MATHEMATICS TEACHERS' SELF-REGULATED LEARNING BEHAVIORS IN AN IMMERSIVE VIRTUAL ENVIRONMENT

by

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ABSTRACT

MATHEMATICS TEACHERS' SELF-REGULATED LEARNING BEHAVIORS IN AN IMMERSIVE VIRTUAL ENVIRONMENT

Virtual Environments (VEs) are emerging with developing technology, and teachers are necessary to educate themselves to employ technology to raise twenty-first century skills in the new generation. In this manner, Immersive Virtual Environments (IVEs) are the settings that encourage learners to be engaged, independent, and motivated, which are the features of self-regulated learners. The current study aims to investigate mathematics teachers' self-regulated learning (SRL) behaviors in IVEs during problem-solving since promoting students' SRL behaviors are possibly encouraged by teachers' SRL behaviors. By considering the purpose of the study, a case study was conducted with eleven middle school mathematics teachers who were able to practice during the Pandemic by Prisms, an IVE focusing on exponential growth through a game. The video records were taken for the think-aloud data collection process. After the participants experienced the immersive environment, a semi-structured interview was conducted to get reflections on the experience. The transcripts of the records are analyzed by a coding scheme that includes four main phases of SRL behaviors: planning, monitoring, strategy use, and evaluation. The findings demonstrated that while planning has been the least referred SRL behavior, strategy use behavior was the most addressed SRL behavior. This study is significant to see similarities in the existing literature; however, understanding such environments requires further investigation before it is included in educational settings.

ÖZET

MATEMATİK ÖĞRETMENLERİNİN SARMALAYAN SANAL GERÇEKLİK ORTAMLARINDA ÖZ-DÜZENLEME DAVRANIŞLARI

Teknolojinin beraberinde getirdiği yeniliklerden biri olan sanal gerçeklik ortamları, öğretmenlerin öğrenme ortamlarına dahil ederek öğrencilerin 21. yüzyıl becerilerini de geliştirmek adına kullanabileceği, bu anlamda kendilerini de geliştirmesi gereken bir ortamdır. Bu ortamların bir çeşidi olan sarmalayan sanal gerçeklik ortamları öğrenenlerin katılımcı, bağımsız ve motivasyonu yüksek olma gibi öz düzenleme becerilerini desteklediği nitelendirilir. Öğrencilerinin öz-düzenleme davranışlarının desteklenmesinde öğretmeninin öz-düzenleme davranışlarının rolünden ötürü bu çalışmanın amacı matematik öğretmenlerinin sarmalayan sanal gerçeklik ortamlarında problem çözme sırasındaki öz-düzenleme davranışlarını incelemektir. Bu amaç doğrultusunda sarmalayan sanal bir ortamdaki oyunda, 'Pandemic by Prisms'de, çalışabilecek 11 ortaokul matematik öğretmeni gönüllü olarak bu vaka analizi çalışmasına katıldı. Veri toplama sürecinde videolar ile sesli düşünme süreci kaydedilmiş ve katılımcılar daha sonra deneyimlerini paylaşmak adına yarı yapılandırılmış bir görüşmeye de katılmışlardır. Bu kayıtların dökümü 4 ana öz-düzenleme davranışını içeren bir kod şemasıyla kodlanmıştır. Bulgular planlamanın en az atıfta bulunulan, strateji kullanımının ise en çok ele alınan öz-düzenleme davranışı olduğu göstermiştir. Bu çalışma mevcut literatürle benzerlikler göstermesi açısından önemliyken; bu ortamların eğitim alanlarına dahil edilmeden önce daha iyi anlaşılması yeni çalışmaları gerektirir.

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LIST OF ACRONYMS/ABBREVIATIONS

3D	Three Dimensional
4Cs	Critical Thinking, Communication, Collaboration, and Creativity
CAMIL	Cognitive Affective Model of Immersive Learning
CSCL	Computer-Supported Collaborative Learning
ICT	Information and Communications Technology
IVEs	Immersive Virtual Environments
MUVEs	Multi-User Virtual Environments
SRL	Self-Regulated Learning
SVVR	Spherical Video Based Virtual Reality
VEs	Virtual Environments
VR	Virtual Reality

1. INTRODUCTION

In the evolving world, technological advancements have numerous impacts on society and its stakeholders. These impacts might create some possible and unexpected consequences in various fields or groups of individuals. In this manner, education, educators, and learners can be influenced by the evolvements in technology. For example, throughout the previous years, traditional teaching strategies have been reconsidered for not being compatible with the changes and obstacles of the 21st century (Scott, 2015). Within the applicable strategies, the changing learning settings have been crucial to improve *learning and innovation skills*, which are critical thinking, communication, collaboration, and creativity (4Cs). Advancing those skills has a reciprocal effect on developing the other key subjects focused in twenty-first century skills, which are *life and career skills* and *information, media and technology skills*. All those subjects of twenty-first century skills are also influential on linking the learning with the real world. According to this point of view, teaching programs started to include twenty-first century skills which became more significant with the recent technological developments. Educators and teachers adapt the teaching programs and learning processes to advance such skills of students. Learning applications or environments reflecting such skills have gained a place in recent years.

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The recent changes in use of learning applications have been mostly obligatory rather than voluntary because of the pandemic conditions. The influences of COVID-19 pandemic can be noticed in many settings, specifically in education. According to UNESCO (2020), 1.38 billion learners are affected by the closure of national schools worldwide. At the onset of the pandemic, classrooms were turned into online classes complemented by a variety of learning technologies with school closures in 2020. For example, it is stated that 81.8% of total enrolled learners have been affected from country-wide closures in April, 2020 (UNESCO, 2021). In conclusion, the COVID-19 pandemic promoted the use of different learning materials and strategies. For example, learning management systems (e.g., Google Classroom, Moodle, and Edmodo) that support students' 4Cs and innovation skills have been extensively used during the pandemic (UNESCO, 2020). Even though they were already known and common systems, they just began to find growing use in different classroom settings for various grade levels.

Classrooms with novel digital infrastructures have impacts on learning environments' characteristics, mostly related to how the information is presented and the knowledge construction is supported in these settings. Eventually these aspects of environments possibly influence the learning and innovation skills. Over the years, Information and Communications Technology (ICT) has changed the face of education, the process of learning has been affected with the use of various tools such as smartboards, multimedia, or computer programs that basically support students' information, media and technology skills. The use of prevailing ICT in educational settings is also con-

sidered as forceful for encouraging the learning process in effective teaching conditions (Bellou and Mikropoulos, 2006; Smeets, 2005). Their educational benefits can be gathered in a few points; however, it mainly arises from their technological characteristics related to including a variety of information resources. In other words, ICT contributes to reaching plenty of information by using a variety of sources from numerous perspectives and eases the understanding of complex processes via simulations. Consequently, it supports the genuineness of learning settings (Smeets, 2005).

Even with the increase in the popularity of various technological tools, making sense of the advantages of these technologies is significant for increasing the efficiency in using them. For instance, it is already concluded that students' attendance is positively affected by the amount of ICT use. However, this relationship has not been found as consistent for all subjects and levels. Therefore, various studies have focused on factors that affect the usability and efficiency of different ICT tools in various conditions. It was found that the type of software or the way they are used might have a significant effect on learners (Harrison *et al.*, 2002; Smeets, 2005). It means that the choice of software made by teachers and its use might have a critical influence on classroom setting and/or learning process. Besides, both the qualification of teachers in terms of ICT usage and their pedagogical views related to the benefits of technological tools on the learning process might have a significant effect on classroom environments. For instance, Smeets (2005) found that teachers' belief related to the contribution of ICT tools on students' active and independent learning process and teachers' self-confidence in ICT use influence their preferences. In this manner, those teachers who believe in the contribution of ICT tools and feel confident with their skills are likely to prefer some specific ICT tools similar to virtual worlds which encourage students' information-processing skills.

Virtual Reality (VR) technologies which are different from the other ICT tools with their exclusive characteristics are considered as supportive and forceful on interactions of users within the setting. VR is described as a combination of technologies which foster the merge of three dimensional (3D) synthetic and interactive surroundings

that represent real or non-real situations (Mikropoulos and Natsis, 2011). It can also be defined as a user interface that involves a simulated environment (Martín-Gutiérrez *et al.*, 2017; Vesisenaho *et al.*, 2019). Vesisenaho *et al.* (2019) also emphasized that VR users can reach out and analyze the environment by using various senses. Bellou and Mikropoulos (2006) stated the unique characteristics of VR technologies as follows:

- Representations can be created in 3D, named as virtual environments (VEs),
- Users can interact in multisensory channels,
- VEs are available for user's immersion,
- Interactions can be intuitive with "natural manipulations in real life" (p. 122).

These affordances of VEs support learners by facilitating the access to complicated and abstract structures or concepts which are hard-to-visualize (Hu-Au and Lee, 2017; Mikropoulos and Natsis, 2010). Meta-analysis demonstrated that it is science and mathematics content in many cases that are not easily observable or/and challenging to comprehend (Merchant *et al.*, 2014; Mikropoulos and Natsis, 2010). Some contents of science and mathematics can be also experimental in character and demand spatial cognition and higher order thinking abilities, which is why the existing literature includes many studies regarding those contents of science and mathematics in VEs. For this reason, building mental models and deepening the understanding is challenging in science and mathematics. VEs have the potential to help conceptual transformation, thinking ability growth, and cognitive development by visualization and simulation (Mikropoulos and Natsis, 2010). In this regard, VEs can have particular facilitative effects in science and mathematics learning.

Renewal of educational settings in science and mathematics context is possible with the affordances that VEs present to the environment (Vesisenaho *et al.*, 2019). Since building realistic environments that have no easy access became popular in education (Wu *et al.*, 2020), what else VEs offer to learners and how these environments support them have been on the agenda of researchers and educators. For example, the immersive characteristic of VE might activate the attendance of learners in the

process of learning by engaging them in deeper cognitive processes (Vesisenaho *et al.*, 2019). Furthermore, an Immersive Virtual Environment (IVE) surrounds individuals perceptually, and increases the user's sensation of presence or actually being there (Bailenson *et al.*, 2008; Blaskovich *et al.*, 2002). According to Makransky and Petersen (2021), learners' presence and agency originating from the immersive and interactive characteristics are often greater in IVEs compared to non-immersive settings.

While the amount of immersion presented by the virtual environment might have an impact on exposing the feeling of presence, agency can emerge from learners' interaction with virtual environments and control of their actions in such environments (Makransky and Petersen, 2021). In other words, the affordances that immersion, interaction, and control factors create, which are presence and agency of learners, are expected to be higher in IVEs (Makransky and Petersen, 2021). These IVE affordances that influence affective and cognitive factors also eventually support the learner in being engaged and independent. It means that skills for engagement are encouraged in IVEs; but also, some control factors (e.g., how the control is and in which amount it is) and immersion are required as the predictor of presence and agency. Makransky and Petersen (2021) also claimed that the instruction strategies which enhance a greater sense of presence and agency will be possible to advance learning in immersive environments. It is concluded that presence and agency are the encounters that lead to engaging experiences while learning in IVEs (Makransky *et al.*, 2020). Previous studies stated that immersion is critical for engagement and a high amount of presence (Wu *et al.*, 2020). Makransky, Borre-Gude, and Mayer (2019) also concluded that immersive environments support learners in being engaged and getting motivated. Such features are in alignment with self-regulated learning: a phenomenon emphasized in today's education world. Self-regulated learners are expected to be more willing to engage, more motivated to act, and study more effectively (Pintrich, 2003). In other words, learners equipped with such learning characteristics like motivation and self-belief display key features of self-regulated learners (Devolder *et al.*, 2012). Self-regulated learners who are actively involved in the learning process and highly motivated to engage, have potential to effectively interact with IVEs.

Different factors which have an impact on the learning process (e.g., self-confidence, motivation or interest) are studied extensively to better understand VEs for their advancement. Self-regulation is one of these factors that are investigated to figure out the influences in the learning process. Self-regulation can be described as the ability to control one's own thoughts, feelings, and behaviors in order to achieve their objectives (Zimmerman, 2000). Even though how students self-regulate while learning in various learning environments have been examined over the years, there are limited studies which examine the role of SRL in VEs or IVEs. Since the Cognitive Affective Model of Immersive Learning (CAMIL) taking into consideration the role of SRL in IVEs has shown that the affordances of IVE, caused by immersion and interaction, have a potential positive and negative influence on self-regulation (Makransky and Petersen, 2021). Hence, there is a need for investigation of the complex relationship between use of IVEs and users' SRL.

Currently, there is a need for further investigation and clarification of factors significant in promoting self-regulated learning (SRL) (Peeters *et al.*, 2014); however, teachers' role in SRL promotion is already found as one of the factors that are influential (Zimmerman, 2002). Delfino and colleagues (2010) stated that teachers' recognition of SRL is crucial in promoting students' SRL behaviors. Besides, teachers' professional development is also based on their control over their own learning (Delfino *et al.*, 2010). Teachers' dual self-regulation roles as learners and teachers in promoting students' self-regulation behaviors is argued by focusing on modeling the behaviors because the teacher modeling is characterized as presumably significant in promoting SRL (Kramarski and Kohen, 2017; Peeters *et al.*, 2014). The improvement of students' SRL can be aided by examining teachers' SRL behaviors and comprehending its principles. Gordon *et al.* (2007) concludes that teachers who used a mastery goal orientation in the classroom reported having more humanistic control over their learning and were more likely to report having greater self-regulation of their own learning. Furthermore, teachers' knowledge of SRL and their personal use of it may be increased and applied in the classroom (Spruce and Bol, 2015). Based on this intricate relationship between teachers' own SRL, their efforts to promote SRL and students' SRL, teachers' behaviors

on virtual worlds need to be understood at first since such environments have growing popularity and use in educational settings, especially in Turkey. Consequently, this study focuses on examining teachers' SRL behaviors in IVEs.

It is already concluded that supporting learners' self-regulation strategies become notably influential when they are informed about how, when and why a specific strategy is applied. On the other hand, Dignath and Veenman's (2020) review presented that in most of the studies teachers rarely talk about application of a specific strategy with their students. This lack of explicit conversation on strategies, a specific type of teaching move, can be related to teachers' own SRL. While influences of teachers' pedagogical beliefs, their motivational orientations and their self-regulation behaviors on classroom teaching have been examined, there are limited studies that address teacher knowledge related to SRL, their beliefs about SRL or their own self-regulation behaviors (Dignath and Veenman, 2020). Hence, self-regulation behaviors of teachers in such environments still need to be investigated to maximize possible benefits from using virtual environments for teaching.

1.1. Purpose of the Study

Since the beginning of the twenty-first century, an extended focus on virtual environments (VEs) has increased the requirement of investigations related to these settings. Since the VEs are characterized uniquely among the ICT tools, it is vital to investigate learners' use of such environments. Previous studies already concluded that sensory information represented in VEs supports learners' engagement. However, the effectiveness of such environments varied in different settings for various learner characteristics (Perera and Allison, 2015; Radianti *et al.*, 2020; Wu *et al.*, 2020). Factors like interest, intrinsic motivation, self-efficacy, embodiment and cognitive load are described as influential in the learning process in VEs (Makransky and Petersen, 2021). On the other hand, self-regulation might be one of the factors which has an impact on the learning process in VEs. The Cognitive Affective Model of Immersive Learning (CAMIL) by Makransky and Petersen (2021) demonstrates that self-regulation is one

of the cognitive affective factors which has an influence on learning outcomes in IVEs. The lack of clarity on how IVE affordances are related to SRL necessitates further investigation to advance the use of these settings. A key precursor in that context would be to investigate whether and how self-regulation takes place in learners' interaction with VEs.

Panadero (2017) stated that studies related the involvement of technology in learning settings and influences of those technologies on SRL will enable more specialized interventions and learning settings, which should be included into the body of existing knowledge. On the other hand, the literature mostly includes the studies related to students' self-regulation behaviors while learning in various multimedia learning environments; its role in IVEs have been rarely investigated. For example, the existing research findings demonstrate that suitable management and appropriate learner support might advance students' self-regulation behaviors in multi-user virtual environments (MUVEs) (Perera and Allison, 2015). It is already mentioned that teachers or/and their self-regulation behaviors have a promoting influence on students' self-regulated learning (SRL) behaviors (Delfino *et al.*, 2010; Dignath and Veenman, 2020; Zimmerman, 2002). Since the technological developments resulted in evolutions in educational settings, further investigation on self-regulation behaviors is required to advance virtual worlds. Moreover, examining the use of VEs or IVEs in problem-solving may grasp learners' problem-solving skills since such environments are fully characterized.

Especially in the last two decades, educators have adapted their classroom to educational settings which include various technological tools (e.g smartboards, computer-based learning and multimedia materials, and learning apps). Researchers are also focused on such environments, particularly to maximize their effectiveness; so, studies have been conducted to examine the learning process of students at various grade levels and for a variety of content areas. However, studies regarding how teachers or teacher candidates self-regulate in these settings are limited. It is critical to create a frame which considers the self-regulation of teachers because teachers' instructional moves

while working with such environments might have an impact on students' learning process. For instance, Perera and Allison (2015) stated that supporting the learner appropriately can be influential in advancing the self-regulation behaviors of learners. It means that how teachers interact with such environments and their self-regulation behaviors might influence students' behaviors as well (Perera and Allison, 2015; Smeets, 2005).

Studies examining the teachers' SRL behaviors demonstrate that higher teacher motivation for promoting SRL is observed when teachers believe the strength of SRL behaviors (Dembo, 2001). It is also put forward that teachers who are experienced strategy users are able to model strategy use (Paris and Winograd, 2003; Kramarski and Kohen, 2017; Peeters *et al.*, 2014). Furthermore, following the COVID-19 era, integrating technological developments into classroom settings will be inevitable for teachers. The purpose of the study is to examine teachers' self-regulation behaviors in IVEs to have a fuller understanding of how they experience learning in such environments.

1.2. Research Question

For researchers, developing an understanding of teaching and learning practices in immersive virtual environments (IVEs) can be beneficial for supporting the advancement of educational practices. Therefore, the aim of this study is to examine the self-regulation behaviors of teachers in IVEs during problem-solving phases in a mathematical context related to exponential growth. The research question is represented by considering the aim of the study as follows:

(i) What are the self-regulated learning (SRL) strategies of mathematics teachers in immersive virtual environments (IVE) while working on a problem solving task involving exponential growth?

1.3. Significance of the Study

The Mathematics Teaching Program designed by the Ministry of National Education in Turkey describes the education system's purpose as raising individuals who have mathematical, digital, and key scientific/technological competencies among others (MEB, 2018). Those competences are significant since they are all connected to 21^{st} century skills that are expected to flourish in educational settings. Promoting use of multiple learning strategies and creating a variety of educational settings can offer opportunities to raise individuals having those competences/skills. However, in a study, conducted with teachers from different countries, OECD (2012) concluded that even with the active learning strategies, 21^{st} century skills are not distinctly highlighted by teachers. Therefore, even beyond the learning strategies and educational settings, teachers and teaching practices have a key impact on bringing those learner competencies to life.

On the other hand, the diversity of educational settings has also been affected by advancements in technology since various technologies are much more accessible in the last decades. Besides, the COVID-19 pandemic, which has a huge amount of influence all over the world, resulted in notable impacts on education, too. Because of the pandemic, classroom settings have been reshaped in a different way with technological tools. In the whole world, online educational settings have been the new classroom environment during school closures. It means that a collection of learning technologies has been involved in the educational settings for a variety of reasons. Educators have realized that even major changes towards integrating novel technologies into mainstream education can be dealt with (OECD, 2018). Nowadays VR is one of these technologies that are remarkably attractive. Thus, as an extension of efforts to integrate technology into teaching and learning, use of virtual environments (VEs) in the learning process and its affordances need to be investigated.

Towards this aim, a key point for consideration is that the widespread use of virtual environments (VEs) requires the focus of educators and researchers for increasing

the depth of understanding VEs. Harrison *et al.* (2011) and Smeets (2005) stated that both the selection and the use of ICT tools might have an impact on the learners and the learning process. Besides, how teachers act or behave during the teaching process can be also influential. Considering the focus of this study, teachers' self-regulation behaviors can be significant within their efforts to support their students' learning process in VEs (Perera and Allison, 2015; Wu *et al.*, 2021). Since self-regulatory behaviors can be improved, how teachers present the instructions and model those processes (e.g goal setting and self-evaluation) are also crucial (Zimmerman, 2002). Furthermore, it may result in the advancement of learning since the regulation actions support the activation of metacognition and deeper learning (Makransky and Peterson, 2021). Even though students' SRL behaviors and its significance on VEs have been studied, how teachers are able to use these environments and self-regulate in such environments, specifically in IVEs, are not elaborated on in the literature. It needs to be fully understood to support the further steps on promoting learners' SRL behaviors in novel settings, particularly for advancing teaching and learning in contexts of mathematical problem solving in IVEs.

2. LITERATURE REVIEW

In this chapter, the literature related to the Virtual Environments (VEs) and the Immersive Virtual Environments (IVEs) were reviewed. How students and teachers self-regulate their behaviors in these environments were also presented by previously conducted studies. Besides, how teachers' self-regulation behaviors influence learners or/and the learning process is another focus of the chapter.

2.1. Virtual Environments (VE)

Virtual environments (VEs) have evolved in decades and gradually started to be more alike to the real world. Users' purpose has also varied over those years. For example, it is used to support individuals to experience situations that we have limited or no access (Freina and Ott, 2015; Shin, 2017). It also means that it is possible to practice such situations without any risk or harm in those environments. Over many years, virtual environments (VEs) have been offered to classroom contexts to support students' learning. Nowadays, the advancement in technology and its reflections in human life increases the use of these technological tools in the classroom environment. There are studies that show virtual environments positively affect learners' engagement and motivation (Pintrich, 2003; Roussou, 2004). It is also concluded that VEs empower the user interaction with the environment(Makransky *et al.*, 2020).

Virtual reality (VR) or virtual environments (VEs) are described as the combination of technologies which embody the real or non-real situations by enabling the creation of synthetic and interactive three dimensional (3D) environments (Mikropoulos and Natsis, 2010). In other words, VEs are a kind of environment in which we perceive synthetic sensory information that is non-synthetic in reality (Bailenson *et al.*, 2008; Blaskovich *et al.*, 2002). Therefore, the images produced by digital computers serve to activate real-time interaction among users and the environments. Besides, an immersive virtual environment (IVE) intuitively surrounds the person (Bailenson

et al., 2008; Blaskovich *et al.*, 2002). It means that the sensory information is more engaging in an IVE than it is in the real world; so, the novel immersive technologies have created more interest in VR technologies (Radianti *et al.*, 2020). The images and sounds that surround the individual in an IVE creates a sense of captivating environment (Freina and Ott, 2015). Consequently, the affordances of the environment have a potential influence on the learning process in such environments. Indeed, many factors (e.g interest, embodiment, cognitive load, and self-regulation) have been investigated for their impact on the acquisition of knowledge in IVEs (Makransky and Petersen, 2021).

According to the Cognitive Affective Model of Immersive Learning (CAMIL) by Makransky and Petersen (2021), it is realized that current motivational and learning theories are applicable to less immersive media rather than IVE. Therefore, the model presents that the presence and agency of learners, which is caused by immersion and interaction (positive relation, path 1 in Figure 2.1.), has a positive effect in immersive media (Makransky and Petersen, 2021). As well as how these two characteristics, immersion and interaction, are affected by technological features, how learning through cognitive and affective processes are influenced by them are defined in the CAMIL. The model also defines the impacts of affective and cognitive aspects which are interest, intrinsic motivation, self-efficacy, embodiment, cognitive load, and self-regulation (relations, paths from 17 to 22 in Figure 2.1) (Makransky and Petersen, 2021).

How presence and agency affect those factors (relations, paths from 5 to 16 in Figure 2.1) and how they create ultimate learning outcomes is at the center of the CAMIL (relations, paths from 17 to 22 in Figure 2.1). As mentioned previously, these affordances of the virtual environment have an impact on affective and cognitive aspects that are deemed vital in the learning process. First aspect, interest, can be prompted by a new and severe experience that occurs in an IVE with the feeling of presence (Makransky and Petersen, 2021). The feeling of presence which is defined as “a feeling of being there” by Makransky and Petersen (2021, p. 942), is related to how convincing the virtual world is (Freina and Ott, 2015). Freina and Ott (2015) also stated the

authenticity and reality of the environment brings that feeling. Besides, a great amount of agency might have a positive influence on the interest of students (Makransky and Petersen, 2021). The existing literature which compares IVE and less immersive media environments serves to create an influential path that is resulted with large amounts of motivation and enjoyment caused by presence. Makransky and Petersen (2021) also stated that agency has an impact on intrinsic motivation felt by students in immersive learning environments. Likewise, according to the CAMIL, self-efficacy, embodiment and cognitive load demonstrate a positive relation with both presence and agency while learning in IVE (positive relations, paths from 9 to 14 in Figure 2.1).

The last affective and cognitive factor, self-regulation, shows a distinct characteristic that requires further investigation. Makransky and Peterson (2021) state that the potential relation can be in two ways either positive or negative. In the positive direction, it is stated that the immense amount of social presence that leads to producing ideas and actions to achieve the purposes of learning in IVE results in the advancement of self-regulated learning (potential positive relation, path 15 in Figure 2.1) (Zimmerman, 2013). On the other hand, since immersive learning environments require great engagement, they may not bring chances for natural reflections. It means that intense degree of presence and agency in immersive environments might not provoke a monitoring process (Makransky and Petersen, 2021). Thus, the case is the existence of a possible negative relationship (path 15 and 16 in Figure 2.1). In conclusion, as different from the other five factors, the self-regulation path can be in either positive or negative direction in the CAMIL. A lack of clarity on what kind of a relationship this path indicates calls for further investigation.

In conclusion, educators and researchers conducted studies to examine the role of self-regulation in various traditional and multimedia learning environments (Radianti *et al.*, 2020). However, there is a scarcity of studies which consider the role of self-regulation while learning or teaching in VEs, specifically in IVEs. Besides, the CAMIL model, with the current ambiguity in its structure, points towards a need for further investigation; therefore, it is important to understand the self-regulation behaviors in

IVEs for making better sense of these environments and how they can be exploited for teaching. Even though IVEs are rising educational tools which are characterized as beneficial in supporting the interaction and engagement in the learning processes, theoretical understanding related to how learners or teachers interact with those environments and to what extent it is conducive to SRL still needs improvement (Radianti *et al.*, 2020; Wu *et al.*, 2020).

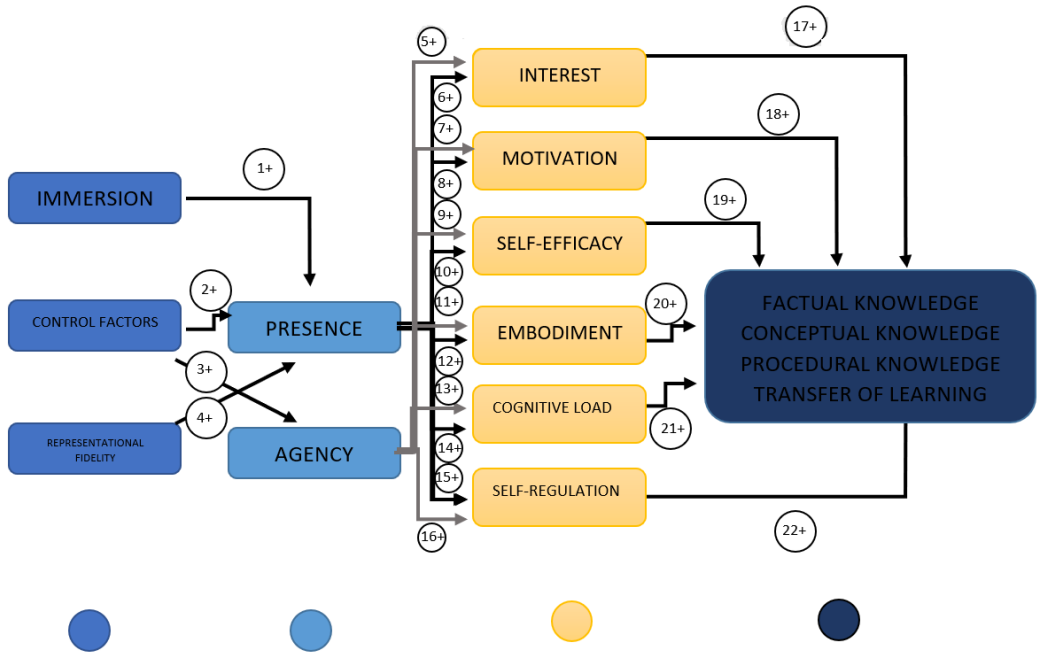

Figure 2.1. The overview of Cognitive Affective Model of Immersive Learning (CAMIL) (Makransky and Petersen, 2021, p. 943).

Not only how students learn but also how teachers experience such environments is critical for efforts to support the ultimate student learning process. Radianti *et al.* (2020) suggests teachers to experience VEs since planning the lesson which includes such technologies is complicated because of the extensive amount of design elements. Both design and implementation processes are significant for the efficient flow and effectiveness of lesson plans. Because of the complicated structure of those environments, it is already concluded that teacher skills related to use of such environments have a critical role in the process (Smeets, 2005). Radianti *et al.* (2020) also claimed

that teachers who had a good previous experience in VEs would be willing to be more practice-oriented while using such applications or environments. Furthermore, Martín-Gutiérrez *et al.* (2017) argued that teachers might tend to stay in their comfort zone instead of adapting new technologies to their plans. Nonetheless, teachers are expected to revise the learning settings according to students' needs and abilities. Teachers need to be able to self-regulate for understanding their students' needs and supporting their learning through improving their self-regulation (Paris and Winograd, 2003; Delfino *et al.*, 2010). Therefore, a key aspect that requires further attention from researchers is teachers' self-regulation and their ability to facilitate students' SRL.

2.2. Self-Regulated Learning (SRL)

Self-regulation is described as monitoring, regulating, and controlling the cognition, motivation and behavior to serve the goals which were set by learners in their learning process (Azevedo and Cromley, 2004; Moos and Azevedo, 2008a; Schraw, 2010). It is also referred to as the combination of planning, monitoring, and controlling abilities of students by Schraw (2010) and Greene *et al.* (2011). Even though common definitions of SRL exist, these definitions are built on different theoretical frameworks which concentrate on various constructs. In the 1970s, students who had a higher academic success were shown to employ monitoring and planning processes as different than students who have a lower academic success; then, in the 1980s, more compound and broader approaches were offered (Moos and Azevedo, 2008b). Then, the research examining the SRL in academic achievement resulted in further refinement of these approaches in the last 40 years.

Not only new models were developed but also the existing ones were improved over those years. For example, Zimmerman had two adaptations to his initial model which was first published in 1989 to demonstrate the influential factors in SRL (Panadero, 2017). Zimmerman's most recent Cyclical Phases Model includes three phases: forethought, performance, and self-reflection. While the *forethought* phase includes task analyzes, goal setting, and planning to reach the goals; in the *performance* phase,

learners pursue the task, monitor the process, and try some self-control strategies to be cognitively involved. Lastly, in the *self-reflection* phase, learners evaluate their own performance. In other words, it is the evaluation of the process to make adjustments in the forethought phase, or rechecking the goals and the plan (Zimmerman, 2000). Therefore, SRL is a cyclical process in which learners are responsible for their own learning.

Pintrich's SRL model is also widely used and it includes four phases: (1) *Forethought, planning and activation*; (2) *Monitoring*; (3) *Control*; and (4) *Reaction and reflection* (Pintrich, 2000). Each of the phases match four areas for regulation which are cognition, motivation/affect, behavior and context. Pintrich's work is crucial since it associates SRL and motivation. Pintrich's SRL model is unique since there is no other model that regards such areas related to regulation of behavior, motivation and affect (Panadero, 2017). Another model that is also commonly used, specifically in studies examining computer supported learning environments, is Winne and Hadwin's model of SRL (Panadero, 2017). It includes four phases, which are (1) *task definition*; (2) *goal setting and planning*; (3) *enacting study tactics and strategies*; and (4) *metacognitively adapting studying*, that are circular within a feedback cycle (Winne, 2011).

Winne (2011) also stated that motivation and emotions are significant factors that appear naturally when a learner interacts in a cognitive and metacognitive process. It is specifically mentioned that a learner can aim to regulate emotions likewise they regulate cognition. Since emotions involve cognitive processes, adjusting them is a way of emotion regulation (Sutton and Harper, 2009). The study of emotion regulation examines how people control the emotions they experience, when they feel them, and how they experience and express them (Gross, 1998). How people express emotions is also described as emotion regulation (Sutton, 2004; Sutton and Harper, 2009). Teachers similar to all individuals may not experience the same emotions in the same circumstances (Sutton, 2004). It means that the emotion regulation behavior may vary for individuals, or teachers. Since experienced teachers believe that effective

emotion regulation increases their effectiveness in the classroom (Sutton and Harper, 2009), examining how teachers regulate their emotions in different educational settings (e.g e-learning environments, multimedia environments, and virtual environments) is crucial for advancing classroom management in such environments.

Furthermore, a common implication of these evolving SRL models is related to creating an opportunity for students to be more active and strategic learners. Students are required to build their own strategies, aims and understandings (Moos and Azevedo, 2009). Therefore, over the years, educators and researchers have been interested in how students self-regulate their behaviors in various learning environments. Aside from the role of SRL in less immersive environments, its role in various virtual learning environments such as 3D Multi-User Virtual Environments (MUVEs) and spherical video based virtual reality (SVVR) has been on the agenda (Perera and Allison, 2015; Wu *et al.*, 2021).

MUVEs refer to a multi-user version of Virtual 3D Environments that can be attractive and effective in educational settings (Perera and Allison, 2015). The possible challenges on the management of MUVEs focused on examining the students' SRL in such environments. The results imply that effective MUVE administration and user assistance can encourage students' self-regulatory behavior, which is advantageous for their educational development (Perera and Allison, 2015). The self-regulated strategy (SRS) - based SVVR is a three moduled approach that includes a self-regulated monitoring module, a database module and a SVVR learning material editing module (Wu *et al.*, 2021). This SRS-based SVVR approach's investigation demonstrated that students in the experimental group did better than the control group in terms of self-regulation (Wu *et al.*, 2021). The results illustrated that in order to attain the desired learning outcomes as well as to help other students in accomplishing their learning objectives, it is critical to encourage and uphold a high degree of student self-regulation in immersive settings (Perera and Allison, 2015).

In less immersive environments, teachers' practice to foster SRL have been already investigated according to the instruction type: (1) *direct instruction of strategies* and (2) *indirect activation of SRL* (Dignath and Veenman, 2021). While direct instruction is the way that strategies are directly fostered by teachers to activate and motivate students' SRL behaviors, indirect activation of SRL is indirect initiations within an educational setting that encourage students to regulate their own learning (Dignath and Veenman, 2021). Even though there are studies on how direct and indirect strategies are observed in school context, IVEs still require further investigation because it is attracting growing interest for classroom use as well as out of school contexts (Bailenson, 2008). Examining teachers' self-regulation behaviors in IVEs would assist educators in advancing the design and use of IVEs for education purposes.

Within the ongoing research on SRL, one of the critical issues is the measurement of SRL. How it is measured has been investigated, since it is commonly examined in various learning settings for different purposes. Even though the variety of purposes might cause a difference in the measurement, some common protocols are represented in the study by Winne and Perry (2000). While self-report questionnaires, structured interviews, and teacher judgements are frequently used protocols to measure SRL as an aptitude, which considers SRL as relatively more stable across contexts and events, SRL as an event is measured in a contingency by using think-aloud measures, error detection tasks, trace methodologies, and observation of performance (Winne and Perry, 2000). Approaching self-regulated learning as an aptitude or event may be preferable under different conditions, and each approach has pros and cons. Since the SRL reflections produced by each protocol vary slightly, using more than one indicator can be meaningful. However, measurement with a few protocols is still inadequate when the protocols are all for aptitude or for event (Winne and Perry, 2000). That is why the current study's measures are both structured interviews and think-aloud measures. In this manner, how students self-regulate their behavior on IVEs and how SRL is measured in previously conducted research on such environments will also be presented in the next section.

2.3. Self-Regulated Learning (SRL) in Immersive Virtual Environments (IVEs)

In order to better understand the self-regulated learning (SRL) behaviors of learners in different contexts engaging with various content, a careful investigation of learners' self-regulation in such contexts has been critical. Since researchers already agree on students' likely success in traditional settings when they adequately self-regulate, understanding self-regulatory behaviors in novel conditions needs to be explored and characterized to promote students' SRL behaviors. While various learning technologies (e.g., e-learning environments, computer-based learning environments, and virtual worlds) are rapidly spreading in learning environments, understanding how learners successfully perform in those environments and why they struggle can be beneficial in the advancement of learning settings and accompanying teaching moves (Azevedo and Aleven, 2013; Perera and Allison, 2015). For instance, Shea and Bidjerano (2010) found that learners can experience an effective learning process in virtual environments when students are able to self-regulate while engaging in learner centered tasks. Even though there are multiple educational theories, models and practices of SRL that researchers agreed on, how to effectively support kids in developing the ability to self-regulate their learning is still not well known (Dignath and Veenman, 2021). For this reason, how the evolution of learning environments and teaching practices have an impact on students' SRL have already been on the research agenda (Peeters *et al.*, 2014; Dignath and Veenman, 2021). Teachers have a critical role in SRL promotion for learners by making decisions on the setting and carrying out the actual execution of the teaching practices (Zimmerman, 2002). Over the years, studies addressed how teachers' instruction strategies on SRL promotion vary for different conditions such as grade level, content, or context. Teachers' transfer of SRL abilities in novel contexts and supporting students' SRL improvement have been reported as aspects requiring support and development (Delfino *et al.*, 2010). Furthermore, teachers' knowledge, beliefs and teaching practices have been found as inconsistent (Dignath-van Ewijk and van der Werf, 2012; Dignath-van Ewijk 2016). That is why, pre-service teachers' training or teachers' professional development in SRL is characterized as significant.

A framework of teaching approaches to enable SRL is presented by Dignath and Veenman (2021) after reviewing studies which examine direct instruction and indirect activation of SRL. The overview of studies showed that only a very small amount of metacognitive strategy instruction has been documented persistently over entire samples (Dignath and Veenman, 2021). Similar results related to the planning phase were presented in the overview (Dignath and Veenman, 2021). In a study by Spruce and Bol (2015), many teachers' ideas on monitoring activities in SRL were not definitely clear; planning or evaluation were rarely identified in teachers' explanations. On the other hand, Veenman and colleagues (2009) showed that teachers' strategies on instruction mostly addressed the orientation and planning instead of monitoring and evaluation.

Since there is a limited amount of research related to self-regulation in virtual environments, there is a continuing need for investigating teachers' SRL and its impacts on learners in virtual environments. It is already suggested that there is a requirement of research which addresses whether self-regulation of learners can be promoted in VR and to understand how the learning environment enables and supports learners' self-regulation (Schunk 2005; Perera and Allison, 2015). For example, Makransky and Peterson (2021) stated that if a learner is active in his/her learning process, it might be also beneficial in the process of self-regulated learning (SRL). So, it is claimed that promoting self-regulation and learning by presenting reflection activities during or after work in immersive virtual environments can be significant (Makransky and Peterson, 2021). In this study, a similar strand of research is conducted with teachers, as an important stepping stone towards integrating IVEs into teaching practices.

2.4. Virtual Environments (VEs) in Mathematics Education

Integration of Virtual Environments (VEs) in the learning and teaching process and its influences on improvement of twenty-first century skills have been significant in today's education world. Because of the contents with complex structure that is hard to comprehend for learners, mathematics has been quite popular in learning and teaching settings that are integrated into such technologies. Involving complicated mathemat-

ical contents and problem-solving skills in VEs can be considered as the cornerstone for educational growth with virtual words since mathematical comprehension and the unique features of VEs reciprocally nourish each other. First of all, VEs encourage deeper cognitive stages, critical thinking, and comprehension and transition of concepts with the support of visualizations (Mikropoulos and Natsis, 2010). In common, they also support an experience on multiple perspectives (Mikropoulos, 2006) which might influence the advancement of problem-solving skills that require critical and comprehensive thinking in various ways. Construction of knowledge and embodiment of learning with social experience in realistic contexts also expected to be encouraged in VEs (Mikropoulos, 2006) and problem-solving processes on exponential growth are possibly advocated by these characteristics of VEs, in the game that the current study is based.

3. METHODOLOGY

This chapter includes the information related to design, participants and instrumentation process by considering the purpose of this study. It also covers the ethical considerations and practices implemented by the researcher. A detailed explanation of the environment that participants interacted with and the data collection processes in that environment is also presented. Finally, the data analysis processes, and the role of the researcher are explained in detail.

3.1. Research Design

Creswell and Poth (2016) state that qualitative research is conducted when there is a requirement to investigate a problem or an issue with a purpose of making sense of the phenomena under investigation in detail. It is also expressed that the reasons for conducting qualitative research can be to figure out the surroundings in which the problem or issue exists (Creswell and Poth, 2016). In this study, the aim is to investigate Immersive Virtual Environments (IVEs) from a SRL perspective. Since IVEs are having an increasing amount of attention in educational settings and they offer fruitful opportunities for exercising SRL, advancement of such learning settings can be only possible with their comprehensive analysis. Creswell and Poth (2016) contend that a case study is a proper method for improving an in-depth understanding of cases. For this study, multiple cases were chosen to document self-regulated learning behaviors of a variety of teachers in such contexts. It is a multiple case study (or a collective case study) that is designed to investigate mathematics teachers' SRL behaviors in an IVE.

3.2. Participants

Considering the aim of the study and the IVE, a video game, Pandemic by Prisms, selected for analysis, a group of mathematics teachers who were able to perform with

VR headset in a video game in English is invited to attend the study because the game in the IVE targeted the development of a mathematics concept, exponential growth, and required English proficiency. Therefore, mathematics teachers with a command of English were chosen as the target population of the study. Convenience sampling method is used by reaching out to the graduates of primary mathematics education program that are available to contact. Middle school mathematics teachers who graduated from a university in Istanbul, Turkey, and whose language of education is English, were invited to participate in the study to ensure the English proficiency level of participants.

One hundred seventy eight graduates were invited to the study via a sharing in the social media group of graduates. Sixteen of them contacted the researcher for further details, eleven of them voluntarily attended the study, and they were all first-time VR users. For those eleven teachers, background information is presented in Table 3.1. Primarily, all participants were in-service mathematics teachers teaching at the middle school level, except for one who was also teaching students at the high school level. Only two teachers were male. All teachers had at least 2 years of teaching experience, with a mean average of 3.7 years. The most experienced teacher had 10 years of experience. While two of the teachers work in public schools, three of them work in private teaching institutes. The remaining six teachers work in private schools. As different from all the other middle school teachers, there was one teacher who worked in a private institute teaching both middle and high school students. The teachers are randomly numbered from 1 to 11 by the researcher for reference due to confidentiality issues. Furthermore, two teachers received master's degrees from the same university. Three teachers are still enrolled in a master's program at various universities. All the master's programs are in the education faculty.

Table 3.1. Participants' Background Information.

	Teaching experience	**Gender**	**School type**	**Grade level**	**Education Level**
Participant 1	0-2 years	F	Private school	Middle school	Master student
Participant 2	3-5 years	F	Private school	Middle school	Undergraduate degree
Participant 3	0-2 years	F	Public school	Middle school	Undergraduate degree
Participant 4	9-11 years	M	Private school	Middle school	Master degree
Participant 5	6-8 years	F	Public school	Middle school	Master degree
Participant 6	3-5 years	F	Private school	Middle school	Master student
Participant 7	3-5 years	M	Private institute	Middle school	Undergraduate degree
Participant 8	3-5 years	F	Private school	Middle school	Undergraduate degree
Participant 9	3-5 years	F	Private institute	Middle school	Master student
Participant 10	3-5 years	F	Private school	Middle school	Undergraduate degree
Participant 11	3-5 years	F	Private institute	Middle and high school	Undergraduate degree

3.3. Instruments

All the instruments of the study were arranged for the project (EARLI, 2020) which involves research groups from 5 different countries that are gathered to comprehend related to pre-service teachers' SRL behaviors in VR based systems. The project team in Turkey, that the researcher has been involved in, collected data from a group of 12 volunteering teacher candidates. Data collected for the project, especially the data collection and analysis processes of the project, has constituted the pilot study for this research. Since the data collection steps of all countries completed before this study, all groups reviewed the overall instrumentation process in the project. Instruments, procedure and data analysis were arranged by making subtle adjustments after the pilot study, according to the purpose of the current study.

While the pre- and post-test were conducted to observe learning outcomes of teacher candidates in the project, in the current study only the pre-test was used to separate any case(s) that were possibly distinct from the others. The questions in the tests are selected according to content related to exponential growth and they were parallel to the ones in the video game, Pandemic by Prisms. According to the purpose, before the learning session, participants' content knowledge related to exponential

growth was firstly measured by using the pre-test. Five mathematics questions related to exponential growth which are consistent with the game were asked in the pre-test (see Appendix A). As relevant to the purpose, there was no time limit to answer the questions. Pre-test includes 5 questions that were checked for their content validity with the pilot study, which is the study of Turkey for the project.

Nine of the eleven teachers responded to all 5 questions correctly. Two teachers answered 4 out of 5 questions correctly and their one mistake was question 2 and 6 in the pre-test (see Appendix A). However, the teachers' did not differ in terms of their pre-knowledge regarding the mathematical concept focused on in this study which is exponential growth as it can be seen in the records. A factor that might have been influential on the pre-test results is the teachers' command of English. Only teachers 1 and 6 actively used English at the time of the study since teacher 1 continued her master program at the same university, and teacher 6 worked in a private school where the language of education was English. Some of the teachers stated that they were having difficulties in understanding or following the instructions/tasks because of English. Then, teachers 3 and 10 (T3 and T10) realized their mistakes on the pre-test during the individual learning sessions. Their statements were related to language barriers. Indeed T10 made the following explanation during the learning session, explicitly pointing out this issue:

> "The same question was in the test (referring to pre-test). ...In option B, it says 'multiplying by 5', isn't it? What does a factor of 5 mean? ...(a pause after hearing the explanation in Turkish) I did it wrong in the test, okey". (see Appendix H, extract 1)

After the application, participants attended a semi-structured interview (see Appendix B) conducted by the researcher, which had the same questions as the interview of the project. Only the question directed to the teacher candidates was restructured according to in-service teachers' experience (see question 10 in Appendix B). As in the project, while the participants were free to use their native language (Turkish) or English, the researcher asked the questions in English except the points for which

further explanation was needed. The interviews took approximately 15-20 minutes to complete. Parallel to what was intended in the EARLI project, the purpose was to have access to participants' opinions on what they did and why.

3.3.1. Pandemic by Prisms: An Immersive Virtual Environment

An immersive virtual environment (IVE), an algebra learning game, was used in this study. It was developed and published by Prisms of Reality Inc. The game, Pandemic by Prisms, "enables kids, parents, and teachers to deepen their understanding of exponential functions through a problem that is affecting all of our lives today, a global pandemic" (Prisms, 2021). It creates a chance to practice the mathematical idea of exponential growth and to develop skills for working with exponential functions (MetaQuest, 2021). The Prisms of Reality Inc. (n.d.) defined the purpose of the design as to gear the participant with basic algebra skills to comprehend the knowledgeable decision making process about an ongoing health issue, relatable to COVID-19 pandemic. The game focuses on expanding the comprehension of exponential functions by visualizing them which is a problem solving process. It presents an opportunity for users to think algebraically in the context of a global problem, the pandemic, to analyze and solve it. The game demonstrates the mathematical model used for analyzing the spread of a virus. The overall purpose contextualizing the work is modeling real-world problems by using mathematics in an IVE and developing understanding related to the key mathematical concept involved (Prisms of Reality Inc., n.d.).

The game consists of two modules that include separate activities (see Figure 3.1) that participants start experiencing after they wear VR goggles. Participants begin with module 1 to get familiar with the environment. They first learn about a virus in the news; then, they become a witness of the virus' spread by joining a task force in the role of a researcher assigned to them in the game (see Figure 3.2). Later, they are invited to a lab to observe the spread of virus and to resolve the potential risks with an aim to support their community by using algebra. First module includes one matching activity related to precautions for the pandemic (see Figure 3.3). When the participants

successfully complete the matching activity, the module screen in Figure 3.1 is viewed and they move into module 2.

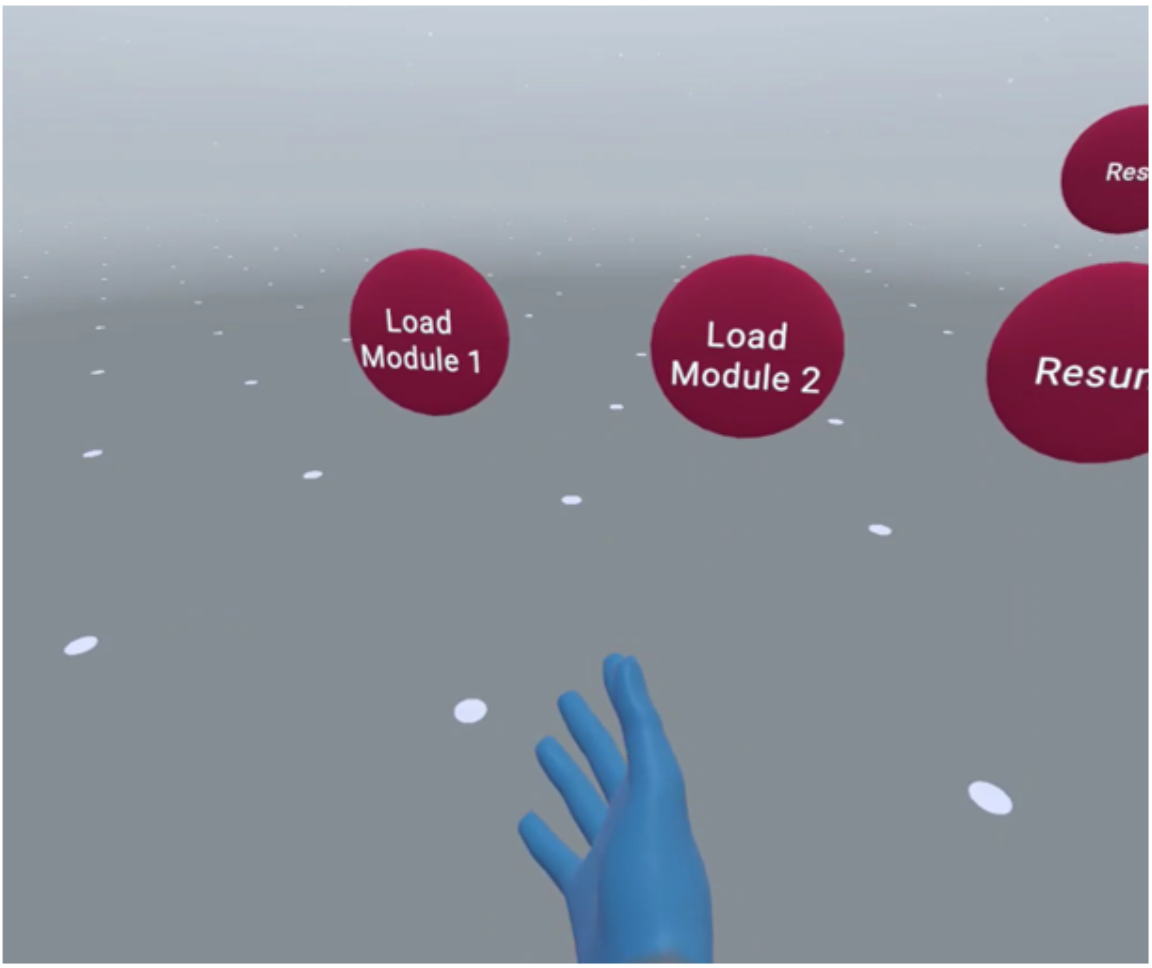

Figure 3.1. Screen Capture from the Entrance of Modules.

Figure 3.2. Screen Capture from the Spread of Viruses in the Module 1.

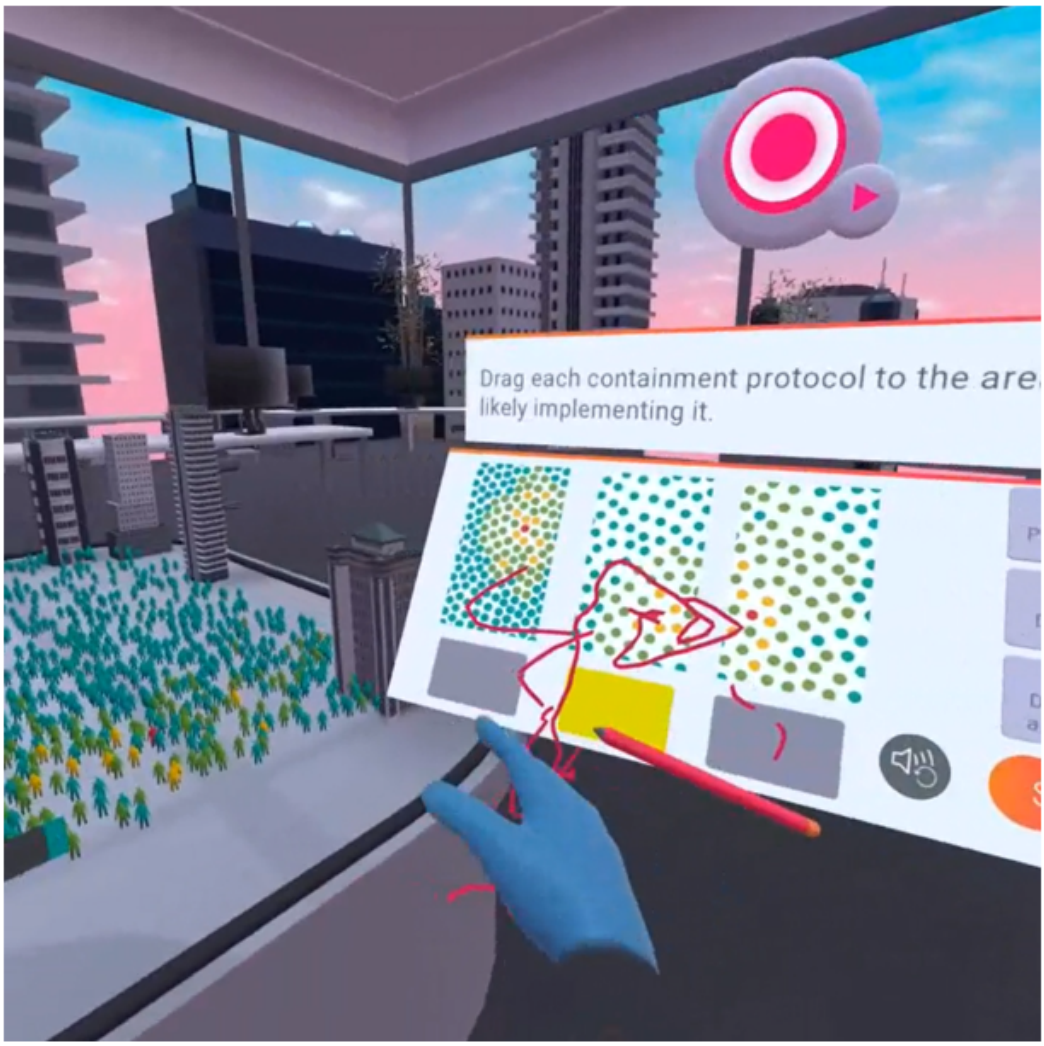

Figure 3.3. Screen Capture from the Matching Activity.

In the second module, more problem solving oriented practices are involved. Participants firstly fill in a table with the number of infected people shown in a graph; then, they convert the numbers into an exponential form (see Figure 3.4). At that point, a video explanation related to exponential functions shows up (see Figure 3.5). After the explanation, participants are expected to find an equation that represents the number of infected people week by week. The animated graph of the equation has shown after the participant writes the correct equation. Two questions related to the position of the graph in other possible scenarios are asked at the final steps for analyzing the process during the problem solving in the role of a researcher.

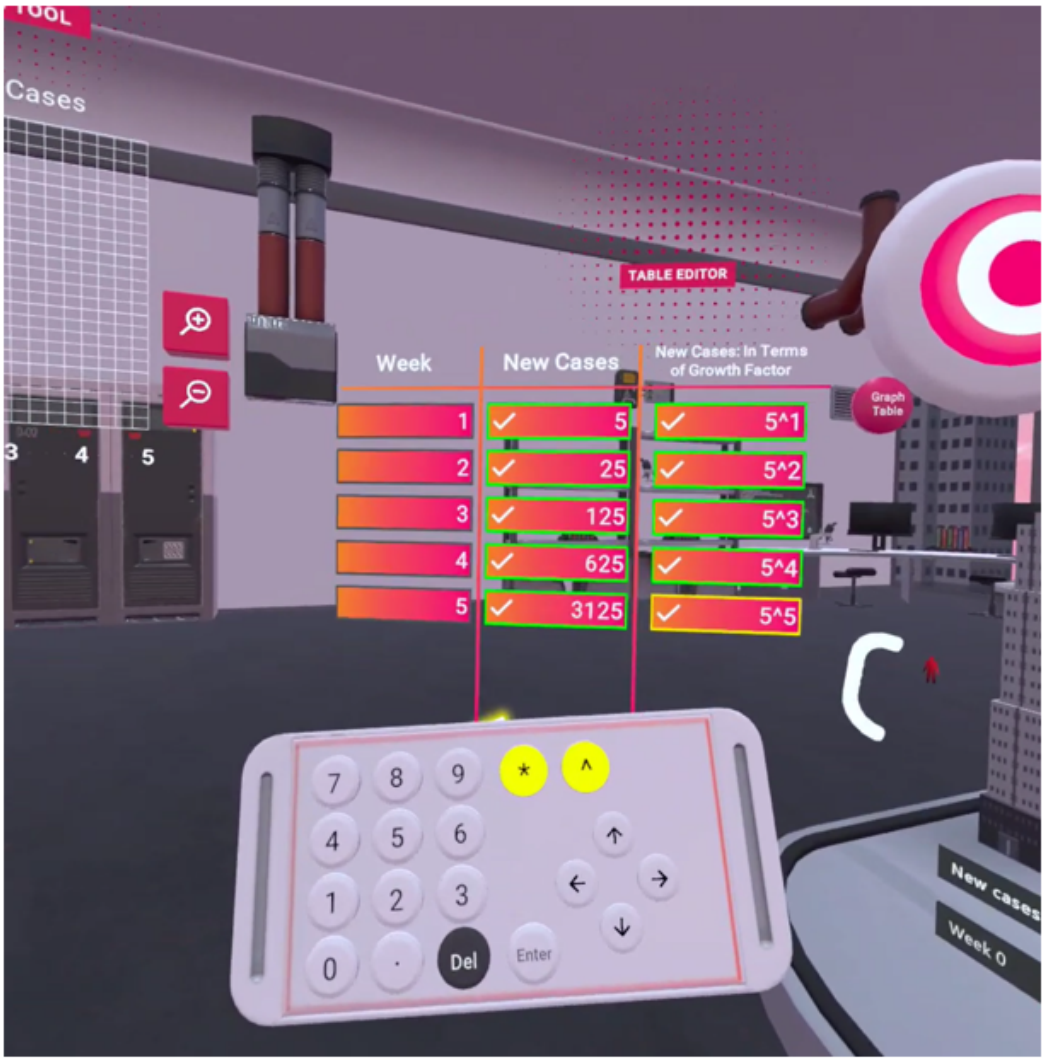

Figure 3.4. Screen Capture from the Table Filling.

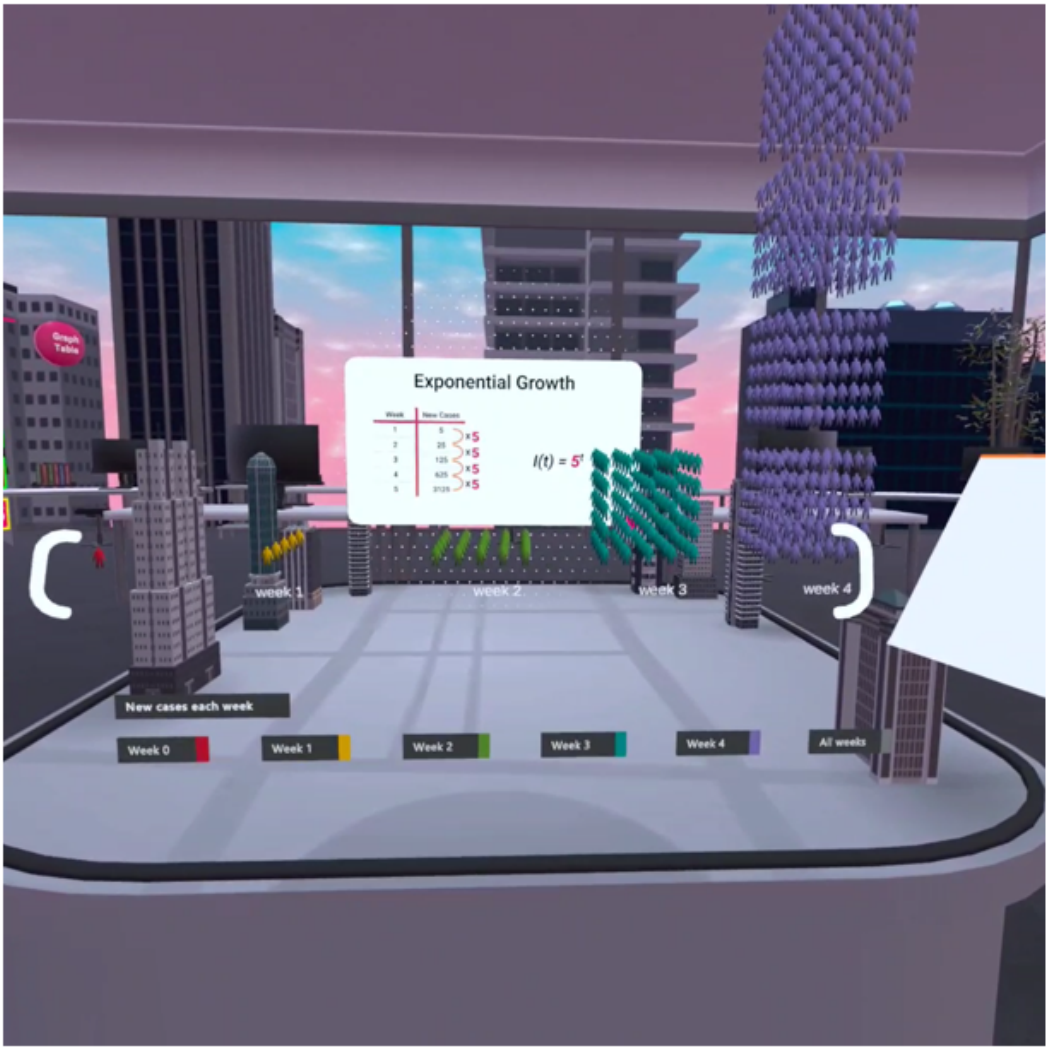

Figure 3.5. Screen Capture from the Video Explanation.

3.4. Procedure

For this study, the approval of Boğaziçi University Institutional Review Board for Research with Human Subjects is taken for the project titled as "Using Multimodal Data from Immersive Virtual Reality (VR) Environments for Investigating Perception and Self-Regulated Learning (SRL)" (see Appendix C for the original version in Turkish). Before the VR experience, all volunteers were informed about the overall process which is also included in the consent form (see Appendix D). They were asked to read

and sign the informed consent form. Any questions about the process of the study were answered by the researcher. One copy of the signed form was offered to the participants. As it is written in the consent form they were free to leave any second of the study without any consequences (see the form in Appendix D).

The study ran in individual learning sessions that lasted for approximately 70-90 minutes including filling out the consent form. In the learning session, after participants signed the consent form, they completed the pre-test in about 15 minutes or less. After a participant completed the pre-test, the environment and the procedure were presented to them by following a protocol. The protocol was also revised according to the exclusions that the researcher and the advisor made in the project. According to the protocol, before the participants started wearing the virtual reality glasses, by pointing out the possible risks of IVE, they were reminded that they were free to leave the study any time they wished in case of discomfort. During the learning session, after the pre-test, Pandemic by Prisms, the task explained in the previous section, was introduced to the participant. They worked on the tool to complete the two-module game that took approximately 40-50 minutes. While module 1 took approximately 10-15 minutes, module 2 lasted for approximately 30-35 minutes before participants reached the end of the game.

Each participant was expected to comply with the think-aloud protocols which are explained after the introduction of the IVE. The explanations of the protocol is in Appendix E. The researcher also reminded the participants to think loudly after 5 seconds of silence during the learning session. The aim of using a think-aloud protocol was to produce data for SRL includes the learner in a specific learning activity, assignment or problem-solving session without further limitations when or what a learner may report by thinking out loud regarding mental states roughly at the same time as their occurrences (Winne, 2010). The researcher transcribed all video records and semi-structured interviews that they collected during the procedure.

3.5. Coding of Self-Regulated Learning (SRL) Behaviors and Data Analysis

This current study examined participants' self-regulatory behaviors in immersive virtual environments (IVEs). An in-depth data analysis process was conducted as required in qualitative studies. Therefore, written transcripts of think-aloud records, and interviews collected in the study were analyzed comprehensively. For the analysis, the coding scheme developed by the project team was reorganized and used in the current study. Since the purpose of the project is obtaining data in cognitive, affective, metacognitive, and motivation self-regulated learning (SRL) behaviors while using VR-based systems, this study does not focus on motivation the way that the project did (e.g., by using a self-report questionnaire). The reason is the project was focused on both phases (i.e., forethought, planning and activation; monitoring; control; reaction and reflection) and areas (i.e. cognition, metacognition, motivation, and context) according to Pintrich's SRL model and also some other aspects related to perception and motivation. On the other hand, the current study is more phases oriented in order to create an overall frame on SRL behaviors in VEs. Development process of the whole coding schema was conducted by the project team. In this process, 6 main steps were followed by the project team.

At first, open coding of 3 interviews was completed by one of the teams, and the initial codes, with a blend of bottom-up and top-down categories, were offered to all teams. During open coding, the code scheme used by Azevedo and Cromley (2004) (see Appendix F for SRL variables) was taken as a starting point. Discussions with the sub-team were the second step in which the definitions of codes were decided. In the third step, three countries' teams searched for examples in 1-2 interviews per team. After these categories, the scheme was rearranged in step 4 with some adjustments and deletions. The fifth step was a multi-layered feedback process. The first two parts of this multi-layered process were to check the structure of the coding scheme for each segment and the clarity of operational definitions and examples. The third part was considering the appropriateness of purpose to refer to research interests and

questions. In this third step, the coding scheme's two segments were separated by the researcher according to the purpose of this study. To be more specific, the scheme had two separate parts that analyzed the aspects of SRL and *impressions and possible uses of VR*. By considering the purpose of the study, aspects of SRL part was used in the analysis process (see Appendix E).

Last part of the multi-layered process was deciding on quality assurance with interrater reliability and researcher triangulation. Blind codings were done by taking a subset of the data; then, agreement was calculated with Cohen's Kappa. Differences were discussed until the agreements were reached. After the project team finalized the coding scheme, the current research's data analysis process followed the same quality assurance process. A participant's transcript randomly selected from the data in the current study was analyzed with a blind coding by the researcher and another team member in the project. To be reported, percent agreement was found as 0.83 and Cohen's Kappa was found to be substantial with a value of 0.77.

Content analysis is a process carried out with variations of written documents, pictures, films or videos, and audiotapes from the forms of human communication (Lune and Berg, 2012). In this qualitative study, the video records and semi-structured interviews, which were conducted and transcribed by the researcher, were the data. The analysis aims to *code* the material as information in a way that may be applied to answer research questions (Lune and Berg, 2012); therefore, in the current study, the content of transcripts from the video records and interviews turned into data by coding with an already developed coding scheme. Then, the analysis reported in the findings section within some quotes.

Creswell and Poth (2016) refer to the role of a researcher to ensure the precision of a qualitative study within the validation strategies. The researcher consults several, distinct sources to offer supporting evidence (Lincoln and Guba, 1985; Yin, 2014); so, in this study, the data sources are triangulated for this purpose. Another term, transferability (Lincoln and Guba, 1985), can be ensured by carefully explaining the

research background and the key underlying assumptions. The analysis of the current study and interpretations presented in this point of view by considering the role of a researcher for accuracy (Creswell and Poth, 2016).

4. FINDINGS

In this chapter, analysis and findings of this study are presented. It consists of 4 main sections relating to 4 basic phases of self-regulated learning (SRL) - planning, monitoring, strategy use (control), and evaluation. These sections are chosen according to the coding process and overall analysis.

4.1. SRL Behaviors Related to Planning

The first self-regulated learning (SRL) behavior, planning, operationally defined as the aims that the participants set for themselves for the VR task, and anticipation of what the experiment would involve (see Appendix G). It is structured as four main subcodes, relating to the aspects of planning: *setting learning goals, setting achievement goals, anticipating difficulties*, and *preparation for the task*. There is also one additional subcode relating to an explicit expression of lack of planning: *reporting absence of planning (or goal setting).*

The frequencies of SRL behaviors according to phases are shown in Figure 4.1 which includes the total of codes in think-aloud and interview data for all teachers. Besides, Table 4.1 also demonstrates each teachers' SRL behaviors. As a result of the coding of both data sources, planning has been found as the least occurring SRL strategy (see Figure 4.1). Except Teacher 1, all teachers referred to a planning process or absence of planning (or goal setting) (see Table 4.1). As can be seen in Figure 4.2., 20% of teachers referred to the absence of a goal setting process. Teachers 5, 9, and 11 specifically addressed that there was no goal setting process during the learning session. In this manner, some of the utterances by these teachers were as follows:

"There was not any goal setting". (T5) (see Appendix H, extract 2)

"I didn't determine a purpose". (T9) (see Appendix H, extract 3)

Many of the subcodes for the planning phase were setting achievement goals as it is seen in Table 4.1 'total' column in the bottom for planning phase; however, there were no goals set for learning. Since teachers have previous knowledge on the exponential functions, they may not think about the setting learning goals related to the content. The teachers set goals for answering the questions correctly or completing the task successfully or/and on time and they referred to it mostly during the interviews when it is specifically asked. On the other hand, both preparation for the task and anticipating difficulties are seen only once. For example, while an extra time did not offer for planning, T4 stated that they prepared themself for the task after they completed the pre-test; later, they referred that in the interview as the following:

> "...it will be something related to exponential function, something like this will come up; then, here is the classic virus. Viruses will spread exponentially, ok, there will be such an activity". (see Appendix H, extract 4)

Table 4.1. Frequency Distribution for Aspects of SRL Phases.

Phases	Aspects	T1	T2	T3	T4	T5	T6
Planning	Setting achievement goals		1	3	1 (1)		1
	Anticipating difficulties						
	Preparation for the task				1		
	Reporting absence					1	

Table 4.1. Frequency Distribution for Aspects of SRL Phases. (cont.)

Phases	Aspects	T1	T2	T3	T4	T5	T6
Monitoring	Monitoring progress	5 (4)	1 (1)	3	1 (1)		1 (2)
	Previous knowledge	1		-1	1 (1)		3
	Content understanding	-1	1 (2)	1 (3)	-1		1 (1)
	System/task understanding	-5	2 (6)	1 (5)	2 (9)	1 (4)	-3
	Relying on system feedback			3		1	-1
Strategy Use	Behavioral regulation	2 (6)	1 (6)	2 (7)	-8	2 (4)	-6
	Emotional regulation	1	3	2		2	
	Cognitive/ metacognitive regulation	13 -10	3 (8)	8 (5)	-11	3 (10)	3 (11)
Evaluation	Performance positive evaluation	2		1 (1)		2 (1)	
	Performance negative evaluation	3 -3	4	4 (1)	4	4 (6)	3
	Perceptions of Pandemic VR - Positive	1	3	6	1	4 (1)	2
	Perceptions of Pandemic VR - Negative	1			4	3 (1)	
	Total	29 (29)	19 -23	34 (23)	15 (32)	23 (27)	14 (24)

Table 4.1. Frequency Distribution for Aspects of SRL Phases. (cont.)

Phases	Aspects	T7	T8	T9	T10	T11	Total
Planning	Setting achievement goals	-1	1		1		8 (2)
	Anticipating difficulties	-1					-1
	Preparation for the task						1
	Reporting absence			1		1	3
Monitoring	Monitoring progress	1	1	1	2 (1)	2 (3)	18(12)
	Previous knowledge	1 (1)		1	1	1	9 (3)
	Content understanding		1 (1)	-1	-1		4 (11)
	System/task understanding	-5	2 (6)	1 (5)	2 (9)	1 (4)	-3
	Relying on system feedback	1				1	6 (1)
Strategy Use	Behavioral regulation	-4	-8	1 (4)	-7	-2	8 (62)
	Emotional regulation		-1				8 (1)
	Cognitive/ metacognitive regulation	2 (2)	2 (1)	2 (2)	3 (3)	1 (1)	40 (64)

Table 4.1. Frequency Distribution for Aspects of SRL Phases. (cont.)

Phases	Aspects	T7	T8	T9	T10	T11	Total
Evaluation	Performance positive evaluation		1				6 (2)
	Performance negative evaluation	2	2 (3)	1 (1)	-1		27 (15)
	Perceptions of Pandemic VR - Positive	4 (2)	2 (3)	2	2 (1)	2	29 (7)
	Perceptions of Pandemic VR - Negative	2 (1)	1 (1)	1		2	14 (3)
	Total	13 (14)	11 (21)	11 (11)	9 (17)	10 (7)	188 (228)

Note. Numbers in the brackets refer to the frequency of codes in think-aloud data and the others refer to the interviews' coding on teachers' SRL behaviors in an IVE, Pandemic by Prism

4.2. SRL Behaviors Related to Monitoring

Another phase of self-regulated learning (SRL) behavior, *monitoring*, corresponds to checking different aspects of one's performance during the VR task (see Appendix G). There are 5 main subcodes of *monitoring* - *monitoring progress, relying on system feedback*, content understanding, system/task understanding, and previous knowledge. Besides, there is a subcode for explicitly reporting the absence of monitoring. It is one of the phases that was met most frequently compared to the total of other phases for all teachers (see Figure 4.1). Table 4.1 indicates that each teacher referred to at least one of the monitoring processes multiple times in the interviews. Each teacher also

displayed a monitoring process at least 3 times while engaged in the game according to the think-aloud data. The most common monitoring aspect was thinking about *system/task understanding* (see Figure 4.1). The subcode is revealed mostly in the think-aloud data (see Table 4.1) since the participants tried to explain the process that they handled and how their thinking focused on exploring and making sense of the experience. However, the experience of SRL behavior reflected in a much more structured way mostly in the interviews. For example, in the interview, T2 made the following explanation:

> "I thought, in the beginning, I should click each time and then I accidentally just tapped it with the hand and then I got like I need to tap, I don't need to click the button..." (see Appendix H, extract 5)

T2's statement was in a positive direction which referred to how the individual tried to support understanding of the interaction with the environment as they progressed. An example in a negative direction was mentioned by T5:

> "In the first part, there were the simulations, 3 different simulations, in there, I couldn't totally comprehend what it means". (see Appendix H, extract 6)

The other aspect found in the study with a high frequency, which refers approximately to 25% of the monitoring incidents, was *monitoring progress* (see Figure 4.1) which occurred in a balanced way in the think-aloud performance and interviews. However, teachers who attended the study didn't show the monitoring progress behavior in similar frequencies (see Table 4.1). Participants explained their monitoring behaviors mostly with a specific behavior such as checking/looking at a table or a graph for answering the multiple choice questions in the task. Except teacher 5, all participants stated a regulation behavior that was categorized as monitoring progress at least once (see Table 4.1). For instance, teacher 10 declared that they checked after all the tasks were completed and before they sent to the console or submitted (see Figure 4.1 for the console that has a submit button that belongs to T9). Some other statements by participants were as follows:

"...I counted the people there to confirm that". (T3) (counting the number of modeled people in innovative bar graph in the first table filling activity) (see Appendix G, extract 7)

"...I mean, I checked a few times whether I did it right or I wrote these numbers correctly". (T9) (referring to the table filling activities) (see Appendix H, extract 8) (see Figure 4.1)

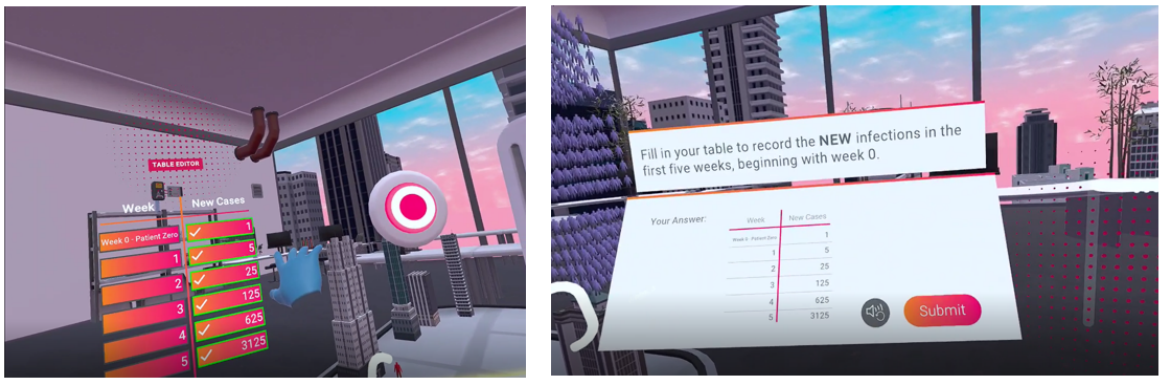

Figure 4.1. Screen capture from teacher 9's table filling activity.

As shown in Figure 4.2, the other aspects of the monitoring phase observed were less frequently. From more frequent to rarely observed, *content understanding, previous knowledge*, and *relying on system feedback* were the aspects of monitoring behavior observed during the study (see Figure 4.2). For example, T3 showed a content understanding while trying to write the equation to form a graph in the game. They used the existing understanding to progress through a specific part of the game. They verbalized this process with the following statement:

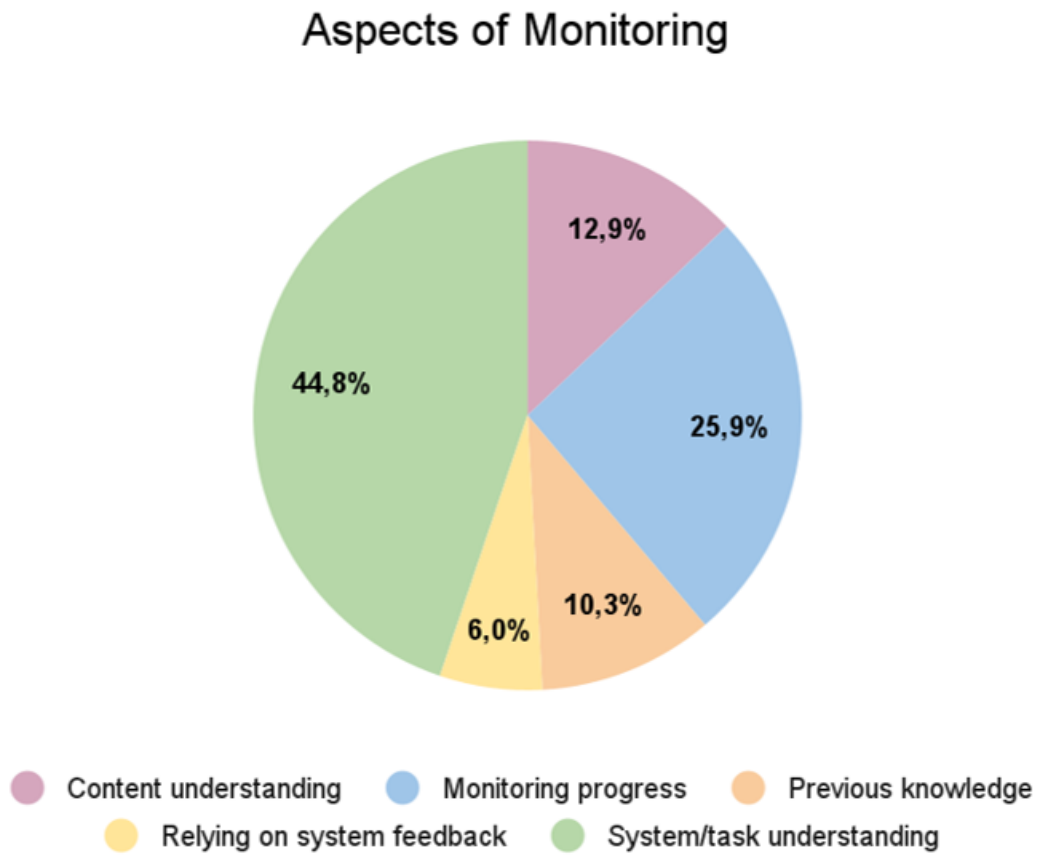

Figure 4.2. The Distribution of Teachers' References to Aspects of Monitoring Behaviors.

> "Do I write 'x' on top of 5? Will 't' not change? It needs to change. (Pause) Okey, it's the same (laugh). It doesn't have to be $y=5^x$". (see Appendix H, extract 9)

Previous knowledge is operationally defined as pre-existing knowledge about the topic and content of the task influences one's performance; so, the content in the game, exponential numbers, revealed previous knowledge in the findings. Participants expressed that in similar ways. The following sentences are belong to teachers:

> "When I understand once, it is exponential, I knew how it will go". (T6) (see Appendix H, extract 10)

> "These are the things that we know already". (T7) (see Appendix H, extract 11)

> "It is supposed to increase as multiples, I knew that anyway". (T9) (see Appendix H, extract 12)

While participants activated their previous knowledge during the think-aloud process, mostly without mentioning it, in order to remember mathematical strategies or content; in the interview, they mostly just mentioned the existence of the previous knowledge as in the examples above. In this manner, participants' statements about their overall experience showed that they were comfortable with the content. As it is mentioned previously, monitoring phase was rarely found as relying on system feedback with 6% (see Figure 4.2). Participants' statements mostly seen in interviews (see Table 4.1. for the distribution). For example, while teacher 3's statement was related to correcting the mistake that they made, teacher 7 mentioned the whole feedback system of the game.

> "Later, it gave feedback in there, it said you did wrong then I thought, until that point like there wasn't any problem". (T3) (see Appendix H, extract 13)

> "The VR itself is already checking my results on every step so, I didn't really have to check. If I was doing the right thing, it was already showing me so, I felt comfortable about it". (T7) (see Appendix H, extract 14)

Even though some participants reported the absence of monitoring behavior, since they demonstrated or expressed the SRL behavior, monitoring, without being aware of it, the frequency of the code analyzed as zero. It might be possible that those participants who mentioned the absence of the behavior may not be sufficiently knowledgeable to discuss it. On the other hand, in the interview, some participants exactly referred to the behavior that they showed in the game. T1's parallel statements from the think-aloud performance and interview were shown below.

> "... it will go as powers of five, 25, then the third week is directly 125; but, let's see (turned to the innovative bar graph and checked) yes, 125". (T1, extract 15) (think-aloud)

> "After I notice the pattern, after this number the other comes (refers to the exponential pattern that is in the table, they already know the next blank), and then I should look at the figure, I checked to see if there is something different". (T1, extract 16) (interview)

4.3. SRL Behaviors Related to Strategy Use

The findings of the study demonstrated that most frequently used self-regulated learning (SRL) behavior was strategy use (see Figure 4.1). It had been coded approximately as half of the all SRL phases. While two of the subcategories, cognitive/metacognitive regulation and behavioral regulation were frequently referred, emotion regulation were rarely stated (see Figure 4.3). Even though T4 and T7 address the absence of strategy use during the interviews, the frequency of the code reported as zero since they showed SRL behaviors' strategy use phase even if it is unconscious. Participants who show the behavior during the game then mentioned it in the interview might possibly have a higher awareness related to their actions or SRL behaviors.

Initially, behavioral regulation is the external help seeking behavior from the researcher or the video. Therefore, it mostly occurred during the learning sessions and reported in the think-aloud data. Even though it was sometimes used to overcome the language barrier, all participants sought external help other than translation. For example, teacher 9 specifically stated that they asked for help and could not get an answer. All participants asked for help in general ways with what and how questions similar to "what am I going to do?" and "how will I do it?". On the other hand, task focused help seeking behaviors were also shown. A statement of T4 is:

"Was I watching from that place where it writes 350?" (see Appendix H, extract 17)

In another example, T7 asked:

"How can I touch that watch?" (see Appendix H, extract 18)

Behavioral regulation phase of SRL behavior was revealed mostly as seeking external help from the researcher rather than the environment. Participants mostly asked for help when they were stuck on a specific action such as relistening the instruction or grabbing the tools around. These actions were explained in the video instruction; however, they somehow could not catch or remember. For example, T9 explained this behavior as follows:

"I asked a question, there was no answer (laugh) I realized that I had to understand it myself and watched it (refers to the video instructions) once again and understood. I knew that I could watch it once more, but it is a need that comes automatically at that moment". (T9, extract 19)

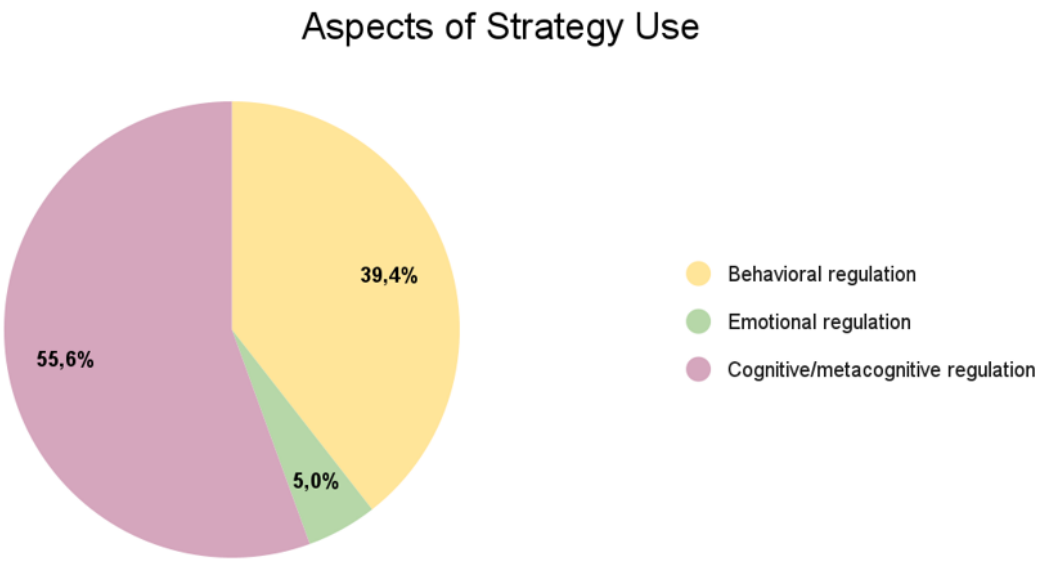

Figure 4.3. The Distribution of Teachers' References to Aspects of Strategy Use Behaviors.

The other SRL behavior that was commonly revealed in the findings was cognitive/metacognitive regulation. It occurred both during the game and it was mentioned in the interviews many times in different forms (see Table 4.1. for the distribution). Repeating and analysis aspects were the most common forms that were observed for 10 out of 11 teachers. Repeating aspect of strategy use was manifested as relistening, rereading, or rewatching. Rereading the questions or options in multiple choice questions, relistening the audio instructions, or rewatching the video instructions were all included in this category. Teachers stated the sentences similarly for this aspect.

> " I replayed the video". (T2, T3, and T8) (see Appendix H, extract 20) (see Figure 4.4)

> "Let me read it again". (T1) (see Appendix H, extract 21)

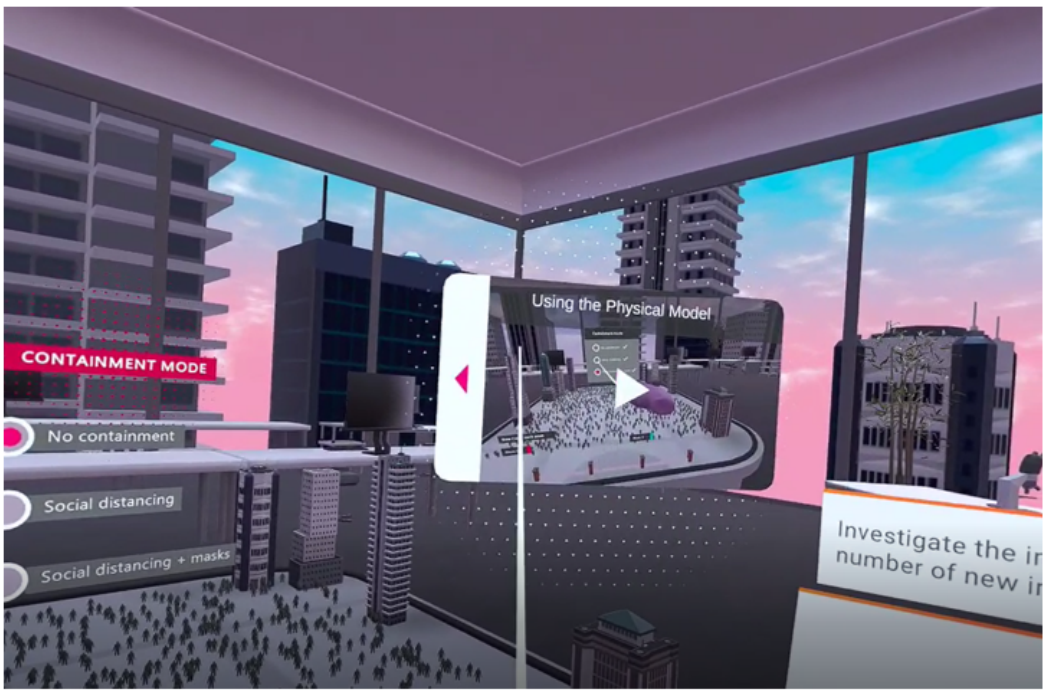

Figure 4.4. Screen capture from teacher 8's rewatching moment.

Even though there were major similarities in the occurrences of the repeating aspect, analysis aspect was shown in various ways even in the same tasks/questions.

> "Of course I wouldn't be able to count all the colors, but red, I know the first person, the first week around it, it shows in yellow, counting them". (see Appendix H, extract 22)

> "Each week was from the previous one; so, hospitalization is as much as how many cases there were in the previous week". (see Appendix H, extract 23)

> "5 to the week, 5 to the 't', 't' is weeks maybe". (see Appendix H, extract 24)

Both of these aspects were mostly observed in the think-aloud, similar to the prior knowledge activation aspect which sometimes merged with analysis behaviors. Prior knowledge activation behavior is also similar to using mathematical strategies since the content related prior knowledge is used during the game. For instance, many participants expressed that 20 percent is one fifth so they can divide the number of infected people by 5 to calculate the number of hospitalization. Some other examples were stated as follows:

> "I don't need to calculate the number of people in the second week, looking from here 5×5 will go as powers of five anyway, 25. Then the third week is directly 125". (T1) (see Appendix H, extract 25)

"In the graphics part I see some geometrical patterns like first we have one person and then a square and then a cube. I used the area of these shapes to calculate the number of people in that shape". (T2) (see Appendix H, extract 26) (see Figure 4.5).

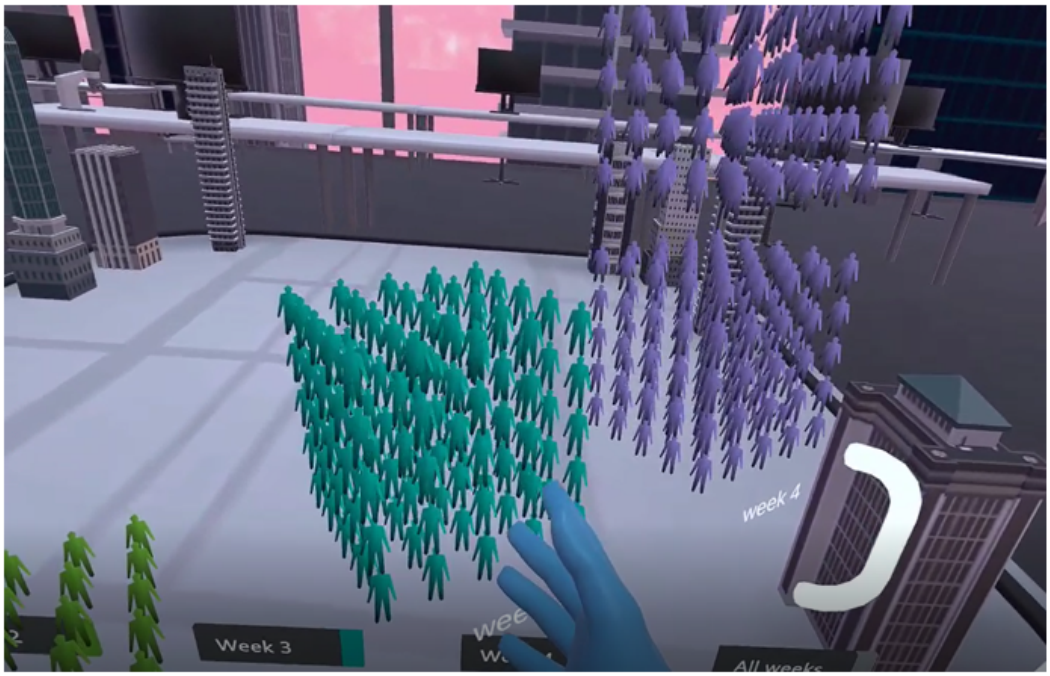

Figure 4.5. Screen capture from teacher 2's counting process in the innovative bar graph.

Another common aspect was trial and error. In half of the occurrences of trial and error SRL behavior, participants stated about their repetitive trials in the interviews. Besides, their actions or statements were found as trial and error aspect of strategy use in the video records. For instance, T5 used the following statement:

> "Then if it's wrong I have to try the star (referring to the * button in the calculator), I'll try that, too". (see Appendix H, extract 27)

And the final aspect of strategy use phase, emotional regulation, had been the least referred behavior (see Figure 4.2). It was less than all the sub aspects stated in the cognitive/metacognitive regulation. Emotion regulation of participants can be exemplified like in the following sentences:

> "Then after noticing it, I said, you know, there might be other things here. Let me look at it, so I can act accordingly. It felt good". (T1) (see Appendix H, extract 28)

> "I say I can do it, (tell her own name), calm down right now, you know you're angry right now, you can do it anyway, calm down, these are the things that you know, you know the technology, I organized myself about it". (T5) (see Appendix H, extract 29)

Teachers mostly had difficulty in expressing their feelings when it was asked. They referred to the process and explained what happened rather than pointing to the feelings that they have. What they did to overcome these processes were mostly help seeking or cognitive/metacognitive regulation actions rather than down-regulating (Sutton and Harper, 2009) the negative emotions.

4.4. SRL Behaviors Related to Evaluation

The final self-regulation behavior is *evaluation*. In this last section, the findings of the study are presented in two main groups: *performance evaluation and pandemic or VR evaluation*. It is possible to say that the frequency of these two main groups were approximately equal (see Figure 4.6). Each of these groups include two aspects as positive or negative. If the performance evaluation aspect was shown in two groups, participants' positive and negative evaluation frequencies differed. Participants evaluated their performance negatively in 75.8 percent of the codes (see Figure 4.5). They either addressed their performance negatively in the interview or in the think-aloud process as in examples:

> "I think it's because of me, I watched the video, I listened, but I had a delay because of understanding". (T3) (see Appendix H, extract 30)

> "I couldn't do it". (T8) (see Appendix H, extract 31)

> "I didn't get it on the test either". (T10) (see Appendix H, extract 32)

Even though it was rare, a percentage of 7.8 (see Figure 4.6), some performance positive evaluations were reported mostly in think-aloud transcripts as in below.

> "Because I'm guessing what I'm going to do next and I'm typing it fastly. It's nice to complete and do it step by step". (T3) (see Appendix H, extract 33)

As it is previously mentioned, participants revealed their previous knowledge by demonstrating their existing knowledge or just referring to its existence. In these examples of evaluation that participants evaluate their performance, participants mostly relate their performance to the previous knowledge that they have. Not only the performance knowledge but also the other aspects of the monitoring phase, mostly system/task understanding, were manifested as a part of their self-evaluation. It is possible that content understanding can be more evaluated than the previous knowledge when a similar study is conducted with students. The other positive or negative evaluations were related to the pandemic or VR itself. Negative perceptions were seen more than twice as likely as positive perceptions (see Figure 4.3). In the examples below, two negative and one positive perception statements are given in order.

> "The videos were too long in some places, they didn't switch from one thing to the next immediately". (T8) (see Appendix H, extract 34)

> "Maybe if there was an option to speed up the videos a little more in the description..." (T11) (see Appendix H, extract 35)

> "I think it's a very nice experience. I think it's like being in a real setting and touching something in the virtual world, it was all very enjoyable". (T10) (see Appendix H, extract 36)

While teachers evaluate the pandemic or VR environment, their negative evaluations mostly referred to instructions in the pandemic or tool usage in VR. Many participants also mentioned that they can be more comfortable the second time and they would like to try it again. Because their positive evaluation showed that they enjoyed attending and experiencing a virtual environment. Their experiences were evaluated as enjoyable because of the interaction with the environment.

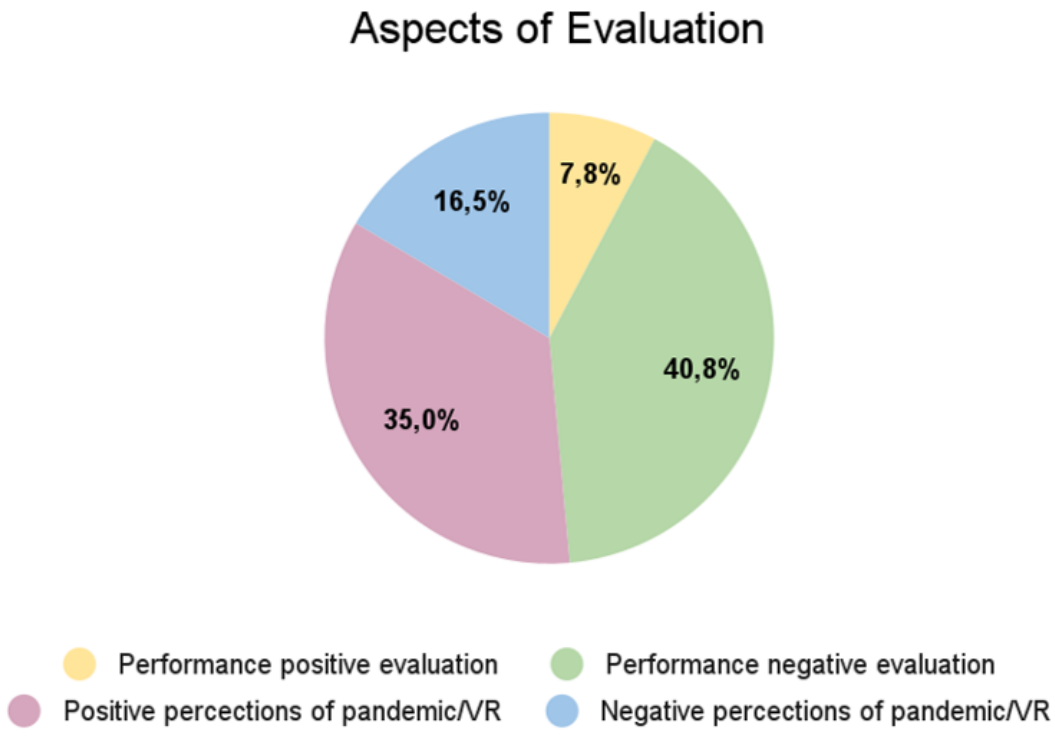

Figure 4.6. The Distribution of Teachers' References to Aspects of Evaluation Behaviors.

5. DISCUSSION

In this chapter, the findings of this study presented in the perspective of the four fundamental phases of self-regulated learning (SRL) behaviors are discussed. The phases; planning, monitoring, strategy use, and evaluation, are overviewed as a whole in the chapter by discussing two main points. Firstly, the frequencies of SRL behaviors' phases and aspects and how they are observed in the current study are discussed. The second point is how the phases or aspects of SRL are overlapping or differing for the cases.

First of all, as presented in the findings, planning has been the least referred SRL behavior. Teachers not only have a similar background knowledge on exponential growth as they showed in the pre-test but also refer to the planning phase rarely during their experience in IVE. It might not be surprising since the similar results found for many studies in the existing literature. The review of Dignath and Veenman (2021) indicated that the planning phase of SRL behavior shows resemblance for different samples. For example, while monitoring and evaluation have been more encouraged than planning in all grade levels for middle school (Zepeda *et al.*, 2019), ten teachers barely referred to planning and evaluation (Spruce and Bol, 2015). The results presented by Spruce and Bol (2015) differ from the current study in terms of the frequency of addressing evaluation behavior. Even though the results show that evaluation is the second least addressed SRL behavior in this study, its frequency is quite higher than the planning behavior.

For the planning phase, conclusions similar to the current study are also observed in studies that are conducted with students interacting in computer-based learning environments and computer-supported collaborative learning (Winters *et al.*, 2008). Winter and colleagues' (2008) analysis demonstrated that in these studies, students relied on low level strategies (e.g., searching the environment) or cognitive strategies rather than planning or monitoring. Even though the results of this study are not

generalizable, it can be hypothesized that rarely referred planning behaviors by all teachers, and frequently addressed help seeking and cognitive strategy use aspects might also be observed similarly in future studies conducted with students in IVEs.

Not only students' behaviors in the learning process but also teachers' planning behaviors during the teaching in IVEs might also result the same way, at a lower frequency, similar to the previous findings on SRL behaviors. In this study, how planning behavior is addressed in different cases does not vary; any of the teachers did not refer to the behavior more than 3 times. The teachers who address planning more than the others, T4 and T7, stated a different behavior than the setting achievement goals during the think-aloud contrary to the usual. It is possible to assume that teachers do not prefer planning behavior or to explain their planning procedures during their learning. Since all teachers' planning behaviors were quite similar for the aspects and the overall results are parallel to the previous findings, it is also predictable that the findings might be related to the phase itself or what environment brings.

Even though the commonalities on planning's aspects referred by the teachers, only T4 prepared themself for the tasks even there was no time for planning as it is presented in the findings. The reason for the rareness of the planning phase might be the absence of time for the phase. Besides, while there were system instructions that direct to the monitoring phase or the interview process gives a chance to reflect on the experience to the evaluation phase, there were no tasks or feedback that led to the planning phase. That might be the reason for planning phase referred rarely and monitoring or evaluation phase addressed more frequently in the current study. Because the monitoring phase mostly referred to the checking of tables and graphs before the submit or after the system feedback that the game offered and the reflections on the experience directed teachers to the evaluation phase.

Different from the current study's results, Veenman *et al.* (2009) found that orientation and planning are reported more than monitoring and evaluation in a sample of 17 middle school classes that teachers are observed. It might be related to learning

settings since the environments' influence on teachers or learners can vary. For example, it is concluded that deeper cognitive strategies such as monitoring have been more popular among students in computer-supported collaborative learning (CSCL) than the learners in non-CSCL (traditional) setting (Winters *et al.*, 2008). Similarly, in a study in which a supported mathematics e-learning environment examined, it is found that students in the e-learning environment addressed more self-monitoring and strategy use than students in the control group (Kramarski and Gutman, 2006). As a result, it might be claimed that technologically supported environments can possibly result in the increase in some aspects of SRL behavior of teachers and students such as monitoring phase as in the studies.

While the total frequency of each phase is higher than the planning, teachers varied on what they referred to during the think-aloud process and the interview. Why they acted differently despite their common background on mathematical knowledge related to exponential growth still needs to be discussed. Teachers' knowledge related to SRL behaviors and how they are able to present that knowledge might be one of the reasons behind the variety. In this scenario, some teachers are not able to self-regulate as learners because they didn't demonstrate the SRL behavior during the game in the IVE especially at a deeper cognitive level even though they are knowledgeable on exponential growth. The common phase was strategy use in many cases, it might be also related to problem solving strategies that teachers used in the low cognitive level instead of deeper stages.

In Delfino and colleagues' study (2010), the monitoring phase of SRL referred more than planning and evaluation phases similar to the current study and trainee teachers' SRL behaviors and its aspects categorized as cognitive/metacognitive and motivational/emotional, which is similar to the aspects of strategy use phase in the current study, cognitive/metacognitive and emotional regulation. In all tasks the cognitive/metacognitive aspects have been observed more frequently than the motivational/emotional aspects as in this study (Delfino *et al.*, 2010). However, in the current study the gap is much higher among the aspects.

It might be related to the reasoning behind teachers' emotion regulation behaviors. It is already investigated why teachers look for regulating their emotions; many teachers stated that it is about effectiveness or positive outcome expectancies (Sutton, 2004; Sutton and Harper, 2009). Another reason is the idealized emotion teacher image (Sutton 2004), and it refers to whether the teacher thinks it is part of the job or it is about professionalism. Because of these rationales behind the emotion regulation, it might be possible to say that teachers can possibly use emotion regulation behaviors mostly while teaching. Besides, mathematical problem-solving strategies of teachers or their regulation behaviors during the problem-solving are probably encouraged to be regulated cognitively/metacognitively rather than emotionally.

When the cases are examined according to the distribution of 4 main phases, in each case, monitoring behavior was observed approximately half of the strategy use behavior or a little more, except one outstanding case which also has the minimum total frequency among the all cases. Also, evaluation has been mostly less referred than strategy use and monitoring behaviors. Even *cognitive/metacognitive regulation* is one of the aspects in strategy use phase, some previous studies addressed *cognitive* and *metacognitive strategy*. For example, Kistneretal *et al.* (2010) categorized the strategies as cognitive, metacognitive, and emotional.

While the subcategories of cognitive strategy includes *elaboration, organization*, and *problem-solving; planning and systematic activity and monitoring and evaluation* are the categories for metacognitive strategy. Kistneretal and colleagues' (2010) study demonstrated that teachers' instructions mostly involve cognitive strategies, specifically elaboration and organization. The current study's findings were not presented that way; however, it is possible to say that it can be interpreted similarly to Kistneretal *et al.*'s (2010) results in terms of cognitive level.

6. CONCLUSION

In this final chapter, initially, the implications of the study are presented by considering the findings of the study. It is followed by the limitations and suggestions for future research are demonstrated again regarding the purpose and the findings of the study.

6.1. The Implications of the Study

In this study, the aim was to examine middle school mathematics teachers' self-regulated learning (SRL) behaviors during problem-solving to grasp the understanding in immersive virtual environments (IVEs). Initially, SRL behaviors are characterized as crucial for success both in academic and life (Kramarski and Kohen, 2017; Peeters *et al.*, 2014). Even though SRL is a complex phenomenon, studies have already concluded that it can be taught (Kramarski and Kohen, 2017). Since it is also indicated that students' achievement on problem-solving, motivation, and interactions in social settings has been positively affected by their self-regulatory behaviors (Zimmerman, 2002), promotion of SRL behaviors is critical on students' success for academia and life. However, there is still an unclarity on how teachers might improve SRL in the most efficient way (Dignath and Veenman, 2021).

The data collected in the video records of the think-aloud processes and in the interviews were transcribed and analyzed to examine mathematics teachers' SRL behaviors in IVEs during the problem-solving. The results of the analysis demonstrated that planning is the least referred SRL behavior among the 4 main phases of self-regulation as similar to most of the studies in Dignath and Veenman's (2021) overview. The other two phases that were near in their frequency were monitoring and evaluation. Finally, it was found that the highest frequency belonged to the strategy use phase of SRL.

The findings might be related to the game's content or presentation. Even though the results of the pre-test showed that teachers have a similar background regarding their knowledge of exponential growth, they demonstrated SRL behaviors not in quite different ways but in various frequencies. While they have a similar background on their knowledge related to the content, why they differ on presenting the SRL behaviors still needs to be regarded by researchers. For example, the instructions or feedback lead the participants to monitor their behaviors/actions or to use strategy for problem-solving such as drawing a graph or writing an equation. Participants also had a chance to evaluate the process or the setting. That might be the reason to observe evaluation phase in the interview; but, monitoring and strategy use phases in think-aloud performance during the problem solving. On the other hand, participants might not have a time to set a goal or plan since there was no specific time or task for that.

The analysis showed that teachers mostly relied on low level strategies (e.g., seeking for external help) or/and cognitive strategies (e.g., repetitive behaviors) rather than planning while solving problems in IVEs. These findings which are similar to results of existing literature demonstrate that teachers' own self-regulation might need improvement because teachers are required to be efficient self-regulated learners at first (Kramarski and Kohen, 2017). When teachers self-regulate as learners, they engage in positive processes to create goals and monitor and assess their own cognition, motivation, and behavior (Pintrich, 2000). For this reason, teacher education programs for pre-service teachers need to be organized to raise teacher candidates as a self-regulated learner. Also, mathematics teachers' professional development should be supported by considering SRL promotion during the problem solving specifically for encouraging students in a similar way.

On the other hand, self-regulation *as a teacher* is a process in which instructors actively and clearly assist students in creating their own SRL (Pintrich, 2000). Self-regulation is a proactive process in this dual role of teachers, as a learner and teacher. It means that self-regulation is not a process that happens to learners, it happens by them (Pintrich, 2002). Moreover, the same proactivity is also the case for teachers

which are the proactive supporters of learners on promoting their SRL (Kramarski and Kohen, 2017). Both teachers and pre-service teachers are also lifelong learners; that is why they need to improve and relate their dual self-regulation roles. Therefore, the results of the study demonstrated that there are some professional implications of this study that require further attention by educators, administrators, and teachers themselves.

Furthermore, since IVEs are novel conditions for class settings, how teachers adapt their dual self-regulation role to renovated educational environments should be another focus for researchers or educators. As it is discussed previously, referring to deeper cognitive stages such as monitoring more in computer-based/supported or e-learning environments compared to traditional settings (control group) have a potential to be obtained because of the learning setting. Likewise, the frequency of monitoring behavior might be the result of the immersive environment in this current study. The possible influences of IVEs on learning process and learners, specifically on promoting their SRL behaviors should be a directive for researchers, and educators.

6.2. Limitations and Suggestions for Future Research

Despite the results' significance in this study for fulfilling the gap in the literature by examining middle school mathematics teachers' self-regulated learning (SRL) behaviors in immersive virtual environments (IVEs), some limitations still need to be regarded in future research. First of all, since the language of Pandemic by Prisms, the immersive virtual environment, is not in participants' mother language (Turkish), some participants stated that they have difficulties in following some of the instructions. Even though their English proficiency level is documented, some of them are not interacting with the language actively. Therefore, further studies can be practiced with teachers who regularly practice in English to avoid possible negative impacts or to increase the interaction of the user with the environment.

Another limitation that is mentioned by the participants is the use of VR tools. For this reason, in future studies, either a brief orientation can be offered before teachers involved in the virtual environment or its influences can be examined. Since, in the current study, all participants were first time users, the future work might examine how teachers' self-regulated learning (SRL) behaviors differ among first time and experienced users. Besides, varying the data collection methods can be influential to more deeply examine the teacher behaviors since the measurement of SRL has been on the researchers agenda over the years. The combination of instruments, which measure SRL as an aptitude and event are used in the study, can be enriched with a self-report questionnaire or/and observation. It also can be used to analyze the relation between self-reported and observed SRL behaviors.

In further studies, the promotion of SRL can be investigated with these suggestions. Teacher instructions for promoting students' SRL can be observed in an immersive virtual classroom setting, and it can be supported by analyzing teachers' self reports and students' reports. It means that this study investigated teachers' SRL behaviors in IVEs; it didn't examine the promotion of SRL in such environments. Regarding this, it might be suggested to focus on promoting students' SRL behaviors in future research to flourish the comprehension among SRL and VEs.

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APPENDIX A: ALGEBRA I - PRE-MODULE ASSESSMENT SURVEY

Pandemic by Prisms

Algebra I - Pre-Module Assessment Survey 1

Mandatory fields are marked with an asterisk (*) and must be filled in to complete the form.

1. Please write your first and last name.

2. The equation □(□) = □□^□ models the number of bacteria in a petri dish each hour. Which of the following is true? *

(A) There are 7 new bacteria in the petri dish each hour

(B) The bacteria grow in the petri dish for 7 hours total

(C) The number of new bacteria in the petri dish increases by a factor of 7 each hour

(D) None of the above

3. Consider the table and equation below. Which of the following is true? *

Function A:

x	y
1	3
2	9
3	27

Function B:

$$f(x) = 3x$$

Figure A.1. Algebra I - Pre-Module Assessment Survey 1.

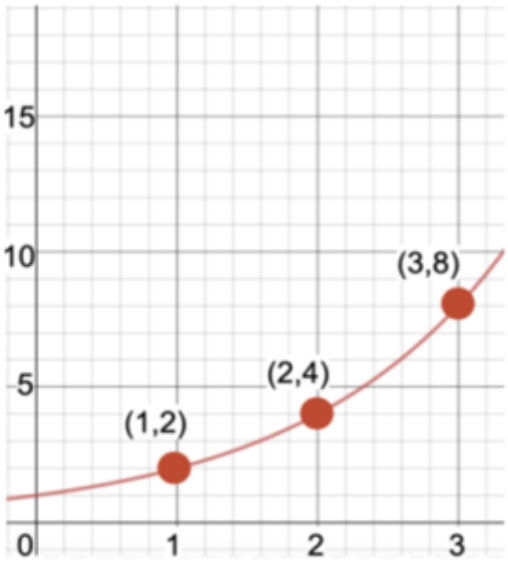
(A) Functions A and B represent the same function

(B) Function A grows faster than Function B

(C) Function B grows faster than Function A

(D) Functions A and B differ by a constant

4. Which of the following equations represents the function in the graph below? *



(A) $y=4^x$

(B) $y=x+1$

(C) $y=x^2$

(D) $y=2^x$

5. A city is experiencing a viral outbreak. In the first week, 1 person has the virus. In week 2, there are 4 new infections. In week 3, there are 16 new infections. If you wanted to determine the number of new infections in week 4, what would you do to the number of new infections in week 3? *

(A) Add 4 to the number of new infections in week 3

(B) Multiply the number of new infections in week 3 by 2

(C) Divide the number of new infections in week 3 by 4

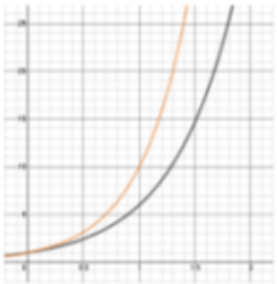
(D) Multiply the number of new infections in week 3 by 4

Figure A.2. Algebra I - Pre-Module Assessment Survey 2.

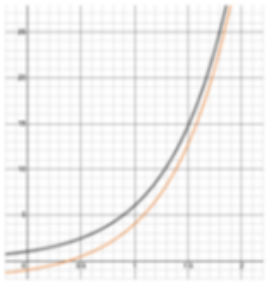
6. A scientist is experimenting with a new strain of bacteria. They find that the bacteria initially have a growth rate of 6, and can be modeled by the graph below (in black). *

Which of the following graphs (in orange) represents how this model would change if the scientist were to heat up the bacteria (which decreases the growth rate of the bacteria)?

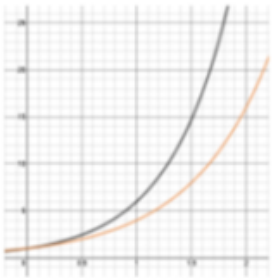
A) The graph would become steeper



B) The graph would be shifted down



C) The graph would become shallower



D) The graph would be shifted up

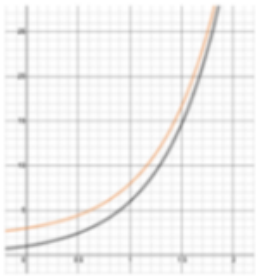


Figure A.3. Algebra I - Pre-Module Assessment Survey 3.

APPENDIX B: SEMI-STRUCTURED INTERVIEW

Interview Questions

Interviewer: I would like to ask you some questions about your experience in this VR environment and your working throughout the task. My first question is:

Question 1: What have you enjoyed the most in the task?

Question 2: What have you enjoyed the least?

Question 3: What goals did you set for yourself at the beginning of this task?

Question 4: Have you used any particular strategy to enhance your learning during the task? Can you give an example?

Question 5: Did you check your progress while you were working on the VR task? How?

Question 6: How did you help yourself learn/understand during the task?

Question 7: What aspects of VR did you find challenging and why?

Question 8: Can you tell me about your emotions/feelings during the task? Why did you feel the way you did? If your feelings weren't pleasant did you do anything to change this?

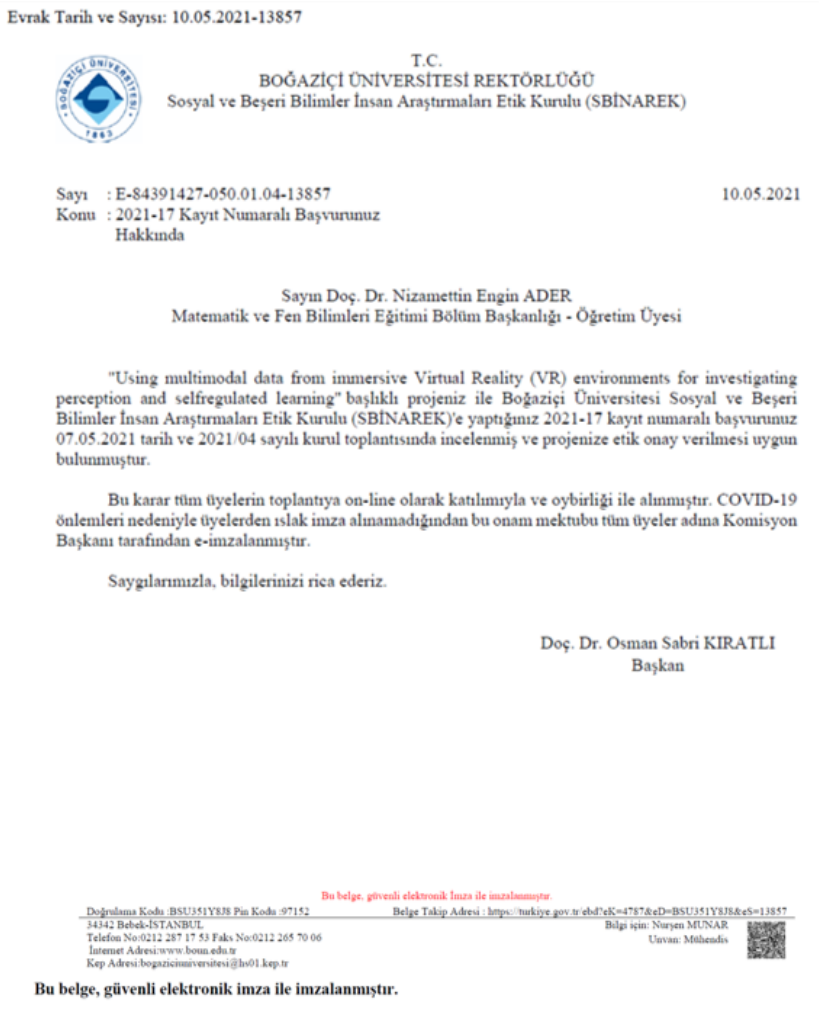
Interviewer: Thank you for sharing all these details with me. Now I would like to talk about the use of VR in education more broadly, based on this and your previous experience (if there is) using VR in learning contexts. My first question for this part is:

Question 9: What obstacles can you anticipate for applying VR in your future teaching?

Question 10: Considering your undergraduate (and graduate) teaching programme and your job experiences: how important do you think the use of innovative learning technologies is for teaching, especially inTurkey? How important is teaching and learning using VR?

Question 11: Is there anything else would you like to share with me on the topic?

APPENDIX C: THE APPROVAL OF BOGAZICI UNIVERSITY INSTITUTIONAL REVIEW BOARD FOR RESEARCH WITH HUMAN SUBJECTS



Evrak Tarih ve Sayısı: 10.05.2021-13857

T.C.
BOĞAZİÇİ ÜNİVERSİTESİ REKTÖRLÜĞÜ
Sosyal ve Beşeri Bilimler İnsan Araştırmaları Etik Kurulu (SBİNAREK)

Sayı : E-84391427-050.01.04-13857 10.05.2021
Konu : 2021-17 Kayıt Numaralı Başvurunuz Hakkında

Sayın Doç. Dr. Nizamettin Engin ADER
Matematik ve Fen Bilimleri Eğitimi Bölüm Başkanlığı - Öğretim Üyesi

"Using multimodal data from immersive Virtual Reality (VR) environments for investigating perception and selfregulated learning" başlıklı projeniz ile Boğaziçi Üniversitesi Sosyal ve Beşeri Bilimler İnsan Araştırmaları Etik Kurulu (SBİNAREK)'e yaptığınız 2021-17 kayıt numaralı başvurunuz 07.05.2021 tarih ve 2021/04 sayılı kurul toplantısında incelenmiş ve projenize etik onay verilmesi uygun bulunmuştur.

Bu karar tüm üyelerin toplantıya on-line olarak katılımıyla ve oybirliği ile alınmıştır. COVID-19 önlemleri nedeniyle üyelerden ıslak imza alınamadığından bu onam mektubu tüm üyeler adına Komisyon Başkanı tarafından e-imzalanmıştır.

Saygılarımızla, bilgilerinizi rica ederiz.

Doç. Dr. Osman Sabri KIRATLI
Başkan

Bu belge, güvenli elektronik İmza ile imzalanmıştır.
Doğrulama Kodu :BSU351Y8J8 Pin Kodu :97152 Belge Takip Adresi : https://turkiye.gov.tr/ebd?eK=4787&eD=BSU351Y8J8&eS=13857
34342 Bebek-İSTANBUL Bilgi için: Nurşen MUNAR
Telefon No:0212 287 17 53 Faks No:0212 265 70 06 Unvan: Mühendis
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Kep Adresi:bogazicniversitesi@hs01.kep.tr

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Figure C.1. The Approval of Bogaziçi University Institutional Review Board for Research with Human Subjects 1.

APPENDIX D: INFORMED CONSENT FORM

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Title of the study: Self-regulated learning (SRL) behaviors of mathematics teachers in immersive virtual environments (IVEs)

Principal investigator: Hazal Dalak

Thesis advisor: Assoc. Prof. Engin Ader

Purpose of the study

VR has unexplored potential for understanding complex learning processes. The aim of the study is to explore how the VR environment could be used to support and understand more about learning processes. The results of this experiment would help the teachers to understand how novel technologies affect their own learning process and how VR can be leveraged as a learning environment in remote learning conditions (e.g., in COVID). This study will test whether the researcher can collect meaningful multimodal multichannel data about teachers' cognitive, affective, metacognitive, and motivation processes by instrumenting them (e.g., physiological sensors) while they solve VR-based STEM problems.

Description of the research procedures

If you agree to participate in this study you will be asked to do the following things:

• Fill a questionnaire to report about your prior knowledge related to the subject. The questionnaire will be presented to you before the VR-based task.

• Wear a VR headset, use handheld VR controllers

• Complete VR-based learning tasks.

• Wear physiological sensors that attach to one of your wrists and one palm of your hand.

• Participate in a brief interview about your experiences at the end of the session.

Risks

Some people experience cybersickness, like motion sickness, while using VR. If you feel any discomfort at any time during the experiment, let the researcher know and she will stop the experiment. There are no other expected risks in participating in this study.

Benefits of being in this study

By participating in this study you will have the opportunity to experience learning in VR first hand. Further, the study will make you aware about learning processes when studying STEM subjects and eventually transfer the information when teaching students with VR.

Confidentiality

All the information gathered in this study will be handled confidentially and will not be made available to anyone outside the researcher and the thesis advisor. After data collection, the data will be pseudonymized and archived safely for later use. Data gathered in this study will be stored for five years on an external drive and on a secure server, after which the data will be destroyed. The results of this study will not reveal any information about individual students. Below the researcher asks for a separate permission to use pictures or video of you in presentations of this research.

Participation in this study is voluntary. You have the right to refuse or withdraw from the research at any time without any consequences.

I have read and understood the information about the research. ☐ Yes ☐ No

I am willing to take part in this research ☐ Yes ☐ No

I allow pictures taken of me to be used to present the research ☐ Yes ☐ No

I allow video taken of me to be used to present the research ☐ Yes ☐ No

This consent form has been signed in two copies, one for each party.

Name of the participant _____

Name of the researcher _____

Place and date _____

_____ _____

Signature of participant Signature of researcher

Figure D.1. Informed Consent Form.

APPENDIX E: THINK-ALOUD PROTOCOL

The researcher explained the protocol with the following statement: "Since you have completed the pretest, it is expected that you will complete the tasks in the virtual environment as I stated. I am going to explain to you what I would like you to do while you are solving the problems in that virtual environment. It is called think-aloud. Think-aloud is something you do where you simply turn up the volume in your head and you say everything you are thinking, reading, inspecting, and doing while you are in the VR environment. In other words, you should be thinking out loud as if you are speaking to yourself while you work through the problems, and I ask you to think out loud continuously throughout the entire task. I mean, during the task, I expect you to 'think-aloud' continuously. You are free to use the language that you wish, Turkish or English. Both the computer screen and you will be on video record to collect think-aloud data as you informed in the consent form. It is quite significant to tell what you are doing and what you are thinking every second. So, I will be reminding you to think loudly".

APPENDIX F: SELF-REGULATED LEARNING VARIABLES BY AZEVEDO AND CROMLEY (2004)

Table F.1. Self-Regulated Learning Variables by Azevedo and Cromley (2004).

Planning	Prior knowledge activation	**Monitoring**	Judgment of learning (JOL)
	Recycle goal in working memory		Feeling of knowing (FOK)
	Sub-goals		Self-questioning
	Planning		Content evaluation
			Identify adequacy of information
			Monitoring progress toward goals
Strategy use	Find location in environment	**Task difficulty and demands**	
	Goal-directed search		Help seeking behavior
	Ealuate content as answer to goal		Control of context
	Mnemonics		Expect adequacy of information
	Read notes		Time and effort planning
	Coordinating informational sources		Task difficulty
	Taking notes		
	Re-reading		
	Selecting new informational source	**Interest**	
	Free search		Interest statement
	Summarization		
	Inferences		
	Draw		
	Hypothesizing		
	Knowledge elaboration		
	Read new paragraph		
	Memorization		

APPENDIX G: CODING SCHEME FOR DATA ANALYSIS

Table G.1. Coding Scheme with Four Main Phases of Self-Regulated Learning.

Phase	***Definition***	***Codes***	***Definition***	***Q.no***
Planning	aims that the participants set to themselves for the VR task; anticipation of what the experiment would involve	Setting learning goals	"individuals seek to increase their ability or master new tasks" (Elliott & Dweck, 1988, p. 5)	*3*
		Setting achievement goal	"individuals seek to maintain positive judgments of their ability and avoid negative judgments by seeking to prove, validate, or document their ability and not discredit it;" (Elliott & Dweck, 1988, p. 5)	*3*

Table G.1. Coding Scheme with Four Main Phases of Self-Regulated Learning. (cont.)

Phase	***Definition***	***Codes***	***Definition***	***Q.no***
		Anticipating difficulties	expected aspects that could cause problems for completion of the VR task	*6 and 7*
		Preparation for the task	actions taken in advance in order to better complete the VR task	*6*
		Reporting absence of p lanning (or goal setting)	explicit reference to not setting goals and no expectations	*3*

Table G.1. Coding Scheme with Four Main Phases of Self-Regulated Learning. (cont.)

Phase	***Definition***	***Codes***	***Definition***	***Q.no***
Monitoring	express metacognitive awareness of several facets of the self, the task, and the environment (Pintrich, 2000), references to checking different aspects of one's performance during the VR task	Monitoring progress	checking behavior to proceed during the task	*5*
		Relying on system feedback	indications if the system feedback influences one's actions in the VR environment	*5*
		Content understanding	about the mathematical content	*5*

Table G.1. Coding Scheme with Four Main Phases of Self-Regulated Learning. (cont.)

Phase	***Definition***	***Codes***	***Definition***	***Q.no***
		System/task understanding	Indications of the extent to which the task and the handling of the VR has been understood and implemented	*5*
		Previous knowledge	pre-existing knowledge about the topic and content of the task influences one's performance	*5*
		Reporting absence of monitoring	explicit reference to not engaging in any monitoring during the VR performance	*5*

Table G.1. Coding Scheme with Four Main Phases of Self-Regulated Learning. (cont.)

Phase	***Definition***	***Codes***	***Definition***	***Q.no***
Strategy use	techniques and actions to manage various aspects of task-solving processes, self or environment (Pintrich, 2000)	Behavioral Regulation	help seeking – acquisition of external help (Pintrich, 2000; Azevedo & Cromley, 2004) either from the researcher or video about the VR tools and environment (prompting guidance for using VR)	*4*
		Emotional regulation	regulating the cognitive processes that in involved in emotions by , decreasing negative emotions or sustaining/ increasing positive emotions (Sutton & Harper, 2009)	*4 and 8*

Table G.1. Coding Scheme with Four Main Phases of Self-Regulated Learning. (cont.)

Phase	***Definition***	***Codes***	***Definition***	***Q.no***
		Cognitive/ Metacognitive regulation	any strategy for trying to understand the task or solve a problem in the VR (e.g., exploring VR, trial and error, repetitive use, analysis, prior knowledge activation, self-instruction, rewatching (Azevedo & Cromley, 2004))	*4*
		Reporting absence of strategic behavior	explicit reference to not employing strategies during the VR performance	*4*

Table G.1. Coding Scheme with Four Main Phases of Self-Regulated Learning. (cont.)

Phase	***Definition***	***Codes***	***Definition***	***Q.no***
Evaluation	general assessment of the experience can be process or product related (Pintrich, 2000); from a retrospective point of view. (e.g., participants' impressions of the VR environment, its features, functionality, content, mathematical features)	Performance positive evaluation	positive a ssessment of one's performance	*1 and 2*
		Performance negative evaluation	Negative assessment of one's performance	*1 and 2*

Table G.1. Coding Scheme with Four Main Phases of Self-Regulated Learning. (cont.)

Phase	***Definition***	***Codes***	***Definition***	***Q.no***
		Perceptions of Pandemic VR - Positive	positive impressions of the VR environment and its features about VR functionality, content and mathematical features	*1 and 2*
		Perceptions of Pandemic VR - Negative	Negative impressions of the VR environment and its features about VR functionality, content and mathematical features	*1 and 2*

APPENDIX H: TRANSLATED TRANSCRIPTS

Table H.1. Turkish (Original) and English Version of Referred Transcripts.

1	P10: Bu sorunun aynısı testte de vardı değil mi? ...B şıkkında 5 ile çarpıyoruz diyor değil mi? (Türkçe açıklamanın ardından duraksar) Testte de yanlış yapmışım, okeey.	P10: The same question was in the test (referring to pre-test). ... In option B, it says 'multiplying by 5', isn't it? What does a factor of 5 mean? ...(a pause after hearing the explanation in Turkish) I did it wrong in the test, okey".
2	P5: Hiçbir goal setting yoktu.	P5: There was not any goal setting.
3	P9: Belirlemedim amaç.	P9: I didn't determine a purpose.
4	P4: ...işte exponential function ile alakalı bir şey olacak, karşıma böyle bir şey gelecek, ondan sonra tamam işte klasik virüs, virüs ex ponential şekilde yayılacak, tamam böyle bir aktivite olacak.	P4: ...it will be something related to exponential function, something like this will come up; then, here is the classic virus. Viruses will spread exponentially, ok, there will be such an activity.
5	P2: I thought in the beginning I should click each time and then I accidentally just tapped it with the hand and then I got like I need to tap, I don't need clicking the button.	P2: I thought, in the beginning, I should click each time and then I accidentally just tapped it with the hand and then I got like I need to tap, I don't need to click the button...

Table H.1. Turkish (Original) and English Version of Referred Transcripts. (cont.)

6	P5: İlk etapta bu şu 'simulation'lar vardı ya 3 farklı 'simulation' orada aslında tam ne denilmek istediğini kavrayamadım.	P5: In the first part, there were the simulations, 3 different simulations, in there, I couldn't totally comprehend what it means.
7	P3: ...bunu teyit etmek için oradaki insanları saydım.	P3: ...I counted the people there to confirm that.
8	P9: ...yani defalarca doğru mu yaptım bu sayıları doğru mu yazdım kontrol ettim.	P9: ...I mean, I checked a few times whether I did it right or I wrote these numbers correctly.
9	P3: Beşin üzerine X yazamıyor muyum? O t değişmeyecek mi? Değişmesi lazım. (bekler) Tamam zaten aynı (güler), y = 5 üzeri x olması gerekmiyor.	P3: Do I write 'x' on top of 5? Will 't' not change? It needs to change. (Pause) Okey, it's the same (laugh). It doesn't have to be $y=5^x$.
10	P6: 'Exponent' olduğunu bir kere anlayınca nasıl gideceğini biliyordum.	P6: When I understand once, it is exponential, I knew how it will go.
11	P7: These are the things that we know already.	P7: These are the things that we know already.
12	P9: Katları şeklinde artması gerekiyor zaten bunu bildiğim için.	P9: It is supposed to increase as multiples, I knew that anyway.
13	P3: Daha sonra orada geri dönüt verdi hani yanlış yaptın dedi o zaman düşündüm o ana kadar hiçbir problem yok gibi.	P3: Later, it gave feedback in there, it said you did wrong then I thought, until that point like there wasn't any problem.

Table H.1. Turkish (Original) and English Version of Referred Transcripts. (cont.)

14	P7: The vr itself already checking my results on every step so I didn't really have to check if I was doing right so it was already showing me so I felt comfortable about it.	P7: The VR itself is already checking my results on every step so, I didn't really have to check. If I was doing the right thing, it was already showing me so, I felt comfortable about it.
15	P1: ...beşin kuvvetleri olarak gidecek, 25, o zaman üçüncü hafta direkt 125 ama bakalım (dönüp kontrol etti) evet 125.	P1: ... it will go as powers of five, 25, then the third week is directly 125; but, let's see (turned to the innovative bar graph and checked) yes, 125.
16	P1: Örüntüyü fark ettikten sonra, şimdi buradan sonra işte şu sayı gelmeli ve o zaman şekle de bakmalıyım, hani belki farklı bir şey vardır diye kontrol ettim.	P1: After I notice the pattern, after this number the other comes (refers to the exponential pattern that is in the table, they already know the next blank), and then I should look at the figure, I checked to see if there is something different.
17	P4: Şu 350 yazan yerden mi izliyordum?	P4: Was I watching from that place where it writes 350?
18	P7: Nasıl dokunuyorum o saate?	P7: How can I touch that watch?

Table H.1. Turkish (Original) and English Version of Referred Transcripts. (cont.)

19	P9: Soru sordum, cevap gelmedi (gülüyor) cevap gelmeyince kendim anlamak zorunda olduğumu fark ederek bir kere daha izleyip anladım. Bir kere daha izleyebileceğimi biliyordum ama otomatik olarak sorma ihtiyacı oluyor o anda.	P9: I asked a question, there was no answer (laugh) I realized that I had to understand it myself and watched it (refers to the video instructions) once again and understood. I knew that I could watch it once more, but it is a need that comes automatically at that moment.
20	P2: I replayed the video. P3: Videoyu tekrar izledim. P8: Videoyu tekrar izlemiştim.	P2, P3, and P8: I replayed the video.
21	P1: Tekrar okuyayım.	P1: Let me read it again.
22	P1: Tabi tüm renkleri sayamayacaktım ama kırmızı hani ilk kişi biliyorum onun etrafındaki ilk hafta işte sarıyla gösteriyor onları saymak.	P1: Of course I wouldn't be able to count all the colors, but red, I know the first person, the first week around it, it shows in yellow, counting them.
23	P2: Her hafta bir öncekinden şey yaptı yani kaç vaka varsa bir önceki hafta kadar 'hospitalization' oldu.	P2: Each week was from the previous one; so, hospitalization is as much as how many cases there were in the previous week.
24	P11: 5 üzeri hafta, 5 üzeri t, t hafta galiba.	P11: 5 to the week, 5 to the 't', 't' is week maybe.

Table H.1. Turkish (Original) and English Version of Referred Transcripts. (cont.)

25	P1: İkinci haftada kaç tane var hesaplamama gerek yok, şuradan bakınca 5 × 5, zaten beşin kuvvetleri olarak gidecek, 25, O zaman üçüncü hafta direkt 125	P1: I don't need to calculate the number of people in the second week, looking from here 5 × 5 will go as powers of five anyway, 25. Then the third week is directly 125.
26	P2: In the graphics part I see some geometrical pattern like first we have one person and then a square and then a cube. I used the area of these shapes to calculate the number of people in that shape.	P2: In the graphics part I see some geometrical patterns like first we have one person and then a square and then a cube. I used the area of these shapes to calculate the number of people in that shape.
27	P5: O zaman yanlışsa yıldızı (hesap makinesindeki * tuşundan bahsediyor) denemem lazım, onu da deneyeceğim.	P5: Then if it's wrong I have to try the star (refers to * button in the calculator), I'll try that, too.
28	P1: Sonra onu fark ettikten sonra dedim ki hani burada başka şeyler de olabilir. Hani bi ona da bakayım, ona göre hareket edeyim. O iyi geldi.	P1: Then after noticing it, I said, you know, there might be other things here. Let me look at it, so I can act accordingly. It felt good.

Table H.1. Turkish (Original) and English Version of Referred Transcripts. (cont.)

29	P5: Ben bunu yapabilirim diyorum, (adını söylüyor) şu an sakin ol, hani şu an sinirin şey tamam sen bunu zaten yapabilirsin sakin ol bildiğin şeyler, teknoloji biliyorsun kendimi organize ettim o konuda.	P5: I say I can do it, (tell her own name), calm down right now, you know you're angry right now, you can do it anyway, calm down, these are the things that you know, you know the technology, I organized myself about it.
30	P3: O benden kaynaklı bence, videoyu izledim, dinledim fakat daha sonradan anlamamdan dolayı bir gecikme yaşadım.	P3: I think it's because of me, I watched the video, I listened, but I had a delay because of understanding.
31	P8: Ben bunu beceremedim.	P8: I couldn't do it.
32	P10: Testte de anlamamıştım bunu.	P10: I didn't get it on the test either.
33	P3: Çünkü az sonra yapacağım şeyi tahmin ediyorum ve hızlı hızlı giriyorum ve tamamlayıp tamamlayıp bunu adım adım yapmak da güzeldi.	P3: Because I'm guessing what I'm going to do next and I'm typing it fastly. It's nice to complete and do it step by step.
34	P8: Videolar çok bazı yerlerde uzun geldi, bir şeyden sonra hemen diğerine geçmiyordu.	P8: The videos were too long in some places, they didn't switch from one thing to the next immediately

Table H.1. Turkish (Original) and English Version of Referred Transcripts. (cont.)

35	P11: Belki açıklama kısmında videolar biraz daha hızlandırabilme seçeneği olsaydı...	P 11: Maybe if there was an option to speed up the videos a little more in the description...
36	P10: Bence çok güzel bir deneyim yani, ıı, bir ortamda bulunuyormuş gibi olmak, bir de sanal dünyada falan bir şeylere dokunmak bence, bütün hepsi çok keyifliydi bence.	P10: I think it's a very nice experience. I think it's like being in a real setting and touching something in the virtual world, it was all very enjoyable.