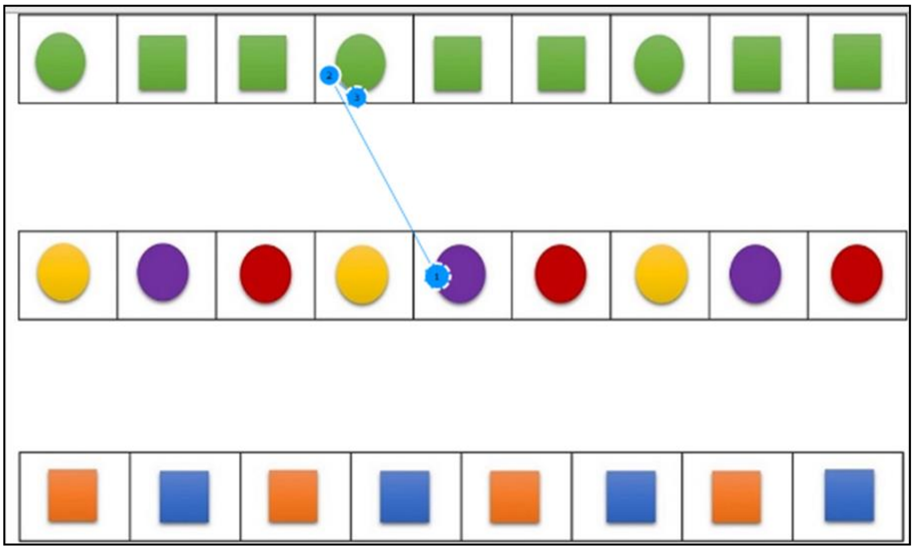


Figure 56. The gaze plot belonging to Rec 06 to find ABC pattern

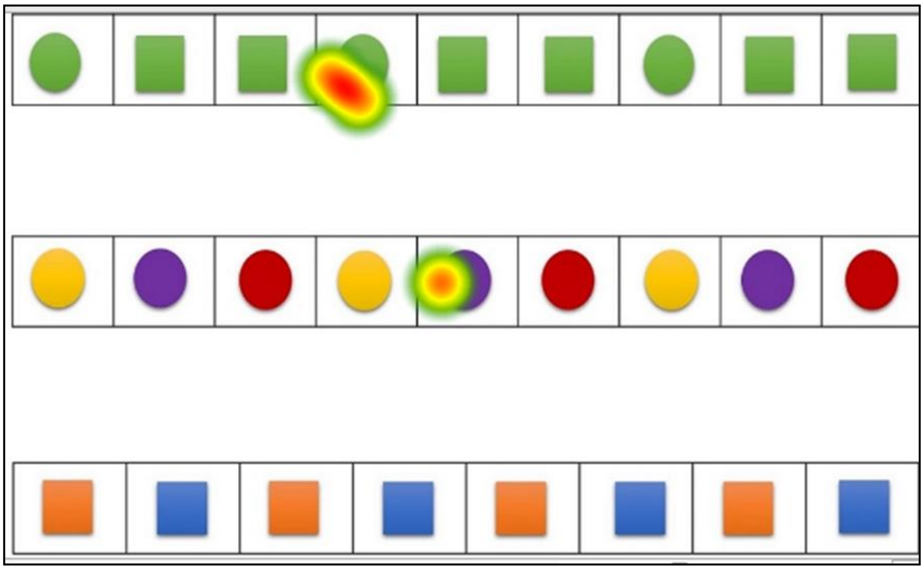


Figure 57. The heat map belonging to Rec 06 to find ABC pattern

Later then, the child was asked to find the core unit of the ABC pattern. As displayed in Figure, the child had difficulty to find the core as looking at the whole pattern for many times. Starting from the beginning of the pattern (see Figure 58), s/he gazed forward and backward (See Figure 59). The heat map also supported these findings (see Figure 60).

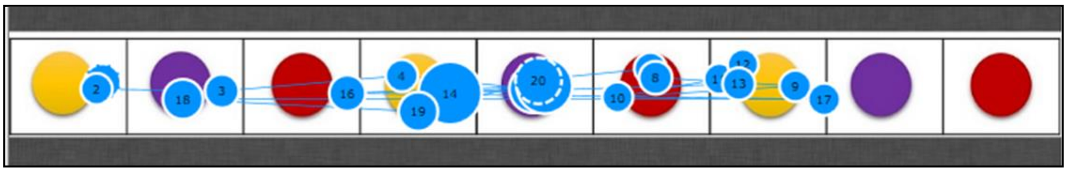


Figure 58. The gaze plot belonging to Rec 06 to find ABC core unit

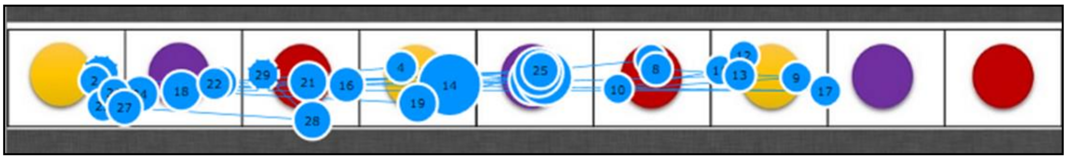


Figure 59. The gaze plot belonging to Rec 06 to find ABC core unit with help

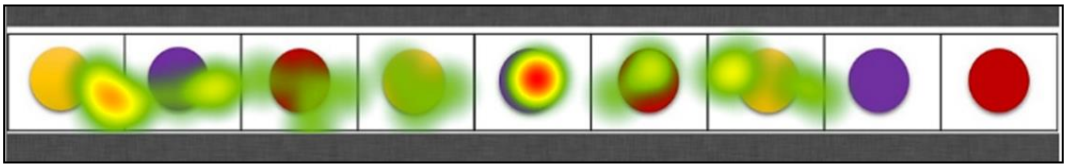


Figure 60. The heat map belonging to Rec 06 to find ABC core unit with help

On the other hand, for the second example shown to the child to find the AB, ABB, and ABC pattern, s/he could find the correct pattern types without any feedback. Indeed, the related gaze plots and heat maps supported a clear and focused eye-tracking data. For example, when the child was asked to find an AB pattern, as shown in Figure 61, the child started scanning from the AB pattern and looked at ABB pattern for a very short time. Later then, the child visited the AB pattern in a determined way.

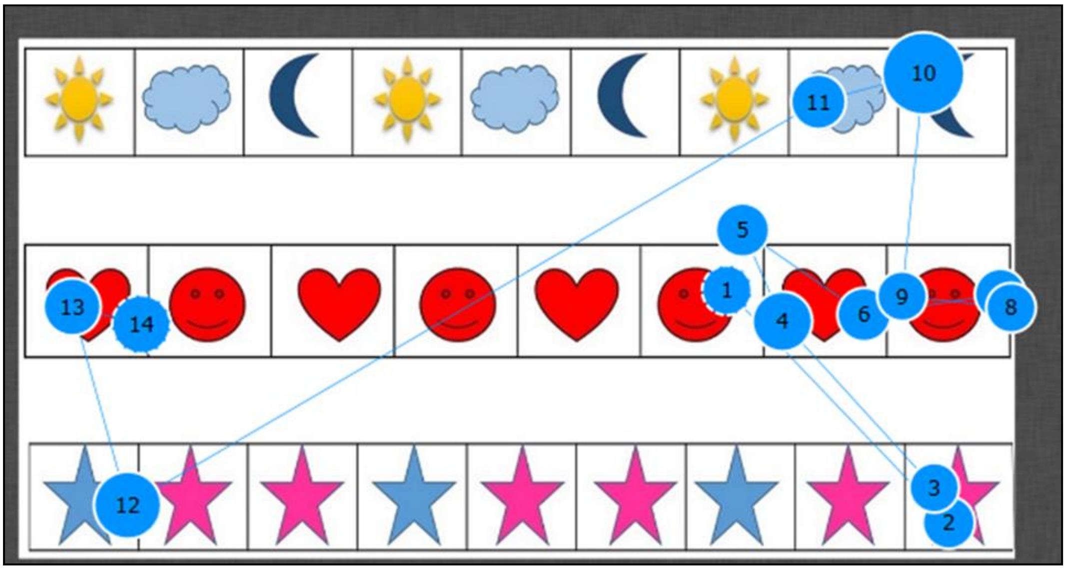


Figure 61. The gaze plot belonging to Rec 06 to find AB pattern without help

The heat map also supported these findings, as displayed in Figure 62, below.

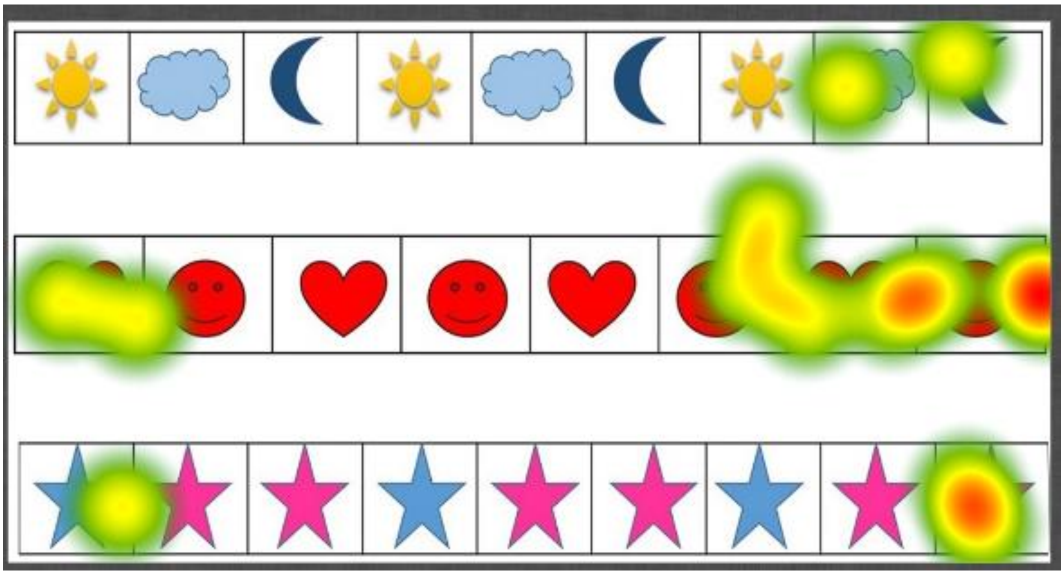


Figure 62. The heat map belonging to Rec 06 to find AB pattern without help

Later then, the child was also asked to find the core unit of the AB pattern. This time, the child was trained on finding the core unit of a pattern. So, as displayed in Figure 63, it seems that the child clearly noticed the core unit as looking at the beginning of the pattern. The heat map also supported these findings (see Figure 64).

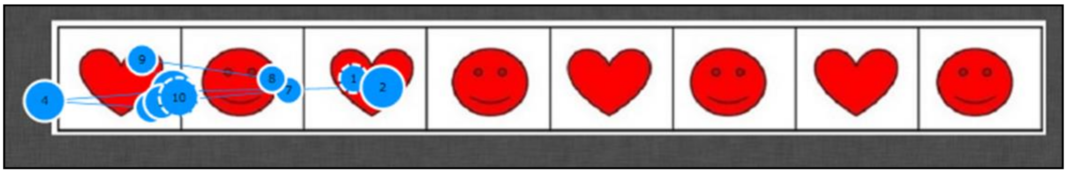


Figure 63. The gaze plot belonging to Rec 06 to find AB core without help

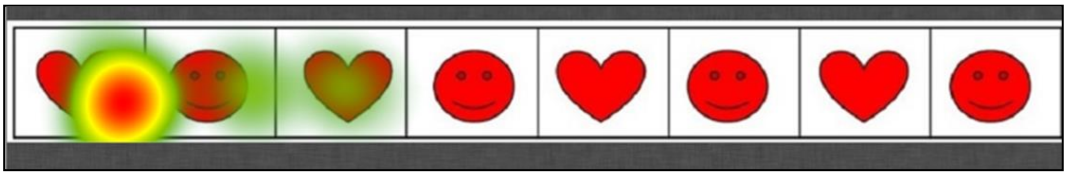


Figure 64. The heat map belonging to Rec 06 to find AB core without help

Similarly, when the child was shown the same examples and asked to find ABB pattern, s/he started scanning the patterns from the middle of the screen. However, the fixations clearly showed that the child mostly focused on the correct one as looking at the beginning of the ABB pattern (see Figure 65).

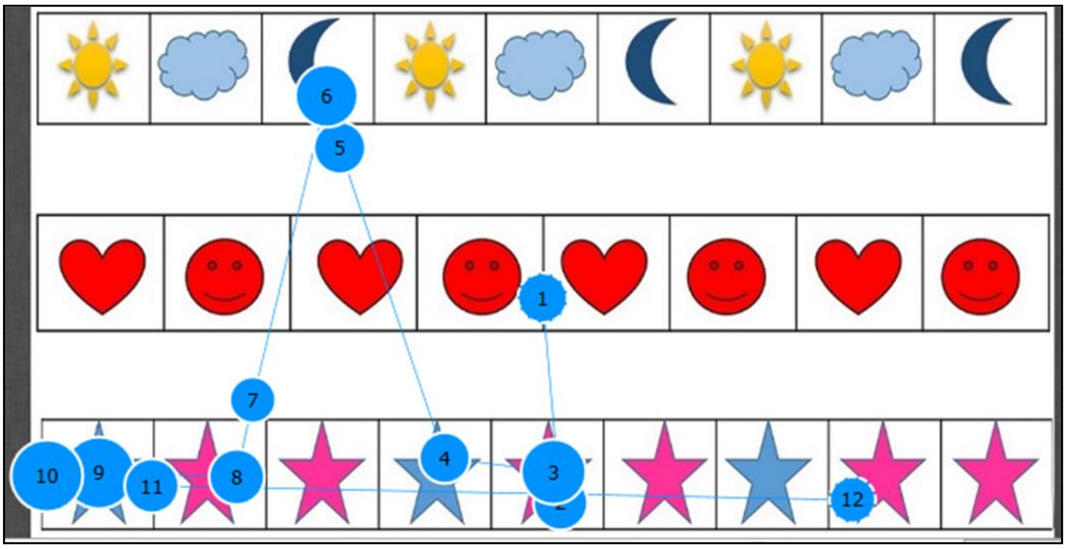


Figure 65. The gaze plot belonging to Rec 06 to find ABB pattern without help

The heat map also supported these findings as demonstrated in Figure 66.

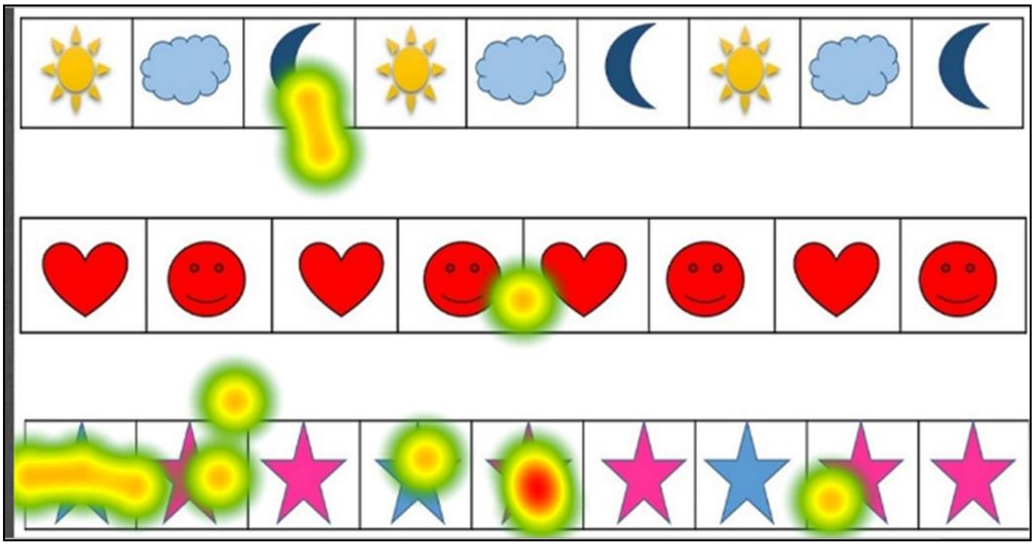


Figure 66. The heat map belonging to Rec 06 to find ABB pattern without help

Later then, the child was also asked to find the core unit of ABB pattern. This time, the child was trained on finding the core unit of a pattern. So, as displayed in Figure 67, it seems that the child clearly noticed the core unit as looking at the beginning of the pattern. The heat map also supported these findings (see Figure 68).

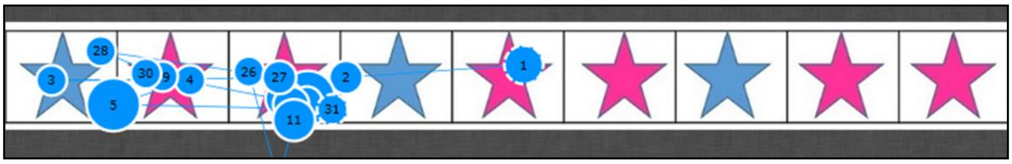


Figure 67. The gaze plot belonging to Rec 06 to find ABB core without help

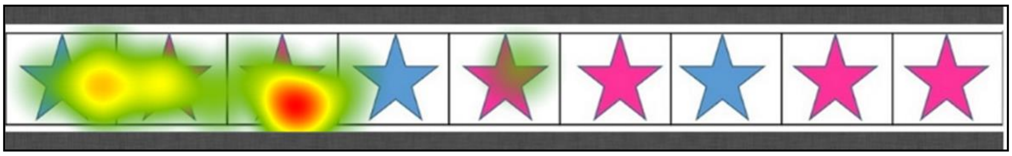


Figure 68. The heat map belonging to Rec 06 to find ABB core without help

Lastly, when the child was shown the same examples and asked to find the ABC pattern, s/he started scanning the patterns from the middle of the screen. However, the fixations clearly showed that the child mostly focused on the correct ABC pattern as looking at the beginning of the ABC pattern (see Figure 69). Therefore, it can be said that the child can recognize the core and use the core unit to find the related pattern type.

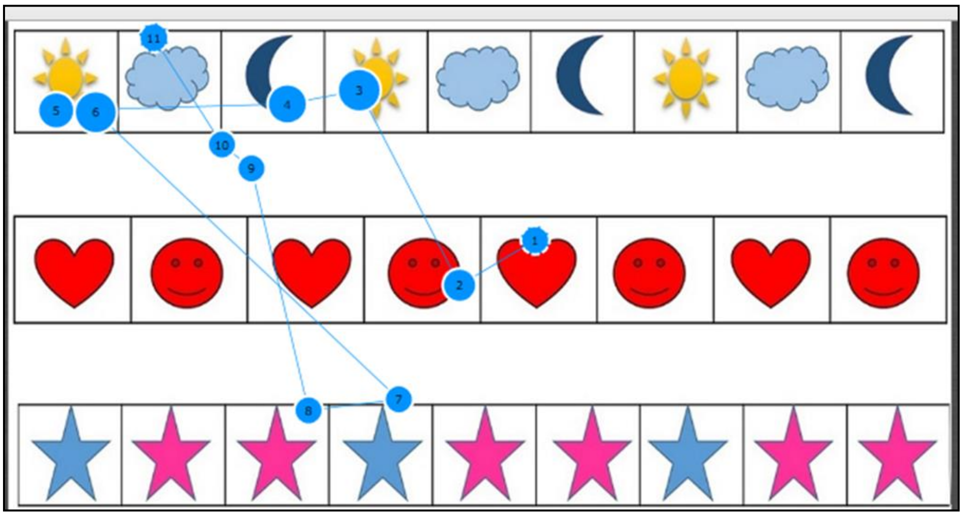


Figure 69. The gaze plot belonging to Rec 06 to find ABC pattern without help

The heat map also supported these findings as demonstrated in Figure 70.

Figure 70. The heat map belonging to Rec 06 to find ABC pattern without help

Later then, the child was also asked to find the core unit of the ABC pattern. This time, the child was trained on finding the core unit of a pattern. So, as displayed in Figure 71, it seems that the child clearly noticed the core unit as looking at the beginning of the pattern. The heat map also supported these findings (see Figure 72).

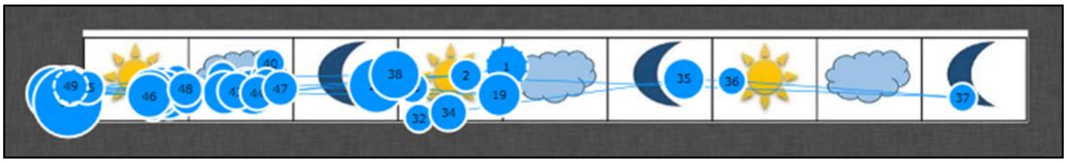


Figure 71. The gaze plot belonging to Rec 06 to find ABC core without help

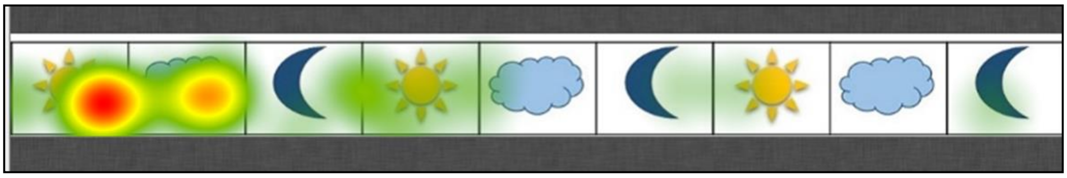


Figure 72. The heat map belonging to Rec 06 to find ABC core without help

As it is seen, both the gaze plot and the heat map helped to understand the child's cognitive reactions to find the pattern types as well as the core unit of the related pattern.

CHAPTER 5

DISCUSSIONS, CONCLUSION, AND IMPLICATION

The final chapter of this study is concluded in two sections. First, the findings of the research data are interpreted. Second, the possible implications and recommendations are presented.

5.1 Conclusion and Discussion

The present study served to evaluate the efficacy of a revised version of Hypothetical Learning Trajectories (HLTs) on patterning proposed Clements and Sarama (2009; see Baroody, Yilmaz, Clements, & Sarama, 2019 for the revised version). Moreover, with the help of the eye-tracking methodology, the study revealed the cognitive mechanism underlying several patterning skills.

5.1.1 RQ 1: Does instruction in which Learning Trajectories (LT) levels are taught consecutively (e.g., presenting children at level n-instructional tasks from level n+1, then n+2, and so forth) result in greater learning than instruction that uses the same activities without regard to developmental order or business-as-usual instruction?

After controlling for overall pretests scores, an Analysis of Covariance (ANCOVA) revealed a significant and, as indicated by large effect size, a highly substantial difference between the treatment (the gradual HLT-based intervention) and the passive control condition (regular classroom instruction or business-as-usual) on the overall score at the delayed posttest. The active control condition (integrated non-HLT-based intervention) likewise significantly and highly substantially outperformed and business-as-usual condition.

When each patterning skill (i.e., extension, translation, and core identification) was separately investigated, significant differences were found between at least one intervention group and the business-as-usual group. Specifically, for the extension skill, a significant and highly substantial difference was detected between the gradual HLT-based intervention and the business-as-usual group. However, a non-significant but substantial difference was found between the integrated non-HLT-based intervention and business as usual group. Moreover, the participants in the gradual HLT-based intervention were more successful than the integrated non-HLT-based intervention but no significant difference was found between them. In terms of translation skills, a significant and highly substantial difference was detected between the integrated non-HLT-based intervention and business-as-usual group but not between the gradual HLT-based intervention and business-as-usual group. Moreover, unlike significance levels between the gradual HLT-based intervention and business-as-usual group, as indicated by large effect size, a highly substantial difference was found between them. In addition, even though non-HLT-based intervention group performed better than the gradual HLT-based intervention, no significant but considerably substantial difference was found between them. Lastly, regarding core identification skills, a significant and highly substantial difference was found between the gradual HLT-based or the integrated non-LT-based group and business-as-usual group. However, no significant but considerably substantial difference was found between non-HLT-based intervention group and the gradual HLT-based intervention, even though children in non-HLT-based intervention group outperformed. The reason for the results that children children in integrated non-HLT group did better than the children in gradual HLT-group might be that children in integrated non-HLT group got the idea of the core before HLT-group children because they were instructed from the beginning of the training. Therefore, they could be more successful in Level 3 and Level 4.

The positive change in both treatment and active-control group support that children at this age and maturity level have the ability to improve their advance patterning skills such as translation (i.e., abstraction) and core identification. The lack of growth by business-as-usual group indicates that without structured patterning instruction, kindergartners may well not make progress on such skills. Therefore, early childhood education programs can be revised as giving more emphasis on the sophisticated HLT levels on patterning and early childhood teachers can pay more attention to this necessity when planning patterning instruction aligned with children's developmental progressions.

Both the gradual HLT-based children and integrated non-HLT children benefitted significantly from the targeted patterning instruction. That is, as some participants in the integrated non-HLT training appeared to thrive with the challenge of learning many new ideas, the results of the present study show that one method may not suit all children. This finding is parallel to the previous literature about the instruction of the early mathematical skills recommended by The National Association for the Education of Young Children (NAEYC, 2002; 2012) and National Council for Curriculum and Assessment (NCCA, 2014). Moreover, this result can be explained by Vygotsky's (1978) Zone of Proximal Development (ZPD), which is defined as "there is a gap between any student's…actual developmental level as determined by independent problem-solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers" (p. 86). It is not known whether HLT-based children would not have done the same if they received the integrated non-HLT instruction. But what observed that children in integrated non-HLT group was really challenged and they could improve their skills with scaffolding. Therefore, they gained more scores regarding translation and core identification scores. That is, children may have different HLT levels and need to be encouraged to improve their current level of thinking.

5.1.2 RQ 2: How do children establish their patterning skills (i.e., extension, translation, and core identification)?

Eye-tracking methodology and qualitative analyses revealed a number of interesting findings. For example, the heat maps demonstrated that when children were asked to extend a given AB pattern, they had prolonged viewing unfocussed gazing on overall the pattern, however;

mostly focused on the last core of the model pattern. This finding supports that children are first looking at the whole pattern to identify it, and then they use the last core to extend the given pattern. These cognitive behaviors were similar to the extension of the ABB and ABC pattern type (see the heat maps in Figures 26, 27, 28, 29, and 30). Moreover, the fixation duration measures quantitatively supported these findings related to the patterning extension skills. These findings are contrary to claims that children usually apply the "one-to-one appearance matching" (Collins & Laski, 2015; Threlfall, 1999) and compare the elements of the pattern either within or at the beginning of the pattern because they are not aware of the unit of repeat (i.e., unit core) during the pattern extension skill (Lüken, 2018). Instead, the present results indicate that children may implicitly be aware of the core unit of the pattern and use this this awareness to correctly extend simple repeating patterns. In other words, children's fixations on the third core may support that they use the last core as a reference to extend the given pattern. What makes this result more impressive was that children naturally had applied this strategy because they had not been trained about core-identification skills. Therefore, extension skills may not be related just comprising the elements and focusing on the sequence or one-to-one appearance matching but also implicitly viewing the core unit of the pattern (cf. Collins & Laski, 2015; Lüken, 2018; Threlfall, 1999).

When it comes to pattern translation, the heat maps revealed different cognitive behaviors. While children mostly displayed similar cognitive behavior and clearly focused on the third core of the pattern during the extension of AB, ABB, and ABC pattern, their cognitive behavior differed regarding translation of the AB, ABB, and ABC pattern types.

When children were asked to translate the given AB pattern into different materials, after looking at all core units of the pattern, they mostly focused on the first and the second core unit of the model pattern. The same was true for translating ABB pattern type into different materials. Unlike extending a pattern, translating a pattern involved some intense fixation dots were seen within the whole pattern as more marked in ABB pattern (see Figures 31 and 32). The case of the ABB pattern can be explained by its double elements (i.e., BB) Its double elements because it is claimed that containing double elements may create more challenges than containing single elements for translation tasks (Lüken, 2018). Having prolonged gazing on AB and ABB pattern can be because of the complexity of the translation skill itself since it requires mental manipulation (Collins & Laski, 2015) and abstraction (Rittle-Johnson, Fyfe, McLean, & McEldoon, 2013). Indeed, in the literature, a significant relationship was found between translation skills and working memory (e.g., Collins & Laski, 2015; Rittle-Johnson et al., 2013). That is, children may have so many variables to deal with when they try to accomplish a translation task. Moreover, some researchers think that cognitive flexibility (e.g., Schmerold et al., 2017) and inhibition components (Collins & Laski, 2015; Schmerold et al., 2017) can also be related to translation tasks. Similarly, in the present study, it can be said that children were overwhelmed by many things to consider and needed to frequently check the model pattern to make sure they are following the right sequence.

Interestingly, children demonstrated different fixations for translating the ABC pattern type compared to AB and ABB pattern. That is, children mostly focused on the task to be done rather than the model pattern. Moreover, the findings support that children focused on the third core unit of the given ABC pattern and the first core of the translated ABC pattern. This finding is different from translating AB and ABB pattern because children were generally looked at the model pattern during translation skills. One possible explanation of this result may be the children got familiar with the translation process and grasped and used the pattern's structure to translate the pattern. This finding is similar to Rittle-Johnson and colleagues' (2015) finding that children can use the underlying structure of the pattern to translate it into new media. However, with the help of eye-tracking data, the present study moved the findings reported by Rittle-Johnson et al. (2015) one step forward by explaining children's translation skills. Specifically, fixations positions on the heat map indicated that, once children had grasped the pattern's structure, they pretend the translated pattern is a new pattern and just extended it by looking at the third core of the model pattern. This finding is interesting because the latter procedure of the translation task is so similar to the procedure for the extension tasks explained above.

Lastly, regarding the core-identification skill, two set of patterns were presented including six patterns, two each of AB, ABB, and ABC patterns. Children were first asked to identify the AB pattern and the core unit of this pattern, and then one of the two other patterns in the next sessions. For the core-identification process in the first set of pattern, children almost visited all pattern types even though they were asked to find the AB pattern. This process was similar to find the core unit of the AB pattern since children also visited all core units. In the second set, however, children clearly focused on the AB pattern though visited other pattern types. Moreover, they more consciously focused on the core unit of the AB pattern.

ABB pattern seemed difficult to be recognized in both set of the patterns. That is, when children were asked to find ABB pattern, they after looking over the patterns, mostly focused on ABC type pattern even though they were asked to find ABB pattern. It was also not easy to find the core unit of the ABB pattern since children's fixations were spread throughout the core units of the pattern.

Surprisingly, when children were asked to find the ABC pattern among other patterns, they easily found the ABC pattern. In other words, after taking a quick look at all pattern types, children could recognize the ABC pattern. However, children reacted differently for the AB and ABB pattern as their fixations spread across the all pattern types. The heat maps and the fixation duration measures supported these observations. This may not be resulted from the easiness of the ABC pattern type. Rather, children may get more familiar with the ABC pattern than AB and ABB pattern because this pattern was always tested last. Indeed, when children were asked to find the core unit of the ABC pattern, they demonstrated similar cognitive behavior that they did for ABB core-identification process. That is, finding the core unit of the ABC pattern was also difficult as children's fixations were spread across the entire pattern without focusing on a core.

In the recent literature, identifying the core unit of the pattern is claimed as the advance level, among other patterning skills (Lüken, 2018; Rittle-Johnson, Fyfe, McLean, & McEldoon, 2013; Sarama & Clements, 2009). Therefore, it can be said that children might have the challenge of identifying the core unit of a pattern However, it was surprising that children could become more successful when they were asked one more unfamiliar task for core identification. As mentioned beforehand, children were presented two sets of pattern in two different sessions. Even though they were shown different examples, they were able to identify the core unit of the patterns in the latter. This finding can be resulted from practice or learning effect. Fortunately, when one participant was examined in detail, more explanatory findings emerged related to the patterning skills. For example, in the first example, the gaze plot displayed that the child indiscriminately followed a path for recognizing an AB, ABB, and ABC pattern as well as finding the core units of the pattern. The child's eyes moved back and forth many times. This clearly indicates the way that novice learners follow (e.g., Koh, Park, Wickens, Ong, & Chia, 2011). However, after developing an understanding of the process, the participant showed more conscious and selective behaviors for core identification task. For example, s/he directly focused on the correct type of the pattern asked for and found it without help. Many fixation bubbles were noticed on the corresponding pattern type rather than alternative patterns. This kind of cognitive behavior is assumed to be established by the expert learners, which was also found in other research studies (e.g., Medin, Ross, & Markman, 2001; Reingold, Charness, Pomplun, & Stampe, 2001). Therefore, when evaluating children's patterning skills, it seems important to consider the progress over time instead of focusing on a single snapshot. Indeed, Clements and Sarama (2018) claim that children can learn and develop their mathematical skills.

In brief then, the data collected with the help of the eye-tracking methodology helped to get meaningful insights into how children accomplish the patterning skills and how such mathematical experiences can be improved for children's mathematical thinking. In other words, the findings of this study not only revealed what was attended but also how the nature and the structure of patterning occurred. Therefore, as presenting a piece of fundamental evidence on patterning skills in this study, it seems that the eye-movement data may provide us a door to open onto children's cognition and acts and there are much more to be gained from eye-tracking data to understand about early mathematical thinking and to develop instructional practices.

5.2 Implication and Recommendations

5.2.1 Implication Regarding Early Patterning Skills

One implication of the present research is that parents, caregivers, or educators of children should not underestimate the patterning skills young children can achieve. Adequate training and proper adult supervision are crucial in the development of patterning skills (Clements & Sarama, 2018). Indeed, the present study supported that children can accomplish even more advanced patterning tasks such as translating and core identification after getting proper training on patterning. However, the children in business-as-usual group (i.e., non-patterning control group) could not accomplish enough the high-level patterning skills (i.e., translation and core identification). This finding shows that the existing early childhood curriculum may not cover enough mathematical patterning. Therefore, it can be said that the training given in the Turkish preschools or kindergartens needs to be carefully designed by including a higher level of patterning skills.

Moreover, the Turkish early childhood education curriculum can be revised and give more attention to the patterning in lesson plans. Furthermore, as educators are the gate-keepers for any innovation adjusted it into to practice, they could be informed and trained about Hypothetical Learning Trajectories (HLT) levels of patterning and the teaching of patterning skills. Therefore, workshops and seminars can be given to teaching faculty in early childhood education departments, early childhood education teachers, and pre-service early childhood education teachers. Moreover, undergraduate courses related to early mathematics can be revised to include patterning in their course programs.

During eye-tracking data collection, it was observed that children tend to look at the middle center of the computer screen. Therefore, software designers or instructional technologists developing computer-supported materials for young children may place critical content in the middle center of the computer screen.

5.2.2 Implication Regarding HLT on Early Patterning

This study helped to validate and revise the Hypothetical Learning Trajectories (HLTs) on patterning proposed by Clements and Sarama (2009). Based on the overall findings revealed, some implications are suggested for patterning HLTs as follows.

- Not 3-year-olds but 4- and 5-year-old children are capable of acquiring high levels of HLTs such as translation and core-identification.

- Using letters to label the elements of a pattern is a distinct form of translating patterns that can be introduced to children early in the trajectory—in Level 2.

- Other aspects of Level 3 (translating a pattern into different objects) may be more challenging and facilitated by understanding the concept of a core unit (i.e., Levels 3 and 4 may need to be reversed).
- The Level 4 activity of counting the number of core units was difficult for many children from both Intervention 1 and Intervention 2. When asked to count the number of the cores, children often simply counted the number of elements in a pattern. This achievement may represent a separate higher level.

- Counting the number of core units (currently an aspect of Level 4) may represent a separate, higher level than the Level 4 skill of simply identifying the core.

5.2.3. Recommendations for Future Research

- This study focused on the teaching and learning of the mathematical patterning for normally developing four- and five-year-old preschool children. Therefore, a further investigation can be conducted to a larger sample as well as including children with special needs.
- This study was examined the effectiveness of the HLT on patterning, a further study can be done to evaluate the effectiveness of HLTs on other mathematical learning areas.
- Since early childhood educators have a significant role in children's development, and further study can be conducted to examine their teaching practices on patterning and their Technological Pedagogical Content Knowledge (TPACK) regarding patterning.
- In early childhood years, the parents or caregivers of young children are considered as primary educators. Therefore, they need to be appropriately guided and encouraged to extend children's interest and knowledge of patterning at-home settings.
- In this study, the repeating patterns were used as a pattern type. A further study can be done considering other pattern types such as growing patterns and spatial patterns.
- A non-random sampling procedure was used in this study. In order to increase the generalization of the study, a random large-scale study including random sampling can be conducted.
- Moreover, a longitudinal study can be done to better understand the development of the patterning skills over years.

- This study was conducted with each participant individually. A further study can be conducted in a classroom setting to investigate the effect of social interaction on early patterning learning.
- In the related literature, a significant relationship was found between patterning skills and general mathematics achievement. Therefore, in future study, an experimental study can be conducted to examine the effect of the patterning scores on children's math achievement scores.
- A future study can be done as a qualitative study exploring children's reactions and responses during the training sessions to gather rich data about children's patterning learning.
- In this study, eye-tracking data revealed that finding the ABC pattern and its core unit is easier than the AB and ABB pattern. To examine the possible reason of this finding, further research may be conducted to empirically examine the effects of the placement and order of the patterns to understand the difficulties of the pattern structures for core identification skills.
- The order of the developmental levels regarding translation and core-identification of the patterns can be revisited to understand whether these two skills need to be reversed or not.
- In the related literature, a significant relationship was found between executive function components and patterning skills. Further experimental research can be done, including the executive function tasks as a pretest.

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APPENDICES

APPENDIX A: METU HUMAN SUBJECTS ETHICS COMMITTEE

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

DUMLUPINAR BULVARI 06800
ÇANKAYA ANKARA/TURKEY
T: +90 312 210 22 91
F: +90 312 210 79 59
ueam@metu.edu.tr
www.ueam.metu.edu.tr

Sayı: 28620816 / 42

22 OCAK 2019

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Dr.Öğretim Üyesi Volkan ŞAHİN

Danışmanlığını yaptığınız Nursel YILMAZ'ın **"Çocukların Soyut Etiketleme ile Matematiksel Örüntüleri Tanıması"** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülmüş ve **2018-EGT-2018** protokol numarası ile onaylanmıştır.

Saygılarımla bilgilerinize sunarım.

Prof. Dr. Tülin GENÇÖZ
Başkan

Prof. Dr. Ayhan SOL
Üye

Prof. Dr. Ayhan Gürbüz DEMİR
Üye

Prof.Dr. Yaşar KONDAKÇI (4.)
Üye

Doç. Dr. Emre SELÇUK
Üye

Doç. Dr. Pınar KAYGAN
Üye

Dr. Öğr. Üyesi Ali Emre TURGUT
Üye

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

DUMLUPINAR BULVARI 06800
ÇANKAYA ANKARA/TURKEY
T: +90 312 210 22 91
F: +90 312 210 79 59
ueam@metu.edu.tr

Sayı: 28620816 / 271

11 MAYIS 2018

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Dr. Öğretim Üyesi Volkan ŞAHİN

Danışmanlığını yaptığınız Nursel YILMAZ'ın **"Çocukların Soyut Etiketleme ile Matematiksel Örüntüleri Tanıması"** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2018-EGT-079** protokol numarası ile **11.05.2018 - 30.12.2019** tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Ş. Halil TURAN
Başkan V

Prof. Dr. Ayhan SOL
Üye

Prof. Dr. Ayhan Gürbüz DEMİR
Üye

Doç. Dr. Yaşar KONDAKÇI
Üye

Doç. Dr. Zana ÇITAK
Üye

Doç. Dr. Emre SELÇUK
Üye

Dr. Öğr. Üyesi Pınar KAYGAN
Üye

APPENDIX B: PERMISSION FROM MINISTRY OF NATIONAL EDUCATION

DS

T.C.
ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

Sayı : 14588481-605.99-E.16406481 — 14.09.2018
Konu : Araştırma İzni

ORTA DOĞU TEKNİK ÜNİVERSİTESİNE
(Rektörlük)

İlgi: a) MEB Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 2017/25 nolu Genelgesi.
b) 15/08/2018 Tarihli ve E.30 sayılı yazınız.

Üniversiteniz Temel Eğitim Anabilim Dalı Okul Öncesi Eğitimi yüksek lisans programı öğrencisi Nursel YILMAZ'ın yürüttüğü **"Çocukların Soyut Etiketleme Yöntemi ile Matematiksel Örüntüleri Tanıması"** konulu tez çalışması kapsamında uygulama talebi Müdürlüğümüzce uygun görülmüş ve uygulamanın yapılacağı İlçe Milli Eğitim Müdürlüğüne bilgi verilmiştir.

Görüşme formunun (3 sayfa) araştırmacı tarafından uygulama yapılacak sayıda çoğaltılması ve çalışmanın bitiminde bir örneğinin (cd ortamında) Müdürlüğümüz Strateji Geliştirme (1) Şubesine gönderilmesini rica ederim.

Turan AKPINAR
Vali a.
Milli Eğitim Müdürü

Güvenli Elektronik İmzalı
Aslı İle Aynıdır.
14../..9../2018

Adres: Emniyet Mah. Alparslan Türkeş Cad. 4/A
Yenimahalle/ANKARA
Elektronik Ağ: www.meb.gov.tr
e-posta: istatistik06@meb.gov.tr

Bilgi için: D. KARAGÜZEL
Tel: 0 (312) 221 02 17
Faks: 0 (312) 221 02 16

Bu evrak güvenli elektronik imza ile imzalanmıştır. https://evraksorgu.meb.gov.tr adresinden de5d-d49f-3522-8b5d-98b1 kodu ile teyit edilebilir.

APPENDIX C: CONSENT FORM

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
TEMEL EĞİTİM BÖLÜMÜ
ARAŞTIRMAYA GÖNÜLLÜ KATILIM FORMU

Sayın Katılımcı,

Bu çalışma Orta Doğu Teknik Üniversitesi Temel Eğitim Bölümü, Doktora öğrencisi Nursel YILMAZ tarafından, Orta Doğu Teknik Üniversitesi Eğitim Fakültesi Temel Eğitim Bölümü öğretim üyelerinden Yrd. Doç. Dr. Volkan ŞAHİN danışmanlığında ve University of Illinois at Urbana-Champaign'de görevli Prof. Dr. Arthur BAROODY yardımcı-danışmanlığında yürütülen "Soyut Etiketlemenin Çocukların Matematiksel Örüntüleri Tanımasına Etkisi" konulu Doktora tez araştırmasıdır.

Bu form sizi araştırma koşulları hakkında bilgilendirmek için hazırlanmıştır.

Çalışmanın temel amacı 48-60 aylık yaş grubunda olan çocukların matematiksel düşünme berilerine katkı sağlamaktır. Bu amaçla, çocukların örüntüleri öğrenmelerinde ve tanılamarında soyut etiketlemenin etkiliği saptanacaktır. Katılmasına izin verdiğiniz takdirde çocuğunuzla bire bir öğrenme etkinlikleri yapılacaktır. Bu çalışmanın pilot çalışması, ABD'nin University of Illinois at Urbana-Champaign'e bağlı Okul Öncesi Eğitim kurumunda da gerçekleştirilmiştir. Çalışmaya katılmak tamamen gönüllülük esasına dayalıdır. Her etkinliğin başında, çocuğunuzdan sözlü olarak onay alınacakatır. Herhangi bir yaptırıma maruz kalmadan çocuğunuz çalışmaya katılmayı reddedebilir veya çalışmayı bırakabilir. Araştırmaya katılanlardan toplanan veriler tamamen gizli tutulacak, veriler ve kimlik bilgileri herhangi bir şekilde eşleştirilmeyecektir. Katılımcıların isimleri bağımsız bir listede toplanacaktır. Ayrıca toplanan verilere sadece araştırmacılar ulaşabilecektir. Bu araştırmanın sonuçları bilimsel ve profesyonel yayınlarda veya eğitim amaçlı kullanılabilir, fakat katılımcıların kimliği gizli tutulacaktır. Ayrıca, bu çalışma ile ilgili herhangi bir risk öngörülmemektedir.

Bu çalışmayla ilgili daha fazla bilgi almak isterseniz: Araştırmayla ilgili sorularınızı aşağıdaki e-posta adresini kullanarak bize yöneltebilirsiniz.

Saygılarımızla,

Yrd. Doç. Dr. Volkan Şahin: vsahin@metu.edu.tr

Nursel Yılmaz: nyilmaz@metu.edu.tr

Bu formu imzalayarak araştırmaya gönüllü olarak katılmayı kabul ediyorum.

KATILIMCININ:		
İsim ve Soyadı	**Tarih**	**İmza**

İki nüsha olarak dağıtılacak formun bir kopyasını doldurup imzaladıktan sonra uygulayıcıya geri veriniz. Diğer kopyasını kayıtlarınız için saklayabilirsiniz.

APPENDIX D: PARENT APPROVAL FORM

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
TEMEL EĞİTİM BÖLÜMÜ
ARAŞTIRMAYA GÖNÜLLÜ KATILIM FORMU

Sayın Veli,

Bu çalışma Orta Doğu Teknik Üniversitesi Temel Eğitim Bölümü, Doktora öğrencisi Nursel YILMAZ tarafından, Orta Doğu Teknik Üniversitesi Eğitim Fakültesi Temel Eğitim Bölümü öğretim üyelerinden Yrd. Doç. Dr. Volkan ŞAHİN danışmanlığında ve University of Illinois at Urbana-Champaign'de görevli Prof. Dr. Arthur BAROODY yardımcı-danışmanlığında yürütülen "**Soyut Etiketlemenin Çocukların Matematiksel Örüntüleri Tanımasına Etkisi**" konulu Doktora tez araştırmasıdır.

Bu çalışmanın amacı nedir?

Araştırmanın amacı, çocukların matematiksel düşünme berilerine katkı sağlamaktır. Bu amaçla, çocukların örüntüleri öğrenmelerinde ve tanılamarında soyut etiketlemenin etkiliği saptanacaktır.

Çocuğunuzun katılımcı olarak ne yapmasını istiyoruz?

Bu çalışma kapsamında çocuğunuza örüntü konusu ile ilgili 12 oturumdan oluşan birebir eğitim verilecektir. Bu eğitimler yaklaşık 10-15 dk sürecektir. Eğitim öncesi ve sonrasında değerlendirme yapılacaktır. Yapılan eğitimler ve değerlendirme esnasında çocuğunuzun yüzü görünmeyecek şekilde video kaydı yapılacaktır.

Çocuğunuzdan alınan bilgiler ne amaçla ve nasıl kullanılacak?

Çocuğunuzla olan görüşmeler kesinlikle gizli tutulacak ve sadece bilimsel araştırma amacıyla kullanılacaktır. Çocuğunuzun ya da sizin isminiz ve kimlik bilgileriniz, hiçbir şekilde kimseyle paylaşılmayacaktır. Araştırma sonuçlarının özeti tarafımdan okula ulaştırılacaktır.

Araştırmanın herhangi bir riski var mıdır?
Bu araştırma kapsamında öngörülen bir risk bulunmamaktadır. Araştırmanın pilot çalışması, ABD'nin University of Illinois at Urbana-Champaign'e bağlı Okul Öncesi Eğitim kurumunda gerçekleştirilmiştir. Katılım tamamen gönüllüdür. Katılım sırasında veya sonrasında araştırmaya dâhil olmaktan istendiği an vazgeçilebilir.

Bu çalışmayla ilgili daha fazla bilgi almak isterseniz: Araştırmayla ilgili sorularınızı aşağıdaki e-posta adresini kullanarak bize yöneltebilirsiniz.

Saygılarımızla,

Yrd. Doç. Dr. Volkan Şahin: vsahin@metu.edu.tr

Nursel Yılmaz: nyilmaz@metu.edu.tr

Bu formu imzalayarak çocuğumun araştırmaya katılmasını kabul ediyorum.

KATILIMCININ:		
İsim ve Soyadı	**Tarih**	**İmza**

İki nüsha olarak dağıtılacak formun bir kopyasını doldurup imzaladıktan sonra uygulayıcıya geri veriniz. Diğer kopyasını kayıtlarınız için saklayabilirsiniz.

1

APPENDIX E: CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: YILMAZ, Nursel
Nationality: Turkish (TC)
Date and Place of Birth: 17 March 1984, Adana
Marital Status: Single
Phone: +90 312 210 7503
Fax: +90 312 210 79 84
email: ny.nurselyilmaz@gmail.com

EDUCATION

Degree	Institution	Year of Graduation
MS	METU Early Childhood Education	2013
Erasmus Student	Ruhr Universitat –Bochum (RUB) Education Sciences	2012
BS	Cukurova University Computer Education and Instructional Technology	2006
High School	Incirlik (EI) High School, Ankara	2002

WORK EXPERIENCE

Year	Place	Enrollment
2009- 2019	METU Department of Early Childhood Education	Teaching and Research Assistant
2017-2018	University of Illinois at Urbana-Champaign, (UIUC), USA	Research Assistant
2011-2012	International School of Bochum, Germany	Assistant Early Childhood Teacher
2006-2008	Kasım Ekenler Elementary School	Instructional Technologies Teacher

PUBLICATIONS

Journal Papers

1- Yılmaz, N., Alıcı, Ş. (2011). Investigating Pre-Service Early Childhood Teachers' Attitudes towards the Computer Based Education in Science Activities. The Turkish Online Journal of Educational Technology (SSCI), 10(3), 161-167.

Presentations

1- Yilmaz, N., Baroody, A.J., Clements, D., Sarama, J., Şahin, V. (2020). Does a Learning Trajectory Facilitate Learning to Recognize the Core Unit of a Repeating Pattern? Paper to be presented at the American Educational Research Association (AERA), San Francisco, USA.

2- Yilmaz, N., Baroody, A.J., Clements, D., Sarama, J. (2020). An Empirical Study to Investigate the Relative Difficulty of Repeating Pattern Structures for Preschoolers. Paper to be presented at the American Educational Research Association (AERA), San Francisco, USA.

3- Yilmaz, A., Yilmaz, N. (2019). Research-Based Parent-Involved Principles for Designing Educational Robotics in Early Childhood Education: A Preliminary Study. Paper was presented at the European Educational Research Association (EERA), ERC/ECER, Hamburg, Germany and published in proceedings.

4- Yilmaz, N., Olgan, R. (2019). Exploring Prospective Early Childhood Teachers' Innovativeness to Facilitate the Change in Education System. Paper was presented at the European Educational Research Association (EERA), ERC/ECER, Hamburg, Germany and published in proceedings.

5- Yilmaz, N. (2019). Mentoring Matters: An Interdisciplinary Mentoring Approach in Higher Education. Paper was presented at the American Educational Research Association (AERA), Toronto, Canada and published in proceedings.

6- Baroody, A.J., Yilmaz, N., Clements, D., Sarama, J. (2019). Does a Learning Trajectory Facilitate Early Patterning Intervention? Paper was presented at the American Educational Research Association (AERA), Toronto, Canada and published in proceedings.

7- Tepgeç, M., Yilmaz, N., Ateş, C., Kestel, S., Tüzün, H. (2017). Use of Digital Games in Mathematics Teaching: A Descriptive Study. Paper was presented at the 11th International Computer & Instructional Technologies Symposium (ICITS), Malatya, Turkey and published in symposium proceedings.

8- Tanış, H., Akçay, A., Yilmaz, N., Yiğit, M. F., Tüzün, H. (2017). A Study on the Usability of a MOOC's Course on Coursera Through the Methods of Eye Tracking. Paper was presented at the 5th International Instructional Technologies & Teacher Education Symposium (ITTES) Izmir, Turkey and published in symposium proceedings.

9- Yilmaz, N. (2016). Technology Use in Early Childhood Education: Investigating Young Children's Mathematical Thinking Skills and Early Childhood Teachers' Instructional Practices by Using Developmentally Appropriate Computer Applications/Mobile Applications. Paper was presented at European Educational Research Association (EERA) Summer School.

10- Yilmaz, N. (2015). Computer Based Mathematics Instruction in Early Childhood Education: A Literature Review of the Recent Empirical Studies. Paper presented at the 4th International Conference on Preschool Education, Ankara, Turkey and published in conference proceedings.

11- Yilmaz, N. & Olgan, R. (2015). The Perceived Attributes of Computer Use (PACU) For Instructional Purposes: An Adaptation Study of the Scale for Preservice Early Childhood Teachers. Paper presented at the 4th International Conference on Preschool Education, Ankara, Turkey and the abstract published in conference proceedings.

12- Yilmaz, N. (2014). Examining the Innovativeness of the Prospective Early Childhood Teachers and the Effect of the Internet Access on their Innovativeness. Paper was presented at the International Conference on Education in Mathematics, Science and Technology (ICEMST) Konya, Turkey and the abstract published in conference proceedings.

13- Yilmaz, N., Alıcı, Ş. (2011). Investigating Pre-Service Early Childhood Teachers' Attitudes towards the Computer Based Education in Science Activities. Paper was presented at the International Educational Technology Conference (IETC), Istanbul, Turkey and published in conference proceedings.

14- Yilmaz, N. (2011). Perceptions of Pre-Service Early Childhood Teachers towards the Using Educational Computer Games. Paper was presented at the International Computer & Instructional Technologies Symposium (ICITS), Elazığ, Turkey and published in symposium proceedings.

<u>Honors and Awards</u>

1- American Educational Research Association (AERA) International Scholars Travel Award, 2019

2- The Scientific and Technological Research Council of Turkey 2214-A Doctoral Research Grant, 2017

3- Semi-finalists at the YFYI'15 Entrepreneurship program launched by METU and METU-Technopolis

4- Middle East Technical University "Thesis of the Year" Graduate Awards, 2014 (For Master Thesis)

5- Lifelong Learning Program (LLP) Erasmus, funded by the European Union (EU), 2012

6- Incentive Program for International Scientific Publications (UBYT) award, initiated by the Scientific and Technological Research Council of Turkey (TUBITAK), 2011

7- International Publication Award, initiated by Middle East Technical University (METU), 2011

8- Cukurova University, undergraduate student achievement (Ranked 2nd student, graduated with high honor).

Professional Service and Competences

1- Reviewer at the Society for Information Technology and Teacher Education (SITE), 2019

2- Reviewer at the American Educational Research Association (AERA), 2014/2016/2017/2018/2019

3- Jury Member at the 4th Eureka Science Projects Contest, METU Development Foundation Schools (METU DF Schools), 2014

4- Reviewer at the Educational Research and Reviews (ERR), 2013

Other Service and Outreach

Volunteer, Envision- STEM Outreach Group, University of Illinois at Urbana-Champaign (UIUC), 2017-2018

Participant, GLOBE- Global Leaders: Orange and Blue Engagement program, UIUC, 2017-2018

Member, GLOBE- Global Leaders: Orange and Blue Engagement program, UIUC, 2017-2018

Mentor, Faculty Technology Mentoring Program, Middle East Technical University (METU), 2015

Professional Affiliations and Memberships

American Educational Research Association (AERA)

Undergraduate Courses Assisted

- Community Service
- Probability and Statistics
- Methods of Teaching in Early Childhood Education
- Instructional Principles and Methods
- School Experience
- Practice Teaching I
- Practice Teaching II
- Introduction to Early Childhood Education
- Mental Health and Adaptation Disabilities
- Maternal and Child Health in Early Childhood Education

Graduate Courses Assisted

- Advance Educational Research

Services Assisted

- The Unit of Strategy Development and Planning in the Department of Early Childhood Education, Middle East Technical University (METU)

FOREIGN LANGUAGES

Advanced English, Basic German

HOBBIES

Travelling, Movies, Yoga, Nature, Dancing

APPENDIX F: TURKISH SUMMARY/TÜRKÇE ÖZET

Giriş ve Alan Yazını

Okul öncesi eğitimde matematik eğitimi önemli bir yere sahip olduğu ifade edilmektedir ve hatta matematik dünyayı anlama, görme ve organize etme olarak tanımlanmaktadır (Van de Walle, Karp, Bay-Williams ve McGarvey, 2018; Zevenbergen, Dole, ve Wright, 2004). Dünyaca çapında öncülük yapan Küçük Çocukların Eğitimi Ulusal Birliği [The National Association for the Education of Young Children] NAEYC, 2002; 2012) ve Matematik Öğretmenleri Ulusal Konseyi [National Council for Teachers of Mathematics] NCTM, 2002) gibi eğitim komite ve kuruluşları da okul öncesi dönemde matematik eğitimin önemini vurgulamakta ve küçük çocukların nitelikli erken matematik eğitimi ile buluşturulması gerektiğine inanmaktadırlar. Bu nedenle, çocukların ilgi, ihtiyaç, merak ve günlük deneyimlerinden yola çıkarak oluşturulan matematik etkinliklerinin geliştirilmesi büyük önem taşımaktadır. Örneğin, matematiksel açıdan yetenekli çocuklar, farklılaştırılmış etkinliklerle desteklenip geliştirilirken, öğrenme zorluğu olan çocuklar ise küçük grup etkinlikleri tasarlanarak yönlendirilebilirler (Kroeger, Brown, ve O'Brien, 2012). Ayrıca, yapılan bazı araştırmalar, oyunun çocukların matematik öğrenmesi üzerinde büyük bir etkisi olduğunu göstermektedir (öreğin; Davies, 2002; Ginsburg ve Golbeck, 2004). Buna ek olarak, teknolojik araçların okul öncesi eğitimde etkili kullanılmasına yönelik öneriler ve araştırmalar da yaygınlaşmaktadır. Örneğin, bazı araştırmacılar, bilgisayar ve diğer teknolojik araçların küçük çocukların beden sağlığına (Cordes ve Miller, 2000) ve uygun olmayan içerikler nedeniyle (Funk, 2001; Wartella ve Jennings, 2000) zararlı olabileceğini düşünürken bazıları da bu tür zararların sadece küçük çocuklar için değil diğer kullanıcılar için de geçerli olabileceğini söylemektedirler (Thompson ve Haninger, 2001). Bu nedenle, kısıtlı ekran zamanları ayarlanarak (Elkind, 2007) ve uygun ebeveyn gözetimi (Healey ve Mendelsohn, 2019; Plowman ve Stephen, 2003) ile küçük çocukların eğitimi için de bilgisayar teknolojilerinden faydalanılabileceği önerilmektedir. Hatta, blgisayar teknolojilerinin etkili ve uygun kullanıldığı takdirde, çocukların öğrenmelerini desteklediğini gösteren çalışmalar yapılmıştır (Ayvacı ve Devecioğlu, 2010; Çankaya, 2012; Demir ve Kabadayı, 2008; Judge, 2005; Kaçar ve Doğan, 2010; Kol, 2012; Clements ve Nastasi, 1993; Haugland ve Wright, 1997; McCarrick ve Li, 2007; McKenney ve Voogt, 2009; Ortega-Tudela ve Gomez-Ariza, 2006; Räsänen, Salminen, Wilson, Aunio, ve Dehaene, 2009; Vernadakis, Avgerinos, Tsitskari, ve Zachopoulou, 2005). Bu sebeple, okul öncesi öğretmenlerin dijtal araçları da kapsayan oldukça çeşitli materyallerden faydalanması gerektiği vurgulanmaktadır (NAEYC, 1996; 2012).

Okul öncesi matematik eğitimde önemli bir yere sahip olan matematiksel örüntüler, çocukların matematiksel düşünme ve becerilerini geliştirmekte ve ilerde matematik öğrenimine yardımcı olmaktadır (Clements ve Sarama, 2009; Fyfe vd., 2015; NCTM, 2010; Rittle-Johnson vd., 2015; Rittle-Johnson vd., 2017). Dahası, örüntüler bir matematik konusundan çok, matematisel düşünme alışkanlığı olarak görülmektedir (Clements ve Sarama, 2009).

Yaygın olarak bilinen üç çeşit örüntü türü bulunmaktadır. Bunlar, tekrarlayan örüntüler (repeating pattern), büyüyün örüntüler (growing pattern), ve uzamsal örüntülerdir (spatial pattern) (Lüken, 2018; Papic ve Mulligan, 2007). Bu çalışmada tekrarlayan örüntüler kullanılacaktır. Tekrarlayan örüntüler, daha küçük bir bölümünün sürekli tekrarlanması ile üretilebilen ve döngüsel bir yapıya sahip olan örüntülerdir (Liljedahl, 2004, s.27). Örneğin, kırmızı-mavi, kırmızı-mavi, kırmızı-mavi veya üçgen-kare, üçgen-kare üçgen-kare gibi modeller basit tekrarlayan örüntülerdür ve bu yapıdaki tekrarlayan örüntüler ABABAB örüntüsü olarak da bilinmektedir (Papic ve Mulligan, 2007). Örüntü öğrenmesinde ve öğretilmesinde en temel ve yaygın olan bazı beceriler vardır. Bunlar, örüntülerin tanınması, aynı yapıda kopyalanması, örüntülerin devam ettirilmesi ve örüntülerin genellenmesidir (NCTM, 2010).

Bu çalışma, okul öncesi 4-5 yaş çocuklarının tekrarlayan örüntüleri öğrenmesinde "Varsayımsal Öğrenme Rotalarının" (Hypothetical Learning Trajectories), etkililiğini ve küçük çocukların örüntü becerilerini nasıl gerçekleştiği araştıracaktır. Bu amaçla, Clements ve Sarama (2009) tarafında geliştirilen ve beş araştırma döngüsü ile revize edilen Varsayımsal Öğrenme Rotaları (öntest sontest kontrol grup seçkisiz deneysel çalışma ile incelenecektir. Ayrıca, göz izleme teknolojisinin yardımı ile çocukların örüntülere ilişkin becerileri nasıl yaptığına dair bilgiler elde edilecektir.

Öğrenme Rotaları

Son zamanlarda benimsenin görüşe göre yapılandırmacı öğrenme yaklaşımı, matematik eğitiminde yapılan bilimsel ve teorik çalışmaların temel yapısını oluşturmaktadır (Steffe ve Gale, 1995). Yapılandırmacı öğrenme yaklaşımı, öğrenme ve öğrenci kavramlarını yeniden tanımlarken, matematik öğretimi için açık ve spesifik bir model sunamamaktadır. Bu nedenle Simon (1995), yine yapılandırmacı yaklaşımı esas alan Varsayımsal Öğrenme Rotalarını (Hypothetical Learning Trajectories) önermiştir. Öğrenme rotaları, üç kısımdan oluşmaktadır. Bunlar, öğrenme hedefi (learning goal), öğrenme etkinlikleri (learning activities), ve öğrenme seviyeleridir (thinking and learning in which the students might engage) (Simon, 1995 s.133). Matematiksel becerilerin öğretilmesinde "Varsayımsal Öğrenme Rotaları" önemli ve yararlı bir araç olarak görülmektedir. Öğrenme Rotaları, çocukların düşünme ve öğrenme şekillerinin bilimsel olarak gözlemlenmesi ve incelenmesi sonucu oluşturulan araçlardır (Clements ve Sarama, 2009; Simon, 1995). Bu çalışmada, Clements ve Sarama tarafından geliştirilen Varsayımsal Öğrenme Rotaları kullanılacaktır.

Göz İzleme Metodolojisi

İnsanın bilişini anlamanın yeni bir aracı olan göz izleme metodolojisi, bireylerin bir ekrana, basılı bir metne veya etrafındaki fiziksel bir ortama baktıklarında göz hareketlerini kaydetmeye yardımcı olur (Holmqvist, Nyström, Andersson, Dewhurst, Jarodzka ve Van de Weijer, 2011). Bu nedenle göz izleme araçları, katılımcıların deneyimleri hakkında araştırmacıların ilgili verileri yorumlamalarına olanak sağlayan benzersiz bilgiler verir (Duchowski, 2007). Nitekim, araştırmacılar bilişsel süreci anlamak için göz izleme metodolojisini kullanarak bazı çalışmalar yapmaya başlamışlardır (Land, 2007; Reingold, 2014).

Göz hareketleri, insanın davranışlarını anlamada çok önemlidir; çünkü gözler, etraftaki bilginin toplanmasına yardımcı olur ve buna uygun olarak zihnin tepki vermesini sağlar (Just ve Carpenter, 1980; Tatler, Kirtley, Macdonald, Mitchell, ve Savage, 2014; Wade ve Tatler, 2011). Başka bir deyişle, göz hareketlerini izleyebilirsek dikkat, konsantrasyon, bilinç, ilgi ve algı ile ilgili ipuçlarını anlayabiliriz. Yani, katılımcılar ekrana bakarken araştırmacılar da göz izleme verileri ile, kişilerin yeni bilgileri edinme konusundaki görsel dikkatlerine ve gördükleri yerle ilgili algılarına yönelik çıkarımlarda bulunabilmektedir (Duchowski, 2006; 2017; Horsley, 2014; Wade ve Tatler, 2011). Bu nedenle, göz hareketleri, insanın biliş ve davranışını yorumlamak için benzersiz ve nesnel veriler sağlayabilmektedir. Göz izleme verileri niteliksel ve niceliksel olarak analiz edilebilir (Lai vd., 2013). Bu amaçla bazı metriklerden faydalanılmaktadır. Örneğin, ısı haritaları (heat maps) ve bakış grafiği (gaze plot) nitel veriler alınmasını sağlarken, odaklanma sayısı (fixation count), toplam odaklanma süresi (total fixation duration), ilk odaklanmaya kadar geçen süre (time to first fixation), gözlem süresi (visit duration), ve gözlem sayısı (visit count) gibi metrikler de nicel veriler elde edilmesini sağlamaktadır (Lai vd., 2013).

Erken Örüntü Eğitimi ile ilgili çalışmalar

Rittle-Johnson, Fyfe, McLean ve McEldoon (2013), dört yaşındaki çocukların tekrarlayan örüntülerle ilgili deneyimlerini incelemek için bir çalışma yapmıştır. Bu amaçla, çalışmaya 66 çocuk dahil edilmiş ve örüntüdeki zorluk incelenmiştir. Çocuklar önce bir ön teste tabi tutulmuş, sonra biraz yardım sağlayan kısa bir eğitim uygulanmış ve daha sonra ise bir son test uygulanmıştır. Ayrıca, çocukların yapmış olduğu hatalar incelenmiş ve çocukların tekrarlayan örüntüler hakkındaki bilgilerini daha iyi anlamak için sözel veriler kullanılmıştır. AAB, ABB ve AABB örüntüleri ile kopyalama, devam ettirme, soyutlama ve birim tanımlama becerileri dahil olmak üzere toplam 10 değerlendirme sorusu kullanılmıştır. Çalışma, çocuklara bireysel olarak sakin bir odada uygulanmıştır. Çocukların cevapları doğru, kısmen doğru, yanlış ve ilgili olmayan cevaplar olarak kodlanmıştır. Elde edilen veriler t-test kullanılarak analiz edilmiştir. Araştırmanın sonuçları, çocukların örüntüleri kopyalama ve devam ettirme becerilerini gösterebildiklerini ve bazılarının ise soyutlama becerisini yapabildiğini göstermiştir. Öte yandan, çok az sayıda çocuk, örüntülerin çekirdek biriminin tanımlanmasında başarılı olduğu bulunmuştur. Ayrıca, doğruluk sonuçları, örüntülerin çekirdek birimlerinin üç element veya dört element olduğuna bağlı olmaksızın benzer zorluklar içerdiğini göstermiştir. Bununla birlikte, çocukların yaptıkları hatalar ayrıntılı olarak incelendiğinde, üç elemanlı çekirdek birimi olan bir örüntüyü devam ettirme becerisinin, dört elemanlı üç elemanlı çekirdek birimi olan bir örüntüye kıyasla daha fazla çocuk tarafından yapıldığı ortaya çıkmıştır.

Fyfe, McNeil ve Rittle-Johnson (2015) soyut etiketlemenin (yani harf ile etiketlemenin) ilişkisel düşünme üzerindeki etkisini araştırmıştır. Bu amaçla, yaşları 3,6 ile 4,9 arasında değişen 62 küçük çocukla çalıştılar. Çocuklar rastgele deney grubuna (yani soyut durum) ve kontrol grubuna (yani somut durum) atandılar. Çocuklara ilk önce örüntü soyutlama ile ilgili bir ön teste uygulandı. Bu oturumda, sekiz farklı örüntü türü (örneğin, AB türünde iki örüntü, AAB türünde iki örüntü, ABB türünde iki örüntü, AABB türünde bir örüntü ve ABC türünde bir örüntü) soruldu. Çalışma sessiz bir odada tek oturum olarak uygulandı ve çocuklar bireysel olarak uygulamaya alındı. Sonrasında, açıklama ve bilgilendirme içeren kısa bir oturum için, çocuklara üç örnek örüntü (AB türünde bir örüntü, AAB türünde bir örüntü, ve ABB türünde bir örüntü) açıklandı ve her gruba aynı prosedür uygulandı fakat etiketleme durumu açısından farklıydı. Örneğin, deney grubuna açıklama yapılırken örüntüler soyut etiketleme kullanılarak tanımlandı, öte taraftan kontrol grubuna örüntülerin fiziksel özellikleri ile açıklama yapıldı., bu örüntüleri farklı materyaller ile tekrar yapmaları soruldu. Çocukların cevapları ANCOVA kullanılarak analiz edildi. Çalışmanın sonuçları, soyut etiketleme grubundaki çocukların kontrol grubundaki çocuklardan daha fazla soru çözdüğünü ve anlamlı bir performans gösterdiğini göstermiştir [$F(1, 58) = 14.67$, $p < .001$]. Ayrıca sonuçlar, daha büyük çocukların daha küçük çocuklardan daha iyi yapabileceğini gösteren bir yaş etkisi de ortaya koymuştur [$F(1, 58) = 5.08$, $p = .03$].

Başka bir araştırmada, Rittle-Johnson, Fyfe, Loehr ve Miller (2015), okul öncesi dönem çocuklarının örüntü deneyimlerinde, ailelerin ve öğretmenlerin düşüncelerini de anlamak için üç araştırma çalışması yapmıştır. Diğer bir deyişle, daha önce 66 küçük çocuğun tekrarlayan örüntü bilgisi araştırılmış ve çocuklar arasında bireysel farklılıklar bulunmuştur. Daha sonra, takip çalışması olarak, yaşları 4.7 ile 5.9 arasında değişen 64 çocukla çalışmışlardır. Toplamda 10 örüntü problemi hazırlanmış ve bunlardan bir tanesi AABB örüntü türünde kopyalama sorusu, bir tanesi ABB örüntü türünde devam ettirme sorusu, bir tanesi AABB örüntü türünde devam ettirme sorusu, bir tanesi ABB örüntü türünde soyutlama sorusu, iki tanesi AABB örüntü türünde soyutlama sorusu, ve iki tanesi AAB örüntü türünde çekirdek birimi tanımlama becerisidir. Ayrıca ABB örüntü türü için bir hafıza testi kullandılar. Uygulama, sessiz bir odada, her çocuk için ayrı ayrı uygulandı. Araştırmacı ilgili görevleri sundu ve çocukların cevaplarını kaydetti. Elde edilen sonuçlara göre, ilkbahardan güz dönemlerine kadar çocuklar örüntü becerilerinde gelişme göstermişlerdir. Ayrıca, çekirdek birim tanımlaması, örüntü soyutlama becerisinden daha zor bulundu, ancak bunun nedeninin çocuklara okul öncesi öğretmenleri tarafından daha az çekirdek birim tanımlama aktivitesi verildiğinden olabileceği açıklandı. Genel olarak, elde edilen bulguların, araştırmacıların sundukları 4 seviyeli (yani Seviye 1, çoğaltma; Seviye 2, devam ettirme, Seviye 3, soyutlama; Seviye 4, çekirdek birim tanıma) kavram haritasını desteklediği bulunmuştur. İkinci çalışmada ise, çocukların aileleri dahil edildi ve ailelerin çocukları ile yaptığı matematik etkinlikleriyle ilgili anket çalışması yapıldı. Anket, basılı ve online olarak tasarlandı ve geri dönüş oranı (%31) düşük olmasına rağmen farklı grupları temsil ettiği belirtildi. Ayrıca öğretmenlerin sınıfta düzenledikleri örüntü etkinlikleri hakkında da bir anket uygulaması yapıldı. Toplanan veriler tanımlayıcı istatistikler kullanılarak analiz edildi. Sonuçlara göre, çocukların örüntü etkinliklerini deneyimlemeleri için hem ailelerin hem de öğretmenlerin çocuklarını sık sık desteklediği görülmüştür. Örneğin, kopyalama, devam ettirme, örüntüleri tanımlama ve örüntü oluşturma ile ilgili bazı etkinliklerin evde yapıldığı gözlemlenmiştir. Bu etkinliklere ek olarak, öğretmenler sınıfta örüntü soyutlama etkinliklerini kullandıklarını belirtmiştir. Ancak, ne aileler ne de öğretmenler tarafından örüntü birimi tanımlama etkinlikleri bildirilmemiştir. Son olarak, üçüncü çalışmada, açıklamada kaynağı ve türünün farklılıkları incelenmiştir. Bu amaçla, 3 tür grup oluşturulmuştur, bunlar: Kendi kendine açıklama grubu (self-explanation group), öğretimle açıklama grubu (instruction group) ve kombinasyon açıklama grubu (combination of both groups) olarak üç grup oluşturdular. Çalışmaya 123 çocuk katılmış ve seçkisiz olarak üç deney grubuna atanmıştır. Ön test, kopyalama, devam ettirme ve soyutlama gibi üç örüntü becerisini içerirken, son test ise kopyalama, devam ettirme, soyutlama ve birim tanımlama gibi dört örüntü görevini içermektedir. Çalışmanın sonunda, yapılan açıklama türlerinin bir fark yaratmadığı ve her türün çocuklara örüntüler hakkında bilgi edinmesine yardımcı olduğu bulunmuştur.

Araştırmalarında, Tsamir, Tirosh, Barkai ve Levenson (2018), ABA türündeki tekrar eden örüntülerin ve diğer yapıdaki örüntüler ile karşılaştırılmasına odaklanmıştır. Çalışmanın katılımcıları dört ve yedi yaşları arasında 11 çocuktur. Çalışma, çocukların ABA türündeki örüntülerin ve diğer örüntü türleriyle ilişkisini araştıran doğal bir yaklaşım olarak tasarlanmıştır. Bu amaçla, çocuklara tablet bilgisayardaki örüntü etkinlikleri sunulmuş ve çocuklar, tablet uygulamasındaki oyunlarla etkileşimi sırasında gözlenmiştir. Bu uygulamada, her ekranda iki farklı örüntü görevi verilmiş ve yalnızca örüntünün en baştaki çekirdek birimi görüntülenmiş ve dikkat çekici şekilde belirtilmiştir. Ayrıca, örüntüdeki eksik elemanlar, örüntünün farklı yerlerinde yerleştirilmiş ve ekranın aşağısında farklı seçeneklerde nesneler sunulmuştur. Sadece doğru cevaplar için, çocuklara geri bildirim (örneğin, harika) verilmiş, ancak geri bildirim veya ipucu olmadan doğru olanı bulana kadar tekrar denemelerine izin verilmiştir. Uygulamalar, çocuğun evinde kullanılmış ve oturumlar videoya kaydedilmiştir. Veriler, çocukların parmak hareketleri, çocuk-yetişkin etkileşimleri ve örüntüleri tamamlamada çocukların tepkileri dikkate alınarak analiz edilmiştir. Elde edilen sonuçlara göre, çocukların çoğu AB modelini (%92), ABB modelini (%84) ve ABC modelini (%83) doğru şekilde yapmıştır. Ancak bunların yarısından azı ABA modelini (%46) doğru bir şekilde yapmıştır. Örüntülerin yapısı arasında önemli bir fark olup olmadığını görmek için istatistiksel bir test yapılmamıştır. Ancak, ABA yapısındaki örüntünün AB, ABB ve ABC türündeki örüntülere kıyasla en zor örüntü türü olduğu belirtilmiştir.

Ayrıca, örüntü ve matematiksel başarıyı araştırmak için bazı boylamsal çalışmalar bulunmaktadır. Örneğin, Rittle-Johnson, Hofer, Fyfe ve Farren (2015), çocuklar 7 yaşında iken ve sonrasında 11 yaşında iken bir çalışma yapmışlardır. Öncelikli olarak, çocuklar yedi yaşlarındayken onların örüntü bilgisi değerlendirilmiş ve ardından çocuklar onbir yaşındayken bir matematik testi (ör. cebir, aritmetik, geometri) uygulanmıştır. Kullanılan matematik testi ve örüntü soruları, Clements, Sarama ve Liu (2008) tarafından geliştirilen Araştırmaya Dayalı Erken Matematik Başarısı

(Research-based Early Math Achievement, REMA) testinden adapte edilmiştir. Sonuçlar örüntü becerisi puanları ile matematik başarı testleri arasında anlamlı bir ilişki olmadığını göstermiştir. Ancak, benzer bir boylamsal çalışma, Fyfe, Rittle-Johnson, Hofer ve Farren (2015) tarafından yapılmış ve çocukların beşinci sınıftayken ölçülen örüntü becerileri ile matematiksel kazanımları (örneğin geometri) arasında anlamlı bir ilişki olduğu bulunmuştur.

Benzer şekilde, Fyfe, Evans, Matz, Hunt ve Alibali (2017) örüntü becerilerini ve matematik başarısını incelemek için bir çalışma yürütmüştür. Araştırmaya yaşları 5-13 arasında değişen 36 çocuk katılmıştır. Bu amaçla, çalışan bellek, örüntü devam ettirme ve aritmetik, ters çevirme ve denklik problemleri gibi matematik görevleri gibi beş test kullanılmıştır. Kullanılan materyallerin renkli çıktısı alınıp lamine edildi. Oturumlar, sessiz bir odada çocuklara ayrı ayrı uygulandı. Çalışmanın sonuçları, daha büyük çocuklar daha iyi olmasına rağmen, çocukların örüntü devam ettirme görevlerini (% 90) başarabildiğini ortaya koymuştur. Sonuçlar ayrıca, yaş ve sözel çalışan bellek gibi değişkenlerinin kontrol edilmesinden sonra, örüntü devam ettirme becerisi ve hesaplama becerisi arasında anlamlı bir ilişki bulunduğunu göstermiştir. Ayrıca, sözel çalışan bellek kapasitesinin örüntü başarısını öngördüğü bulunmuştur.

Matematik başarısı ile ilgili olarak ise, Rittle-Johnson, Fyfe, Hofer ve Farran (2017), 517 düşük gelirli çocuğu içeren boylamsal bir çalışma yürütmüşlerdir. Dört çeşit test, Woodcock Johnson Achievement Battery III ve KeyMath 3 Diagnostic Assessment gibi standart ölçme araçlarından uyarlanarak kullanılmıştır. Önce çocuklar dört yaşlarında iken bir ön teste tabi tutulmuştur ve sonrasında da çocuklar onbir yaşlarında iken tekrar test edilmiştir. Toplanan veriler tanımlayıcı istatistikler ve regresyon testleri kullanılarak analiz edilmiştir. Çalışmanın sonuçları, erken örüntü becerisinin daha sonraki yıllarda matematik başarısını öngördüğünü göstermiştir.

Diğer araştırmaların yanı sıra, bazı araştırmacılar daha yoğun öğretim oturumları kullanmıştır. Örneğin, Papic, Mulligan ve Mitchelmore (2011), okul öncesi dönemdeki yaşları 41 ile 60 ay arasında değişen 41 çocukla deneysel bir çalışma yapmıştır. Bu amaçla, tekrarlayan ve uzamsal örüntüler ile ilgili 14 eğitim oturumundan oluşan altı aylık bir eğitim uygulamışlardır. Her oturum, yaklaşık 18-30 dakika sürmüştür. Ön test, son test ve gecikmeli son test dahil olmak üzere üç değerlendirme oturumlarında Erken Matematiksel Örüntü Değerlendirmesi (Early Mathematical Patterning Assessment, EMPA) kullanılmıştır. Çalışmanın sonuçlarına göre, deney grubunun hem son testte hem de gecikmeli son testte örüntü becerilerini yerine getirmede, karşılaştırma grubundan daha yüksek performans gösterdiği bulunmuştur. Ayrıca, tekrarlanan örüntünün çekirdek birimini ve uzamsal örüntülerin yapısını tanımakta da daha başarılı olduğu görülmüştür. Araştırmacılar ayrıca, örüntü çekirdek birimini tanımlamanın örüntü yapısını tanımada önemli bir etkisi olduğunu bulmuşlardır. Ancak bu çalışmanın bir zayıflığı bulunmaktadır, o da deney grubunun bir okuldan ve kontrol grubunun ise başka bir okuldan seçilmesidir.

Papic ve Mulligan (2007), küçük çocukların üç örüntü türü olan tekrarlayan örüntüler, uzamsal örüntüler ve büyüyen örüntüleri içeren örüntü becerilerini incelemek için bir çalışma yürütmüştür. Bu çalışma bir deneysel çalışma olarak tasarlanmış ve veriler karma yöntem yaklaşımı kullanılarak toplanmıştır. Araştırmacılar, sınıf öğretmenlerinin verdiği eğitimi gözlemlemiş ve çalışmanın sonunda öğretmenlere anket uygulanmıştır. Ayrıca, örüntü oluşturulurken çocukların açıklamalarına ilişkin veriler kaydedilmiş ve bireysel çalışma portföylerinde çocukların çalışma örnekleri toplanmıştır. Çalışmanın sonuçları, çocukların karmaşık örüntüleri öğrenebileceklerini göstermiştir. Kontrol grubu ile karşılaştırıldığında deney grubundaki çocukların, örüntü birimini tanıma, örüntüyü farklı materyallerle oluşturma ve karmaşık örüntü problemlerini çözme gibi becerileri sergiledikleri ortaya çıkmıştır.

Hendricks, Trueblood ve Pasnak (2006) birinci sınıf çocuklarla seçkisiz atanan deneysel bir çalışma yürütmüşlerdir. Deney grubuna basitten karmaşığa kadar çeşitli örüntüler öğretilirken, kontrol grubuna aynı zaman ve sürede diğer akademik materyaller tarafından eğitim verilmiştir. Çalışmanın sonunda deney grubunun örüntüleri tanımlama ve yorumlama açısından anlamlı şekilde daha iyi performans gösterdiği bulunmuştur.

Son zamanlarda, bazı araştırmacılar yürütücü işlevler (executive functions) ve örüntü becerileri ile ilgili çalışmalara yönelmiştir. Örneğin, Schmerold (2015) tezinde birinci sınıf çocukların örüntü becerileri ile bilişsel esneklik (cognitive flexibility), dürtüyü kontrol etme (inhibition) ve çalışan bellek (working memory) gibi yürütücü işlev bileşenleri arasındaki ilişkiyi araştırmıştır. Araştırmacı, örüntünün eksik elemanını tamamlama ve örüntüyü tanımlama için sayılar, harfler, şekiller ve resimlerden oluşan 48 örüntü görevi tasarlamıştır. Bu görevlerdeki örüntülerin yarısı yatay olarak gösterilirken, diğerleri dikey olarak sunulmuştur. Her örüntü problemi bir kez gösterilmiş, ancak çocukların ilgili sorulara cevap vermek için zaman kısıtlaması olmamıştır. Çalışmanın bulgularında örüntüler ile bilişsel esneklik ve örüntüler ile çalışan bellek arasında anlamlı bir ilişki olduğu bulunmuştur. Ancak, örüntüler ile inhibisyon (dürtüyü kontrol etme) bileşenleri arasında anlamlı bir ilişki bulunamamıştır. Ayrıca, örüntülerin, bilişsel esnekliğin ve çalışan belleğin matematiksel beceriler arasında anlamlı bir ilişkisi olduğu bulunmuştur.

Bock, Cartwright, McKnight, Patterson ve arkadaşları (2015), bilişsel esneklik, inhibisyon (dürtüyü kontrol etme) ve çalışan bellek gibi yürütücü işlev bileşenlerinin örüntülerle arasındaki ilişkileri incelemek için bir çalışma yürütmüştür. Çalışmanın örneklemini 88 birinci sınıf çocuğu oluşturmuştur ve çocuklardan örüntüdeki eksik öğeyi tamamlamaları istenmiştir. Çocuklara sayılar, şekiller ve harfler gibi çeşitli materyaller içeren 18 örüntü seti sunulmuştur. Çalışmanın sonuçları, örüntü becerisi ile bilişsel esneklik arasında anlamlı bir ilişki olduğunu göstermiştir.

Benzer bir çalışma da Schmerold ve arkadaşları (2017) tarafından yapılmış ve yürütücü işlevler ile örüntü becerileri, matematik başarısı, okuma başarısı arasındaki ilişkiler incelenmiştir. Birinci sınıf çocukların bilişsel esneklik yetenekleri "Çoklu Sınıflandırmalı Kart Sıralama Testi" (Multiple Classification Card Sorting Test), çalışan bellek becerileri

"Çocuklara Yönelik Zekâ İçin Zeka Ölçeği (Wechsler Intelligence Scale for Children – Revised (WISC-R) Digit Span) testi ve inhibisyon (dürtüyü kontrol etme) becerileri "Stroop Renk-Sözcük Testi" (Stroop Color-Word Test) kullanılarak ölçülmüştür. Çalışmanın sonuçları örüntü ve inhibisyon arasında anlamlı bir ilişki olmadığını göstermiştir. Ancak, örüntü becerisi ile bilişsel esneklik ve örüntü becerisi ile çalışan bellek arasında anlamlı ilişkiler bulunmuştur. Ayrıca, örüntü becerisinin sadece bilişsel esneklik bileşeni tarafından tahmin edildiği tespit edilmiştir.

Miller, Rittle-Johnson, Loehr ve Fyfe (2016) tarafından, yürütücü işlevler ve ilişkisel düşünmenin örüntü becerisindeki rolünü araştırmak için bir çalışma yapılmıştır. Bu amaçla, 4 ve 5 yaşlarındaki 124 çocuk ile öntest-sontest deneysel bir çalışma tasarlanmıştır. Çalışmanın bulguları, inhibisyon (dürtüyü kontrol etme) becerisinin değil ama çalışma belleği, bilişsel esneklik ve ilişkisel düşünmenin, örüntü becerilerinin önemli belirleyicileri olduğunu göstermiştir. Dahası, sonuçlar çalışma belleği yeteneğinin çocukların örüntü becerisinde önemli bir rolü olduğunu ortaya çıkarmıştır.

Tezinde, Hassan (2019) okul öncesi çocukların matematiksel başarıları ve örüntü becerileri ile yürütücü işlev yetenekleri (yani çalışma belleği, inhibisyon ve bilişsel esneklik) arasındaki ilişkiyi araştırmıştır. Çalışmanın sonuçları bilişsel esneklik bileşeninin örüntü becerisinin önemli bir yordayıcısı olduğunu göstermiş, ancak çalışan bellek ve inhibisyon becerilerinin örüntü becerisini yordamadığı bulunmuştur. Diğer taraftan, çalışma belleği ve inhibisyon bileşenleri, genel matematiksel başarısının önemli belirleyicileri olarak bulunmuştur.

Özet olarak, yukarıda da sunulduğu gibi, erken örüntüleme becerileri farklı açılardan incelenmiştir. Örneğin, bazı araştırmacılar örüntüleme becerileri ile matematik başarısı arasındaki ilişkiyi araştırmıştır (Fyfe vd., 2015; Rittle-Johnson vd., 2015; Rittle-Johnson vd., 2017), bazı araştırmacılar da örüntüler ile ilişkisel düşünme arasındaki ilişkileri incelemektedir (Fyfe ve diğerleri, 2015). Ayrıca, araştırmacılar örüntü yapılarındaki zorluklarla ilgili bulgular bulmaya çalıştılar (örneğin, Rittle-Johnson vd., 2013; Tsamir vd., 2018). Son zamanlarda ise, bazı araştırmacılar matematiksel örüntüler ve yürütücü işlevler (executive functions) arasındaki ilişkiyi merak etmişlerdir (örneğin, Bock vd., 2015; Hassan, 2019; Miller vd., 2016; Schmerold, 2015; Schmerold vd., 2017). Şimdiye kadar yapılan araştırmalara bakıldığı zaman, bir uyarlama çalışmasından ayrı olarak (örneğin, Rittle-Johnson, Fyfe, Loehr ve Miller, 2015), hiçbir araştırmanın örüntü eğitimi üzerine oluşturulan Varsayımsal Öğrenme Rotaları ile doğrudan değerlendirilmediği görülmektedir.

Göz izleme ile ilgili çalışmalar

Örneğin, Takacs ve Bus (2016) tarafından yapılan yarı deneysel bir çalışmada, iki farklı hikâye kitabı ortamının (yani, animasyonlu versiyon ve statik gösterim) etkisini araştırmak için göz izleme metodu kullanılmıştır. Veriler, yaşları 4-6 arasında değişen otuz dokuz çocuktan toplanmıştır. Bu çalışmada, iki deney grubu (yani, hareketli sürüm ve statik) ve bir kontrol grubu (yani, okuma yapılmayan) oluşturulmuştur. Çocukların göz hareketleri, çocuklar hareketli ve statik hikâye kitabı dinlediğinde Tobii T120 göz izleyicisiyle kaydedilmiştir. Verileri analiz etmek için, iki deney grubuna ait görsellerdeki toplam odaklanma süresi, her hikâye kitabı için odaklanma sayısı ve ortalama odaklanma süresi gibi ölçümler hesaplanmıştır. Ayrıca, araştırmacılar İlgi Alanlarını (Aera of Interests, AOI's) tanımlamış ve her AOI'daki odaklanma süresini ve odaklanma sayısı hesaplamıştır. Ardından, ANOVA istatiksel analiz yöntemi kullanılarak toplanan veriler analiz edilmiştir. Elde edilen sonuçlara göre, animasyon grubundaki çocukların statik gruptakilerden daha fazla ekranda yoğunlaştığı ortaya çıkmıştır. Ayrıca, gruplarla ilgili ortalama odaklanma süresinde önemli bir farklılık gözlenmiştir. Bu durumda, çocuklar, hareketli gruptaki resimlere statik gruba kıyasla daha uzun süre odaklanmıştır. Bu analizlere ek olarak, AOI'ler hakkında bazı istatistikler de yapılmıştır. Benzer şekilde, önemli bir ana etki, animasyon grubundaki çocukların statik gruba kıyasla ayrıntılara (yani, önemli kısımlara) daha fazla odaklandığını göstermiştir. Sonuç olarak, göz izleme metodolojisi çocukların hikâye kitaplarına görsel dikkatine ilişkin farklı işleme stratejileri ortaya çıkarmaya yardımcı olmuştur. Bu nedenle, hareket veya animasyonların, çocukların dikkatini yönlendirerek öğrenmeyi destekleyebileceği ifade edilmiştir.

Bolden, Barmby, Raine ve Gardner (2015) tarafından yapılan diğer bir çalışmada, göz izleme teknolojisi, çocukların farklı matematiksel çarpım gösterimlerini nasıl algıladıklarını ve yorumladıklarını göstermek için kullanılmıştır. Bu amaçla, 9 ve 10 yaşları arasında dokuz çocuk çalışmaya dahil edilmiş ve üç farklı matematiksel çarpım gösterimleri ile karşılık gelen hesaplamanın eşlenmesi istenmiştir. Her çocuğa ilgili soru ve gösterim şeklini içeren on sekiz statik görselin sunulmuştur. Kalibrasyondan ve kısa tanıtım bölümünden sonra, veriler zaman kısıtlaması olmadan bir EyeTech VT2 göz izleme cihazı tarafından kaydedilmiştir. Daha sonra, elde edilen veriler hem niceliksel olarak (yani, her bir slayttaki odaklanma süresi ve

AOI'leri kullanarak) hem de niteliksel olarak (yani, her bir gösterim tipinde ısı haritaları kullanılarak) analiz edilmiştir. Tek yönlü ANOVA kullanılmış ve sayı çizgisi gösteriminin dizi ve grup gösterimlerinden önemli ölçüde farklı olduğu bulunmuştur. Ayrıca, AOI'ler üzerinde yapılan analizler, sayı doğrusunda harcanan zaman yüzdesinin diğer gösterimlerden önemli ölçüde farklı olduğunu göstermiştir. Ayrıca, çocukların üç farklı gösterimi ve ilgili sembolleri eşleştirmek için kullandıkları stratejileri yorumlamak için ısı haritaları ve video kayıtlarında da yararlanılmıştır. Sonuç olarak, sayı doğrusu ile gösterilen çarpma işleminin daha anlaşılır olduğu ve çocukların çarpımsal düşüncesini geliştirmek için daha az desteği olduğu bulunmuştur.

McEwen ve Dubé (2015) masaüstüne monte FaceLab 5 göz izleme cihazı kullanarak bir araştırma çalışması yürütmüştür. Bilişsel yük teorisine dayanan bu çalışma, eğitsel tablet bilgisayar uygulamalarının, çocukların dikkatini yönlendirmedeki rolü araştırılmıştır. Bu amaçla, tablet bilgisayarlarda basit ve karmaşık matematik uygulamaları hazırlanmış ve yaş ortalaması 7.3 olan 30 çocuk çalışmaya dahil edilmiştir. Her çocuk dikkat, kısa süreli bellek ve çalışan bellek ile ilgili bilişsel görevleri yerine getirmiştir. Ayrıca, çocuklar dört noktalı bir kalibrasyon prosedürünü tamamlamış ve daha sonra basit ve karmaşık matematik uygulamaları gerçekleştirirken, göz hareketleri kaydedilmiştir. Sonrasında ise, odaklanma sayısı ve odaklanma süresi ile ilgili göz izleme ölçümleri hesaplanmış ve ısı haritası incelenmiştir. Farklılıkları tespit etmek için ANOVA kullanılmıştır. Çalışmanın sonunda, basit uygulamaların, yürütücü işlev becerileri hem düşük hem de yüksek olan çocukların içeriğe dikkatlerini vermelerine yardımcı olduğunu ortaya çıkarmıştır. Öte yandan, karmaşık uygulamalarla ilgili olarak, konu ile alakalı içeriğin yürütücü işlev becerisi yüksek olan çocuklar için yardımcı olduğu, fakat yürütücü işlev becerisi düşük olan çocuklar için yararlı olmadığı bulunmuştur.

Schneider ve arkadaşları (2008), göz hareketlerinin çocukların tahmin yürütme problemlerini çözerken sayı doğrusunu nasıl kullandıklarını araştırmak için bir çalışma yapmıştır. Bu amaçla, kesitsel desen (cross-sectional design) oluşturulmuş ve altmış altı ilkokul çocuğu çalışmaya dahil edilmiştir. Çocuklar 1., 2. ve 3. sınıflarda olup, yaş ortalaması sırasıyla 6.8, 8.1 ve 8.9'dur. Çocukların problemleri çözme süreci hakkında daha fazla bilgi toplamak için, Eyelink 1000 göz izleyici kullanılmış ve bitirme süreleri ve odaklanma yerleri gibi bazı metrikler analiz edilmiştir. Çalışmanın sonuçları, tahmin etme problemlerinin, problem çözümü sırasında sayı duyusunun değerlendirmesi olarak kullanılabileceğini göstermiştir.

Özet olarak, göz izleme ile ilgili alan-yazın, küçük çocuklarla göz izleme çalışmaları yapan az sayıda araştırma çalışması olduğunu göstermiştir. Nitekim, 4-6 yaş okul öncesi çocuklarla ilgili sadece bir çalışma yapılmışken (ör. Takacs ve Bus, 2016), diğer çalışmalar 7-10 yaş arası ilkokul çocuklarıyla yapılmıştır. Ayrıca, araştırmacıların çoğunlukla matematik ve Türkçe eğitimi üzerinde yapıldığı görülmüştür. Örneğin matematik eğitimi ilgili olarak dört işlem-çarpma (Bolden ve vd., 2015) ve tahmin yapma (Schneider ve vd., 2008) konuları ile ilgili olurken, Türkçe eğitimi ile ilgili de dijital öyküleme (Takacs ve Bus, 2016) alanlarına odaklandığı görülmüştür.

Örüntü becerileri gittikçe daha fazla dikkat çekmekte ve dünya çapındaki eğitim topluluklarında tartışılmaktadır (örneğin, Ulusal Müfredat ve Değerlendirme Kurulu (NCCA), 2014; Ulusal Matematik Öğretmenleri Konseyi (NCTM), 1989; 2000). Bununla birlikte, örüntü becerileri üzerine az sayıda çalışma yapılmıştır (Burgoyne, Witteveen, Tolan, Malone ve Hulme, 2017; Clements ve Sarama, 2009; Fox, 2006). Örüntülerle ilgili çalışmalar yapan araştırmacılar, erken yaşlarda örüntü becerilerinin önemi ile ilgili bilimsel bulguları ortaya çıkarmışlardır (örneğin, Fyfe, McNeil ve Rittle-Johnson, 2015; Papic, Mulligan ve Mitchelmore, 2011; Pasnak, 2017; Rittle-Johnson, Fyfe, McLean ve McEldoon, 2013). Örüntü becerileri cebirsel düşünme (Clements ve Sarama, 2009) ve daha sonraki matematiksel başarısı için önemli bir alan olarak kabul edilmektedir (Fyfe, Rittle-Johnson, Hofer ve Farren, 2015; Rittle-Johnson, Fyfe, Hofer ve Farran, 2017). Bu nedenle, ilgili literatür, örüntü becerilerinin erken çocukluk eğitimine dahil edilmesi gerektiğini önermektedir (Burgoyne vd., 2017; Sarama ve Clements, 2009; NCCA, 2014). Araştırmacılar örüntü eğitimini etkin bir şekilde tasarlayabilmek ve uygulayabilmek için Varsayımsal Öğrenme Rotalarına ihtiyaç duyulduğunu savunmaktadır (Clements ve Sarama, 2004; 2009; Gravemeijer, 1994; Simon, 1995). Dahası, örüntü öğrenmenin altında yatan bilişsel mekanizmalar hakkında bilgi sahibi olmak, örüntü eğitimi için gerekli olabilmektedir. Bu amaca hizmet etmek için yeni teknolojiler ve metodolojiler ortaya çıkmıştır. Göz izleme yöntemi, bilişsel süreçleri ve öğrenme çıktılarını anlamak için kullanılan metodolojilerinden biridir (Land, 2007; Tsai, Hou, Lai, Liu ve Yang, 2012). Bu nedenle, göz izlemenin öğrenme deneyimleri hakkında eşsiz kanıtlar sağlayabildiği söylenebilir (Duchowski, 2007). Bu amaçla, bazı göz izleme ölçümleri, araştırmacılara izlenen göz hareketleri verilerini yorumlamalarında yardımcı olmaktadır. Kısaca, örüntü becerilerinin önemine yönelik bir ilgi duyulmasına rağmen, küçük çocukların örüntü becerilerine dair eğitim ve öğretim planları ve örüntü eğitiminin değerlendirilmesi ile ilgili bilgileri deneysel olarak anlamak için çok az araştırma yapılmıştır (Clements ve Sarama, 2009; Rittle-Johnson vd., 2013). Bu nedenle, bu çalışma Varsayımsal Öğrenme Rotalarının örüntü öğrenme ve öğretmeyi önemli ölçüde destekleyip desteklemediğinin yanı sıra mevcut Varsayımsal Öğrenme Rotalarının örüntü üzerinde geliştirilmesine yönelik tavsiyeler konusunda yardımcı olacaktır. Daha spesifik olarak, bu çalışma, örüntü eğitimi üzerine Clements ve Sarama (2009) tarafından önerilen Varsayımsal Öğrenme Rotalarının revize edilerek etkilerini incelemeyi ve örüntü becerisinin altta yatan bilişsel mekanizmasını daha iyi anlamak için göz izleme metodolojisinden faydalanmayı amaçlamaktadır.

Çalışmanın Yöntemi

Bu çalışma, Tasarım-Tabanlı Araştırma (Design-Based Research) kapsamında geliştirilen büyük bir projenin son aşaması olan değerlendirme kısmına ait araştırmayı sunmaktadır. Bu amaçla, öncesinde yapılmış olan tüm araştırma döngüleri detaylı şekilde anlatılacak ve daha sonrasında ise son araştırma döngüsü detaylandırılacaktır. Ayrıca, çalışmanın iç-geçerlik tehditlerine karşı alınan önemler, geçerlik-güvenirlik konuları ve araştırmanın sınırlılıkları da bu bölümde anlatılacaktır.

Tasarım-Tabanlı Araştırma (Design-Based Research), eğitim araştırmalarında yeni bir yaklaşım olarak kabul edilmekte ve gün geçtikçe kullanımı yaygınlaşmaktadır. Ayrıca, gerçek eğitim ortamında araştırma yapmaya imkân vermesi, hem nicel hem de nitel yöntemlerden yararlanarak birden fazla kaynaktan veri toplanmasına olanak sağlaması, araştırmacıya birden fazla iterasyon döngüleri oluşturmasına yardımcı olarak eğitim araştırmalarının kalitesini arttıracağına inanılmaktadır (Anderson ve Shattuck, 2012; Bakker, 2018).

Bakker (2018), Varsayımsal Öğrenme Rotaların tasarımı için üç fazdan oluşan bir tasarım modeli sunmaktadır. Bu üç aşama "hazırlık ve tasarım" (preparation and design), "uygulama" (implementation)" ve "analiz ve yeniden tasarım" (analysis and redesign) olarak tanımlanmıştır (Bakker, 2018, s. 59). Bakker (2018) tarafından önerilen çerçeveye dayanarak, bu çalışma tasarım aşamaları ve iterasyonlar içermektedir. Açıklamak gerekirse, ilk araştırma döngüsünde, örüntü ve ilgili literatür hakkında bilinenleri görmek için ön araştırmalar yapıldı. İkinci araştırma döngüsünde, Clements ve Sarama (2009) tarafından önerilen mevcut Varsayımsal Öğrenme Rotaları modifiye edildi ve bu alandaki uzmanlara danışıldı. Yine bu araştırma döngüsünde, 12 oturumdan oluşan öğretim planları, yalızca somut materyallerden oluşan aktiviteler, iki değerlendirme sorusu ve 0 ile 1 arasında değişen değerlendirme-puanlama protokolü hazırlandı. Bunların hepsi, yine alandaki uzmanlar tarafından da gözden geçirildi. Üçüncü araştırma döneminde, değiştirilmiş Varsayımsal Öğrenme Rotalarının uygulaması yapıldı. İki gruptan oluşan randomize bir ön test-sontest kontrol grup deneysel çalışma gerçekleştirildi ve modifiye Varsayımsal Öğrenme Rotaları değerlendirildi. Bulgular ve öneriler tartışıldı ve bir sonraki süreçte yol gösterici çıkarımlar oluşturuldu.

Dördüncü araştırma döngüsünde, alandaki uzmanlar orijinal Varsayımsal Öğrenme Rotalarının geliştiricisi ile iş birliği yapılarak tekrar bir iterasyon yapıldı. Böylece öğretim planları, kullanılan materyaller, değerlendirme soruları ve puanlama protokolü yeniden gözden geçirildi. Açıklamak gerekirse, öğretim planları 12 oturumdan 14 oturuma çıkarıldı ve materyaller sadece somut faaliyetlerden ziyade hem somut hem de bilgisayar destekli olacak şekilde tasarlandı. Ayrıca, değerlendirme soruları üç örüntü becerisini kapsayacak şekilde tasarlandı ve 0 ile 6 arasında değişen kapsamlı bir puanlama protokolü hazırlandı. Sonunda, bu çalışmada kullanılan Varsayımsal Öğrenme Rotalarının son versiyonu geliştirildi ve göz izleme metodolojisinin hazırlıkları yapıldı. Çalışmanın son araştırma döngüsünde ise, deney grupları için gözden geçirilmiş Varsayımsal Öğrenme Rotaları uygulanmıştır. Üç gruptan oluşan randomize ön test-son test kontrol çalışması yapıldı ve revize olan Varsayımsal Öğrenme Rotalarının etkililiği değerlendirildi. Ayrıca alan notları alındı, tüm oturumlar videoya kaydedildi ve göz izleme verileri toplanmıştır. Son araştırma döngüsüne ait bulgulara dayanarak, bu tezin sonuçları ve sonraki çalışmalar için tavsiyeleri tartışma kısmında sunulmuştur.

Bu amaçla 3 deney grubu oluşturulmuştur.

Grup 1: Deneysel grup: Varsayımsal Öğrenme Rotalarına Dayalı olup sıralı olarak ilerleyen gruptur. Bu grup, Varsayımsal Öğrenme Rotalarında belirtildiği gibi önce 2. seviye, sonra 3. seviye, son olarak da 4. seviye becerilerini sırasıyla takip eden 14 oturumluk bir eğitim almıştır.

Grup 2: Aktif kontrol grup: Varsayımsal Öğrenme Rotalarına Dayalı olup sıralı olarak ilerleMEyen gruptur. Bu grup, Varsayımsal Öğrenme Rotalarında belirtilen seviyelerin hepsini içermesine ragmen, 2. ve 3. Seviyeden kısa bir eğitim alarak (her birinden 1 yada 2 oturum) 4 seviye eğitimler almaya daha erken başlamış ve deney grubundaki gibi toplamda 14 oturumluk eğitim almıştır.

Grup 3: Pasif kontrol grup: Hali hazırda, sınıfta verilen geleneksel örüntü eğitimini izleyen gruptur. Bu grup, tekrarlayan örüntülerle ilgili özel olarak hazırlanan bir eğitim almamıştır. Milli Eğitim Okul Öncesi Eğitimi programında yer alan sınıf etkinlikleri dahilinde eğitimler almıştır.

Bu amaçla 2 ana araştırma sorusu alt-araştırma soruları ile aşağıdaki gibi hazırlanmıştır.

Araştırma Soruları

1) Öğrenme Rotaları temelinde ardışık seviyeler ile öğretilen, öğrenme rotaları temelinde olan ama farklı sırada öğretilen veya geleneksel sınıf aktiviteleri ile öğretilen yöntemlerden hangisi çocukların örüntü öğrenimini daha etkili şekilde geliştirmektedir?

a. Çocukların örüntüleri devam ettirme (extension) becerisi açısından sunulan öğretim yöntemlerinden (öğrenme rotaları temelinde ardışık seviyeler ile öğretilen, öğrenme rotaları temelinde ama farklı sırada öğretilen veya geleneksel sınıf aktiviteleri ile öğretilen) hangisi daha etkili olmuştur?

b. Çocukların örüntüleri farklı materyallerle oluşturma (translation) becerisi açısından sunulan öğretim yöntemlerinden (öğrenme rotaları temelinde ardışık seviyeler ile öğretilen, öğrenme rotaları temelinde ama farklı sırada öğretilen veya geleneksel sınıf aktiviteleri ile öğretilen) hangisi daha etkili olmuştur?

c. Çocukların örüntülerin tekrar eden kısmını bulma (core identification) becerisi açısından sunulan öğretim yöntemlerinden (öğrenme rotaları temelinde ardışık seviyeler ile öğretilen, öğrenme rotaları temelinde ama farklı sırada öğretilen veya geleneksel sınıf aktiviteleri ile öğretilen) hangisi daha etkili olmuştur?

2) Çocuklar örüntülere ilişkin becerileri (örüntüleri devam ettirme, örüntüleri farklı materyallerle oluşturma, örüntülerin tekrar eden kısmını bulma) nasıl gerçekleştirmektedir?

Bulgular, Tartışma ve Öneriler

Bu çalışma, örüntü becerileri üzerine, Clements ve Sarama (2009) tarafından önerilen ve Baroody, Yilmaz, Clements ve Sarama (2019), tarafından revize edilmiş Varsayımsal Öğrenme Rotalarının etkinliğini incelemeyi amaçlamıştır. Dahası, göz izleme metodolojisi yardımıyla, çalışma örüntü becerisinin altında yatan bilişsel mekanizmayı ortaya koymayı da amaçlamıştır.

Toplanan veriler, toplam ön test puanları kontrol edildikten sonra, Kovaryans Analizi (ANCOVA) kullanılarak analiz edilmiş ve gruplar arasında anlamlı bir fark ortaya koymuştur. Sonuçlara göre kontrol ve aktif kontrol grubu, geleneksel kontrol grubuna kıyasla daha başarılı olmuştur.

Ayrıca, her bir örüntü becerisi (yani, örüntüyü devam ettirme, örüntüyü farklı materyallerle yapma ve örüntünün çekirdek birimini tanımlama) ayrı ayrı incelendiğinde, yine gruplar arasında önemli farklılıklar bulunmuştur. Spesifik olarak, örüntüleri devam ettirme becerisi için, deney grubu ile pasif kontrol grubu arasında anlamlı bir fark tespit edildi, ancak aktif kontrol grubu ile pasif kontrol grubu arasında anlamlı bir fark bulunamadı. Ayrıca, deney grubundaki çocuklar örüntüleri devam ettirme becerisi açısından aktif kontrol grubuna göre daha başarılı olmasına rağmen aralarında anlamlı bir fark bulunmadı.

Örüntüleri farklı materyaller ile oluşturma becerisi açısından, aktif kontrol grubu ile pasif kontrol grubu arasında önemli bir fark tespit edildi, ancak deney grubu ile kontrol grubu arasında bir fark bulunmamıştır. Ayrıca, aktif kontrol grubu deney grubuna göre daha iyi performans gösterse de, aralarında anlamlı bir fark bulunamamıştır.

Son olarak, örüntünün çekirdek birimini tanımlama becerileri ile ilgili olarak, hem deney grubu ve hem de aktif kontrol grubu ile pasif kontrol grubu arasında önemli bir fark bulunmuştur. Bununla birlikte, aktif kontrol grubu çocukları, deney grubundaki çocuklardan daha iyi performans gösterse de aralarında anlamlı bir fark bulunamamıştır.

Örüntü becerilerinin bilişsel mekanizmaları açısından, göz izleme metodolojisi ve nitel analizler de çok sayıda ilginç bulgular ortaya çıkardı. Örneğin, ısı haritaları incelendiğinde, çocuklar belirli bir AB örüntüsünü devam ettirirken örüntüye genel olarak baktıktan sonra çoğunlukla örüntünün üçüncü çekirdek birimine odaklandığı görülmüştür. Bu bulgu, çocukların örüntüyü tanımlamak için ilk önce bütün yapıya baktıklarını ve ardından verilen örüntüyü devam ettirmek için son örüntü birimini kullandıklarını desteklemektedir. Bu bilişsel davranışlar ABB ve ABC örüntü türlerinin devam ettirilmesi için de benzer şekildedir. Ayrıca, ölçülen odaklanma süresi de örüntüyü devam ettirme becerileri ile ilgili bu bulguları nicel olarak desteklemektedir.

Örüntüyü farklı materyallerle oluşturma becerisi (translation skills) açısından ise ısı haritaları farklı bilişsel davranışları ortaya çıkarmıştır. Çocuklar AB, ABB ve ABC örüntülerini devam ettirme sırasında çoğunlukla benzer bilişsel davranış sergilerken ve örüntünün üçüncü çekirdeğine açıkça odaklanmış olsalar da gösterdikleri bilişsel davranışlar AB, ABB ve ABC örüntü türlerinin farklı materyallerle yapılması açısından farklılık göstermiştir. Spesifik olarak, çocuklardan verilen AB ve ABB örüntüsünü farklı materyallere dönüştürmeleri istendiğinde, çocukların örüntünün tüm çekirdek birimlerine baktıktan sonra, çoğunlukla örüntünün birinci ve ikinci çekirdek birimine odaklandığı görülmüştür. İlginç bir şekilde, çocuklar, ABC türündeki örüntüleri farklı materyallere dönüştürürken verilen örüntüye kıyasla daha çok yapılacak örüntüye odaklanmıştır. Ayrıca, bulgular, çocukların, söz konusu verilen örüntünün üçüncü çekirdek birimine yapılacak olan örüntünün ise ilk çekirdeğine odaklandığını desteklemektedir.

Son olarak, örüntünün çekirdek birimini tanımlama (core-identification) becerisiyle ilgili olarak, her bir örüntü türü için iki farklı örüntü grubu araştırılmıştır. İlk kümedeki örüntülerin çekirdek birimini tanımlama işlemi, ikinci örüntü setinden biraz farklıydı. Birinci örüntü setinde, çocuklar, AB örüntüsünü bulmaları istenmesine rağmen neredeyse tüm örüntü tiplerini ziyaret ettiler. Bu süreç, çocukların AB örüntüsündeki çekirdek birimi bulmaları istendiğinde de benzer şekilde olmuştur. Bununla birlikte, ikinci örüntü setinde çocuklar, diğer örüntü türlerini hızlıca ziyaret etmelerine rağmen AB örüntüsüne açıkça odaklandılar. Diğer bir deyişle, daha bilinçli olarak AB örüntüsünün çekirdek birimine odaklanmış oldular.

Çocukların ABB örüntüsünü bulması her iki örüntü setinde de zor oldu. Yani, çocuklardan ABB örüntüsünü bulmaları istenmesine rağmen, onlar tüm örüntülere baktıktan sonra çoğunlukla ABC örüntüsüne odaklandılar. Ayrıca, ABB örüntüsünün çekirdek birimini bulmak da çocuklar için kolay değildi.

İlginç olarak, her iki örüntü setinde de çocuklar ABC örüntüsüne odaklanıp onu kolayca buldular. Isı haritaları ve odaklanma süresi ölçüleri bu bulguları desteklemektedir. Başka bir deyişle, çocuklardan ABC örüntüsünü bulmaları istendiğinde, onlar tüm türlerine hızlıca göz atıp ve ABC örüntüsünü kolayca gösterebildiler. Bu durum, ABC örüntü türünün kolaylığından değil de aşina olunuşundan kaynaklanabilir. Nitekim, çocuklardan ABC örüntüsünün çekirdek birimini bulmaları istendiğinde, çocuklar ABB örüntüsündeki çekirdek birimi tanımlama süreci için yaptıkları benzer bilişsel davranışları sergilediler. Çocukların bakışları tüm örüntü boyunca yayıldığı için, ABC örüntüsünün çekirdek birimini kolayca tanımlayamadıkları görülmektedir.

Göz izleme verileri, ABC örüntüsü ve onun çekirdek birimini bulmanın AB ve ABB örüntülerinden daha kolay olduğunu ortaya koymuştur. Bu bulgunun olası nedenini incelemek için, örüntü yapılarının çekirdek tanımlama becerileri için zorluklarını anlamak için yerleştirme ve düzeninin etkilerini inceleyen deneysel bir araştırma yapılabilir.

Bu çalışmada, örüntüleri başka materyallere dönüştürme ve örüntünün çekirdek birimini tanımlama becerileri ile ilgili gelişim düzeylerinin sırası gözden geçirilebilir. Bu iki becerinin yer değiştirmesinin gerekip gerekmediği araştırılabilir.

Ayrıca, ilgili literatürde, yürütücü işlev bileşenleri ile örüntüleme becerileri arasında anlamlı bir ilişki bulunmuştur. Bu nedenle, bir sonraki çalışma yapılacak olan ön teste yürütme işlevi ile ilgili ölçme araçlarını da dahil edebilir.

Erken çocukluk dönemi eğitimcileri çocukların gelişiminde önemli bir role sahip olduklarından, öğretmenlerin örüntü konusundaki öğretim uygulamalarını ve onların örüntü konusundaki Teknolojik Pedagojik Alan

Bilgilerini (Technological Pedagogical Content Knowledge, TPACK) incelemek için araştırma yapılabilir.

Erken çocukluk yıllarında, küçük çocukların aileleri veya birincil derecede sorumlu olan yakınları onların eğitimcileri olarak kabul edilir. Bu nedenle aileler, çocukların ev ortamındaki örüntü oluşturma konusundaki ilgilerini ve bilgilerini genişletmek için uygun şekilde yönlendirilmeli ve teşvik edilmelidirler.

Bu çalışma, normal gelişim gösteren dört ve beş yaşındaki okul öncesi dönem çocukları için matematiksel örüntülerin eğitimine odaklanmıştır. Bu nedenle, ilerideki çalışmalar özel ihtiyaçları olan çocuklar da dahil olmak üzere daha geniş bir örneklemle yapılabilir.

Bu çalışmada, matematiksel örüntülerle ilgili Varsayımsal Öğrenme Rotalarının etkililiği incelenmiştir, başka bir çalışma diğer matematiksel öğrenme alanları ile ilgili Varsayımsal Öğrenme Rotalarının etkililiğini değerlendirmek için yapılabilir. Ayrıca, bu çalışma tekrarlayan örüntüler kullanılarak yapılmıştır. Bu nedenle, büyüyen örüntüler ve uzamsal örüntüler gibi diğer örüntü çeşitleri de dikkate alınarak bir başka çalışma yapılabilir.

İlgili literatürde, örüntü becerileri ile genel matematik başarısı arasında anlamlı bir ilişki bulunmuştur. Bu nedenle, gelecek çalışmada, örüntüleme puanlarının çocukların matematik başarı puanları üzerindeki etkisini incelemek için deneysel bir çalışma yapılabilir. Ayrıca, örüntü becerilerinin yıllar içinde gelişimini daha iyi anlamak için boylamsal bir çalışma yapılabilir.

Bu çalışmada rastgele olmayan bir örnekleme prosedürü kullanılmıştır. Çalışmanın genellemesini arttırmak için, rastgele örneklemeyi içeren büyük ölçekli bir çalışma yapılabilir.

Son olarak, gelecekteki bir çalışma, çocukların örüntü öğrenme konusunda daha zengin verilerinin toplanması için eğitim oturumları sırasında çocukların tepkilerini ve bu tepkilerin etkilerini araştıran nitel bir çalışma olarak yapılabilir. Ayrıca, sosyal etkileşimin erken örüntü becerileri edinilmesi üzerindeki etkisini araştırmak için başka bir çalışma bir sınıf ortamında yapılabilir.

APPENDIX G: TEZ İZİN FORMU/THESIS PERMISION FORM

ENSTİTÜ/ INSTITUTE

Fen Bilimleri Enstitüsü /Graduate School of Natural and Applied Sciences ☐

Sosyal Bilimler Enstitüsü/ Graduate School of Social Sciences ■

Uygulamalı Matematik Enstitüsü/Graduate School of Applied Mathematics ☐

Enformatik Enstitüsü/ Graduate School of Informatics ☐

Deniz Bilimleri Enstitüsü/ Graduate School of Marine Sciences ☐

YAZARIN / AUTHOR

Soyadı / Surname : Yılmaz
Adı / Name : Nursel
Bölümü / Department : Temel Eğitim-Okul Öncesi Eğitimi

TEZİN ADI / TITLE OF THE THESIS (İngilizce / English): THE EFFECT OF THE HYPOTHETICAL LEARNING TRAJECTORIES AND THE CONTRIBUTION OF THE EYE-TRACKING TECHNOLOGY IN UNDERSTANDING THE YOUNG CHILDREN'S MATHEMATICAL PATTERNING RECOGNITION AND GENERALIZATION

TEZİN TÜRÜ/ DEGREE: Yüksek Lisans ☐ Doktora ■

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2. Tez iki yıl süreyle erişime kapalı olacaktır. / Secure the entire work for patent and/or proprietary purposes for a period of two years. * ☐
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A copy of the decision of the Institute Administrative Committee will be delivered to the library together with the printed thesis.

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