USING IMMERSIVE VIRTUAL REALITY IN CLIMATE CHANGE EDUCATION

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USING IMMERSIVE VIRTUAL REALITY IN

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DECLARATION OF ORIGINALITY

I, İpek Paksoy, certify that,

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ABSTRACT

Using Immersive Virtual Reality in Climate Change Education

This study aimed to investigate sixth-grade student's level of understanding about the impacts of sea level rise, their climate change worries, and hopes after participating in an immersive virtual field trips-integrated inquiry-based learning (iVFTs-IBL) experience. A 360-degree documentary about melting glaciers and a VR boat experience about sea level rise designed by the researcher were used in the exploration phase of the two hour-long inquiry learning experience. In order to assess student understanding before and after the intervention, a five-item test about the impacts of sea level rise was adopted to Turkish. This test was used together with a formative assessment instrument, a KLEW chart. Climate Change Hope and Climate Change Worry Scales were also used to collect data in two data points. The results showed that there was a significant difference between the pretest and posttest scores of the understanding test, which was supported by written student responses in the KLEW chart. While students' mean scores for climate change worry remained nearly the same before and after the intervention, their climate change hope scores significantly increased after they participated in the iVFTs-IBL experience.

ÖZET

İklim Değişikliği Eğitiminde Sürükleyici Sanal Gerçekliğin Kullanımı

Bu çalışma, 6. sınıf öğrencilerinin deniz seviyesinin yükselmesinin etkileri hakkındaki sürükleyici sanal geziler entegre edilmiş sorgulamaya dayalı öğrenme deneyimine (iVFTs-IBL) katıldıktan sonra anlayış düzeylerini, iklim değişikliği endişelerini ve iklim değişikliğinin önlenmesine yönelik umutlarını araştırmayı amaçladı. İki saat süren sorgulayıcı öğrenme deneyiminin keşif aşamasında, eriyen buzulları konu alan 360 derecelik bir belgesel ve araştırmacı tarafından tasarlanan deniz seviyesinin yükselmesini konu alan VR tekne deneyimi kullanılmıştır. Uygulama öncesi ve sonrasında öğrencilerin anlamalarını değerlendirmek için deniz seviyesinin yükselmesinin etkilerine ilişkin beş maddelik bir test Türkçe'ye uyarlanmıştır. Bu test, biçimlendirici bir değerlendirme aracı olan KLEW şemasıyla birlikte kullanılmıştır. İklim Değişikliği Umut ve İklim Değişikliği Endişe ölçekleri de iki veri noktasında veri toplamak için kullanılmıştır. Sonuçlar anlama testinin ön test ve son test puanları arasında KLEW şemasındaki yazılı öğrenci cevaplarıyla da desteklen anlamlı bir fark olduğunu göstermiştir. Öğrencilerin iklim değişikliği endişesi ortalama puanları, uygulamadan önce ve sonra hemen hemen aynı kalırken, iklim değişikliğinin önlenmesine yönelik umut puanları, iVFTs-IBL deneyimine katıldıktan sonra önemli ölçüde arttı.

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ABBREVIATIONS

IVR: Immersive Virtual Reality

iVFT: Immersive Virtual Field Trip

IBL: Inquied-Based Learning

iVFTs-IBL: Immersive Virtual Field trips-integrated Inquiry-Based Learning

ISLRAI: Impacts of Sea Level Rise Assessment Instrument

CCE: Climate Change Education

CCHS: Climate Change Hope Scale

CCWS : Climate Change Worry Scale

KLEW: Know-Learn-Evidence-Wonder

IPCC: Intergovernmental Panel on Climate Change

UNESCO: United Nations Educational, Scientific and Cultural Organization

UNFCCC: United Nations Framework Convention on Climate Change

LP: Learning Progression

VR: Virtual Reality

5E: Engage, Explore, Explain, Elaborate, Evaluate

CHAPTER 1

INTRODUCTION

Climate change is one of the most important global issues because the future of all humanity and life on Earth depends on it. The predicted consequences of rising temperatures as a result of continued greenhouse gas emissions are already becoming a reality. One of these consequences is sea level rise, which has already risen by about 21-24 centimeters since 1880 (Lindsey, 2022). According to the IPCC, the rise will reach 2 meters by 2100 (IPCC, 2023). The impacts of sea level rise, such as coastal erosion, storm surges and saltwater intrusion, particularly affect communities and habitats in low-lying coastal areas (Barbier, 2015), such as the coastal regions of Turkey. Therefore, sea level rise is a locally relevant, significant impact of climate change that needs to be addressed for learners.

In addressing climate change, education has a crucial role which confirmed by many international agreements (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2017). Climate change education (CCE) has been seen as a way out, preparing the next generations for a future shaped by this problem and empowering them to take action and make decisions. However, climate change is a challenging issue to address in education due to its complex nature, which includes scientific, economic and social perspectives, as well as invisible reasons with distant consequences (Busch et al., 2019; Busch & Osborne, 2014; Perkins et al., 2018). For effective and meaningful learning about climate change, learner-centered pedagogies and critical inquiry were identified in current studies as useful (Monroe et al., 2019, Perkins et al., 2018). Therefore, inquiry-based learning, which is an effective method for student learning (e.g., Cakir, 2017; Furtak et el., 2012; Garcia I Grau et al., 2021;

Lazonder & Harmsen, 2016), stands out as a commonly used approach in climate change education.

Although there are great efforts by educators in K-12 and higher education, together with CCE researchers, the contribution of these efforts is in reality quite limited, as they have mostly resulted in increased knowledge and awareness of climate change, but not in behavioural changes or pro-environmental actions, which are climate-friendly, environmentally responsible actions that contribute to reducing greenhouse gas emissions (Busch & Osborne, 2014; Koll muss & Agyeman, 2002). Research by environmental educators and psychologists suggests that people who are psychologically distant from the risks of the climate crisis do not attempt to take climate-friendly actions and decisions (Markowitz & Beilenson, 2021; Spence et al., 2012). Therefore, a common hypothesis is that making the causes of climate change and the predicted consequences more real, close, current and relevant can serve to drive climate change action (Markowitz & Bailenson, 2021). The answer to how CCE can sustain this reality and promote climate change engagement can be found in a rapidly developing technology called immersive virtual reality (IVR). IVR creates an artificial reality that imitates the real-world by immersing users to a computer-based environment (Furht, 2008). Increasing body of research on virtual reality technologies in education has suggested that with unique features that provide users with presence, immersion, embodiment, vividness, interaction and more, IVR can be a promising tool for CCE (Fauville et al., 2020). An example of this use is immersive virtual field trips (iVFTs) which are simulated real-life experiences in physical locations (Klippel et al., 2020). These trips that use IVR technology can create educational experiences that allow students to explore a virtual environment as they would in real life.

Although IVR technologies started to become affordable in more recent years, most people still do not have access to VR headsets yet. This novelty and inaccessibility may hinder the reveal of the effectives of IVR as an instructional tool for climate change learning. Research on using VR and IVR in education showed that virtual reality technologies can engage learners, increase motivation and interaction, enhance learning outcomes (Ahn, Le & Bailenson, 2013; Kilmon et al., 2010; Sacks et al., 2013). More recent studies that focus on using IVR for environmental education and CCE also declared similar results (Ahn et al., 2014; Bailey et al., 2015; Fonseca & Kraus, 2016; Markowitz et al., 2018). In particular, iVFTs have shown positive outcomes in climate change learning while promoting enjoyment and interest at the same time (Makransky & Mayer, 2022; Petersen et al., 2020).

Although IVR a potential in climate education, most of the research in this area assesses the knowledge level outcomes of IVR-based activities (Fauville et al., 2020) whereas the aim of CCE should be promoting climate change engagement for all of its components cognitive, affective and behavioral engagement (Lorenzoni et al., 2007). In particular, the emotional connectedness, which immersive experiences can provide, offers a unique way to regulate affective factors related to climate change action like hope, worry, fear, interest. Especially climate worry and hope have a crucial role in offering solutions, change in behaviors and supporting related policies about climate change (Sangervo et al., 2022; Smith & Leiserowitz, 2014). Therefore, immersive climate change learning needs to target climate hope and worry while enhancing understanding. There are some studies showing that the use of IVR for climate change education can be useful for that purpose; however, in most of these studies, the used IVR interventions are offered to learners in short periods of time. In addition, a systematic review showed that 68% of the research conducted using IVR did not mention their theoretical foundation by explicitly referring to any learning theories explicitly (Radianti et al., 2020).

Therefore, a common problem is integrating IVR experiences into CCE by considering the design of a whole learning environment that includes tasks, activities, tools, discourse elements combined with appropriate pedagogies based on the educational research. There is a need for more research that investigates the contributions of IVR in cognitive and affective gains for climate change when they designed based on existing theories in the field. In this study, an inquiry-based learning experience is designed according to the learning progression of sea level rise (Breslyn et al., 2016) which is an important learning topic related to in CCE. With the aim of supporting understanding of sea level rise while promoting hope and worry about climate change, iVFTs were integrated into the developed lesson. This study has the potential to address these needs in the literature for research on inquiry learning environments supported by virtual reality to promote comprehensive climate change learning. In this study, by examining the integration of iVFTs into climate change education, possible contributions of IVR to climate change education in the future can be evaluated. The results can help educators to take a position on integrating immersive technologies into their educational process when teaching climate change. Also, researchers and policymakers can foresee the future of IVR for enhancing CCE while fostering climate hopes and worries and improving learning intertwined with them.

1.1 Purpose

The aim of this study was to examine sixth-grade students' understanding of the impacts of sea level rise, their worries and hopes about climate change after participating in an immersive virtual field trips-integrated inquiry-based learning (iVFTs-IBL) experience about sea level rise.

1.2 Research questions

i. Do sixth-grade students' level of understanding of sea level rise improve after participating in iVFTs-IBL experience about sea level rise?

  i.i Is there a significant difference between sixth-grade students' pretest and posttest scores as measured by the learning progression instrument about impacts of sea level rise (ISLRAI) after participating in the iVFTs-IBL experience?

  i.ii How do sixth-grade students' understanding of sea level rise change as evident in their explanations written in the KLEW chart after participating in the iVFTs-IBL environment about sea level rise?

ii. Is there a significant difference between sixth-grade students' pretest and posttest scores on Climate Change Worry Scale after participating in the iVFTs-IBL environment about sea level rise?

iii. Is there a significant difference between sixth-grade students' pretest and posttest scores on Climate Change Hope Scale after participating in the iVFTs-IBL environment about sea level rise?

1.3 Definition of terms

1.3.1 Climate change

Intergovernmental Panel on Climate Change (IPCC) defines climate change as "A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer" (IPCC, 2018, p. 544). This definition differs from the one in the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 by differentiating human-induced and natural attributed climate change. However, in this study, the term "climate change" was used to refer to current human-caused changes in the world's climate.

1.3.2 Sea level rise

Sea level rise is the increase in global mean sea levels because of an increase in Earth's atmospheric temperature and climate change. It has risen about 21–24 centimeters since 1880 (Lindsey, 2022).

1.3.3 Climate change education

Climate change education (CCE) refers to educational contributions for understanding and addressing climate change, promoting climate-friendly actions, and developing effective responses for mitigation and adaptation by engaging with all stakeholders (UNESCO & UNFCCC, 2016). CCE also involves "creatively preparing children and young people for a rapidly changing, uncertain, risky, and possibly dangerous future" (Stevenson et al., 2017, p. 68).

1.3.4 Climate change worry

Stewart (2021) defines climate change worry as “primarily verbal-linguistic thoughts (rather than images) about the changes that may occur” (p. 4). It is the summated score of responses to the five-point Likert scale developed by him called the Climate Change Worry Scale, in which a higher summated score shows a higher level of worry.

1.3.5 Climate change hope

Li and Monroe (2018) define climate change hope as “individuals’ belief that they and society in general can generate pathways and are able to execute the pathways to solve problems caused by climate change” (p. 6). It is the summated score of responses to the five-point Likert scale developed by Li and Monroe (2018) and called the Climate Change Hope Scale which a higher summated score shows a higher level of hope.

1.3.6 Immersive virtual reality

Virtual reality is defined as a real or simulated environment in which a perceiver experiences telepresence (Steue, 1992). According to the Encyclopedia of Multimedia, Immersive virtual reality (IVR) is the technology that provides an artificial environment that replaces users' real-world in by aiming to completely immerse users and engage them inside the computer-generated almost real world (Furht, 2008).

1.3.7 Immersive virtual field trip

Immersive virtual field trips are digital experiences that mimic a real-world trip by allowing exploration of virtual representations of physical places by using immersive technologies such as head-mounted displays (Klippel et al., 2020).

CHAPTER 2

LITERATURE REVIEW

This study brings together two popular research areas in the last decades, climate change education (CCE) and immersive virtual realities (IVR). This section first addresses the need for climate change education, then presents existing challenges and problems it is facing. Next, a brief introduction to virtual reality and immersive virtual reality in education is mentioned. Then previous research about the main focus of this study which is the effects of using IVR in CCE presented and discussed. Lastly, the place of this study in the current literature and its significance for addressing existing deficiencies is mentioned.

2.1 Climate change and sea level rise

Global climate change is one of humanity's most vital issues due to its ongoing global effects and the predicted ones in the near future. With the rapid growth in population, energy consumption, trade, travel, and other human activities, human influence on Earth’s climate has come to a point that threatens all living beings on the planet (McMichael, 2003). In August 2021, the 6th assessment report issued by many scientists in the Intergovernmental Panel on Climate Change (IPCC) was described as “a code red for humanity” by pointing to the irreversible effects of climate change on Earth and all living things. According to the scientific community, limiting global warming to 1.5 degrees Celsius and as a result, reducing the catastrophic consequences of climate change is still possible, but it will necessitate significant adjustments and social changes (IPCC, 2019).

One of the irreversible consequences of the climate crisis is the increase in the level of the world's oceans, also known as sea level rise. IPCC (2023) reported that sea level rise is inescapable due to ongoing ocean warming and ice sheet melting and will continue to rise for centuries to thousands of years. The rate of sea level rise will vary depending on future emissions, but under the high greenhouse gas emission scenarios, it is projected to “approach 2 meters by 2100 and in excess of 15 m by 2300" (IPCC, 2023, p.42). Low-lying coastal zones are more vulnerable to the severe impacts of sea level rise, including coastal erosion, storm surges, and salt-water intrusion (Barbier, 2015). Over 600 million people live near the sea, in coastal regions that will be affected by these impacts (United Nations, 2017). Türkiye, as a country surrounded by the sea on three sides, is projected to experience a sea level rise of about 1 meter over the next century in the “business as usual” scenario of high emissions (World Bank Climate Change Knowledge Portal, n.d.) Therefore, sea level rise is a locally relevant and significant effect of climate change which need to be addressed for learners.

2.2 Climate change education

Today, more than 33 countries have already declared a “Climate Emergency” and since 2015, 197 countries have signed the Paris Agreement to react to the climate crisis. However, even though climate change will impact everyone individually, its consequences appear to people as far away from them since these are stated on global and national scales. While the severity of the consequences of climate change, such as sea level rise, is increasing daily and becoming more visible in everyday life, one solution for public awareness and behaviour change is public education (UNESCO & UNFCCC, 2016). Education can help build a better understanding of climate change, community engagement, and knowledge of solutions for collectively responding to this global issue (Busch et al., 2019). Therefore, the role of education is essential for acting against climate change as education that promotes environmental citizenship, can progressively foster social transformation for sustainability (Lorenzoni et al., 2007; Perkins et al., 2018). As a result, there is an increasing interest in climate education research to understand ways to address climate change in classrooms (Monroea et al., 2019; Reid, 2019).

However, the results of the increasing effort by climate change educators and researchers showed that communicating the causes and consequences of climate change is difficult due to its complex nature as an environmental and social problem (Perkins et al., 2018; Reid, 2019). There are several challenges to teaching climate change. Firstly, it has invisible causes such as the greenhouse effect, greenhouse gas emissions, or ice-albedo feedback, and it has distant consequences, which are mostly seen more in climate-vulnerable areas of the world or predicted to be seen in the near future. Since the majority of the human population today live in urbanized cities, their daily life is not affected by climate extremes that much (Moser, 2010). As a result, public perception is psychologically distant from climate change, bringing fewer concerns about it (Spence et al., 2012). Other problems for climate change understanding investigated in environmental psychology include skepticism in public, the complexity of the issue, uncertainty in climate science, a global and long time scale that is away from everyday experiences and emotions such as helplessness and hopelessness (Whitmarsh, 2011). Therefore, even though education is a key to climate action and empowerment, for the need for urgent mitigation and adaptation, learners need to be supported in these identified areas while engaging in practices of climate change learning. For that reason, while targeting cognitive level outcomes such as understanding the causes and impacts of climate change, affective level outcomes such as interest, hope, worry, anxiety, and fear should be considered in learning experiences designed for CCE.

2.2.1 Climate change worry and hope

Climate change is a complicated and emotionally charged issue and there is emerging evidence that emotions impact people's attitudes and actions related to this problem (Jones & Davison, 2021). While emotions can shape perceptions and beliefs about climate change, it is critical to maintaining hope for the future since hopelessness leads to pessimistic views and can have a negative impact on climate change mitigation (Ratinen, 2021). In that sense, hope and worry are important emotional responses to climate change, and both can be influenced by the level of knowledge and understanding individuals have about the issue. While some studies showed that knowledge of climate change might increase worry and loss of hope, others showed that meaning-making enables maintaining hope and developing coping strategies (Sangervo et al., 2022). The climate change understanding of students predicts their constructive hope, which is related to the view that people are capable to act for climate change (Ratinen, 2021). Hope might act as a motivating drive and has a particularly positive impact on pro-environmental behavior (Ojala, 2012). Ojala's work (2012, 2015) with students on hope and coping in climate change education has demonstrated that learning about climate change mechanisms is not only a cognitive activity but also incorporates emotions triggered by the severity and complexity of the issue.

Similar to hope, worry about climate change is a strong predictor of support for climate-change mitigation policies (Smith & Leiserowitz, 2014). Also, climate worry and hope are connected and adaptable emotions that may be required to inspire humanity to develop solutions to climate change (Sangervo et al., 2022). They might function as motivators encouraging students to find solutions to climate change problems. Also, cognitive and affective experiences should be integrated and considered in CCE to prevent long-term impacts on the attitudes and behaviors of adults (Jones & Davison, 2021). Therefore, educators should foster hope and regulate worry in climate change learning environments to take part in the development of a more involved, aware, and resilient generation of climate change advocates.

2.2.2 Learning progressions in climate change education

Climate change is a topic that has multiple dimensions and therefore requires an in-depth understanding of several other subtopics, such as human factors, mechanisms, history, impacts, mitigation, and adaptation strategies. For this reason, several researchers have developed learning progressions on climate change or related sub-topics (Breslyn et al., 2016; Breslin et al., 2017; Jin & Anderson, 2012; Jin et al., 2013; Mohan et al., 2009; Schramm et al., 2018). Learning progressions (LPs) are defined as "hypothetical models of learning developed with the aim of informing the design of standards, curriculum, instruction, and assessment in K-16 settings" (Duncann & Rivet, 2018, p.422). LPs are particularly useful for describing student learning over time at different levels of complexity, as they provide cognitive models that illustrate how learners move from intuitive thinking to scientific reasoning (Duncann & Rivet, 2018; Jin et al., 2019).

Jin and Anderson (2012) created a learning progression for K-12 students about energy in social and ecological systems and the carbon cycle, which are both crucial constructs for climate change learning. Later they designed a teaching intervention with 717 students according to that detailed previous model with a five-practice LP framework (Jin et al., 2013). Based on these LPs, they developed and implemented a two-week teaching program; and their findings indicated considerable learning gains for 7th to 12th-grade learners (Schramm et al., 2018). Another empirically validated LP about carbon cycling includes four levels and a multi-year perceptive that focuses on processes whose global imbalance is the fundamental cause of climate change (Mohan et al., 2009). More recently, a conditional climate change LP related to sea level rise projections was created and reported by a study conducted with middle school and university students (N= 172) (Breslyn et al., 2016). Building upon this study, Breslyn et al. (2017) developed a conditional four-level LP for climate change that includes four levels for each dimension of climate change: mechanism, impacts, human activity, and mitigation-adaptation.

Unlike learning progressions that take long time periods and happen over a course or curriculum of several years, LP can occur in a short period, such as within a unit or lesson (Merritt et al., 2008; Schramm et al., 2018; Steedle & Shavelson, 2009; Yin et al., 2013). For example, by using a learning progression, Merritt et al. (2008) examined change in sixth-grade students' understanding of the particle nature of matter during a chemistry unit. Similarly, Langbeheim et al. (2022) investigated the role of pictorial representation in student level of reasoning according to levels in a chemistry LP. Besides, many researchers stated that LPs could be useful in creating instructional materials, strategies, or assessment practices (Alonzo & Gearhart. 2006; Sztajn et al., 2012; Langbeheim et al., 2022) as in this study.

This study used an LP developed by Breslyn et al. (2016) about sea level rise resulting from the iterative work with middle school students and undergraduate students. The LP consists of three components: causes and mechanisms, scale and representations, and impacts of sea level rise. For each of these parts of the topic, learning progressions consisting of four levels have been developed. In this study, while designing the iVFTs-IBL environment, apparent levels and described student thinking about impacts of sea level rise part of the LP was used (see Figure 1 and Figure 2).

Impacts of sea level rise

	Level 1 (Lower Anchor)	Level 2	Level 3	Level 4 (Upper Anchor)
Impacts of sea level rise	Students identify that an impact of sea level rise is that some land will be covered by water, though they are not able to elaborate on specific consequences of sea level rise.	Students understand that sea level is projected to rise in the future and are able to identify a limited number of specific consequences, though they do not understand that sea level rise will have local effects including those related to storm surge.	Students understand that local impacts of sea level changes can differ, but cannot explain primary factors that can cause this difference. Students are able to elaborate on specific consequences of sea level rise such as loss of habitat, in-land flooding during storms, property loss, and erosion.	Students understand that local sea level changes can differ from global trends based on regional variations in factors such as geographic uplift or subsidence and ocean currents. Students are able to elaborate on specific consequences of local sea level rise. Students recognize that sea level rise projections are based on available data and may be lower or higher than predicted.

Figure 1. The impacts of sea level rise LP developed by Breslyn et al. (2016)

Description of learners' thinking at each level of the conditional LP.

Level 1: Students can explain that sea level rise will result in islands and coastal areas being covered in water but they can only describe very general consequences, most often stating that humans will need to relocate. They frequently describe the impact on animals, especially penguins and polar bears, which are frequently mentioned in the media.

Level 2: Students can list a limited number of consequences. While students are familiar with the concept of sea level rise, they are unsure if it is presently occurring or is a future event. They are also unsure of how much the sea level will rise and therefore the extent of the impacts. In addition, students consider sea level rise to be uniform, with all coastal areas and islands experiencing the same rise in sea levels. Finally, students do not consider storm surge from severe weather events when considering the impacts of sea level rise. This level is characterized by a more static conceptual understanding of sea level rise.

Level 3: This level represents a conceptual shift to a more dynamic understanding that, while average sea levels are rising consistently and gradually, storm surge can lead to impacts periodically being felt further inland. Students can describe a wider variety of consequences and can provide more detail than in the previous level. Based on their ability to use data and graphs projecting sea level rise, students have a better understanding of the timing and degree of sea level rise, and therefore the severity of the impacts. Students also understand that local variations exist but primarily attribute this to topography and do not consider geologic factors and ocean currents.

Level 4: Students understand that local impacts will vary depending on changing geologic features as well as ocean currents. At Level 4, student understanding grows more sophisticated in that they understand projections are useful for predicting impacts but are tentative and may change. Here they understand that projections are based on models that make assumptions about ice melt, thermal expansion, human activity, and other factors.

Figure 2. Description of learners' thinking in impacts of sea level rise LP (Breslyn et al., 2016)

2.2.3 Inquiry-based learning in climate change education

Climate change is a multi-dimensional complex topic that is related to various areas and educational subjects such as science, environmental education, social studies classes, and so on. Also, the target audience varies from K-12 to university level and even all public. As a result, there is a wide range of CCE approaches for teaching climate change. Some specific underlined strategies for addressing these challenges include making the problem more personally relevant by focusing here and now rather than on the global scale, including other dimensions than science, including social, economic, and political aspects of climate change, making a connection with other science topics such as carbon cycle, chemical concepts in carbon-based molecules, photosynthesis, concepts of the ocean and atmospheric circulation (Busch &Osborne, 2014). Recently, Monroea et al. (2019) conducted a research review to identify effective CCE strategies in teaching the issue. They stated that focusing on what is relevant and meaningful in-person, such as linking personal actions or community problems with personal behaviors, supports learning gains in climate change education. In addition, the review has shown that the best pedagogical approach to CCE is using engaging and active methods in learning activities. Critical inquiry with learner-centered pedagogies and authentic participation are founded useful in CCE (Perkins et al., 2018). This is consistent with environmental education guidelines suggesting learner-centered, inquiry-based, hands-on learning opportunities for developing understanding and new skills in environmental issues (North American Association for Environmental Education [NAAEE], 2004). Therefore, commonly used approaches in CCE put student-centered active learning at their center, and they include experiential, inquiry-based, problem-based, and project-based learning approaches, which have been proven to be effective for science and environmental education (Bybee et al., 2006; Monroea et al., 2019).

In problem-based learning, students solve authentic, real-world problems related to climate change. They apply knowledge and skills to solve these environmental problems. However, climate change problems are generally connected with many other issues and have various dimensions that require interdisciplinary work to solve them (Weber & Khademian, 2008). Therefore problem-based learning approaches for CCE are more suitable to use in secondary education and higher education levels. Project-based learning is similar to problem-based and inquiry-based learning in areas of student-centered, active learning with encouraging critical thinking skills. As in inquiry-based learning, it emphasizes the process rather than knowledge but with this approach, students create project outputs such as visual materials, innovative applications in school or the area, and tangible, meaningful products (Barron et al., 1998). For that reason, it requires the development of more long-term projects. This makes it more suitable for learning experiences that continue for a longer period of time.

Besides these approaches, inquiry-based learning (IBL) is another mostly used pedagogical approach in climate change education. Inquiry-based methods use essential questions that lead to student understanding about the main principles and arguments around the issue by focusing on the process of discovery and self-directed investigations (Pedaste et al., 2015). Several meta-analyses found that when students are supported throughout the learning experience, IBL can be quite effective compared to other methods (Furtak et al., 2012; Lazonder & Harmsen, 2016). In IBL, students engage in the process with their own ideas; this enables them to build strong connections between ideas in various subject areas. The natural curiosity of students is supported to ask questions and discover environmental topics. Since climate change is a multidisciplinary issue the variation in student ideas provided by inquiry learning enables to create an effective learning environment in climate change issues. In pedagogy, the scientific process broken into small steps lets learners focus on significant elements of scientific thinking; these steps called inquiry phases get connected and create an inquiry cycle (Pedaste et al., 2015). From various different frameworks and inquiry cycles described in the literature, one of the most influential ones is the 5E learning cycle model by Bybee et al. (2006).

2.2.3.1 5E model of inquiry-based learning

The 5E inquiry-based model suggests five inquiry phases for the learning cycle: Engagement, Exploration, Explanation, Elaboration, and Evaluation, and these phases structure learning (Bybee et al., 2006). Students get motivated in the engagement phase, which is the first phase of the 5E model. They get engaged with the topic and are encouraged to investigate it. In the next step, which is Explore, students explore materials, ask questions and work to find answers in various ways. This phase mostly includes the main inquiry activity, which students will investigate and then construct their explanations in the next phase, Explain. This phase makes student learning visible by letting students show their understanding as a result of their examination. The following phase is called Elaboration. In this step, students expand and deepen their learning by applying on what they learned in novel settings. The last phase of the cycle enables students to reflect on their learning by evaluating their learning (Rodriguez et al., 2019)

Existing studies about 5E learning showed the effectiveness of this inquiry model in many ways (Cakir, 2017; Furtak et el., 2012; Garcia I Grau et al., 2021). The meta-analyses by Furtak et el. (2012) investigated experimental and quasi-experimental studies conducted over one decade and stated that the 5E approach positively affects student learning. Another metanalysis (Cakir, 2017) investigated studies conducted in Turkey again for one decade and concluded that the 5E instruction model affects students' academic achievement, scientific practice skills, and attitude toward science. A recent study (Garcia I Grau et al., 2021) assessed the long-term effects of the 5E teaching model on students' conceptual understanding of the kinetic-molecular model. 725 students were tested, and the results showed that students whose teachers had been introduced to the 5E model five years ago outperformed the control group who had been taught using conventional methods.

Although the IBL and 5E model of learning are not new, the availability of new technologies has started to be a critical component of inquiry-based methods since they can advance IBL. Because technology integration in inquiry cycles offers students new environments they can explore, organize their questions and findings, communicate with experts, collaborate with others and more (Owens et al., 2002). Therefore, technology can deal with challenges in IBL (Edelson et al., 1999) and improve learning about climate change (Petersen et al., 2020).

2.3 Technologies in climate change education

Climate change education is challenging due to these multiple perspectives and being far from hands-on laboratory experiments. Therefore, climate change pedagogies need to be integrated with appropriate technologies to combat these drawbacks and support meaningful learning that inspires action-taking. Technologies such as remote sensing, interactive presentations with graphics and music, documentation, games, and simulations that enable learners to see the reality of the future and the results of our actions by mimicking reality (Monroea et al., 2019). Also, educational technology used in CCE promises positive learning gains as similar to all other contents. For example, Makrakis et al. (2012) designed a web-based hypermedia environment integrated into the primary school curriculum for students to gain information, change attitudes and take action about climate change. Their information and communications technologies enabled a CCE design consisting of interactive activities for authentic learning situations supported by tools like concept maps, videos, spreadsheets, and discussion forums. Schott (2017) conducted virtual field trips and stated significant climate change learning gains for university students. Petersen et al. (2020) also found that the virtual field trip increases student scores in declarative knowledge, self-efficacy and intentions to change behaviors.

Varma and Linn (2012) developed and used an interactive technology-enhanced curricular module about the greenhouse effect and climate change called Global Warming: Virtual Earth. Inquiry-driven activities with virtual experiments, visualization and data examinations in the module resulted in increased scientific knowledge and understanding of climate change for middle school students (Varma & Linn, 2012). Bush et al. (2018) used and compared simulations with complex and simpler inferences as climate education technologies. Findings showed that students who work with more authentic technology and complex interface demonstrated higher engagement levels, learning gains, and ideas about scientists' work in the field. The studies showed that the use of computer-based climate models in CCE can promote scientific understanding and reasoning about climate change, scientific methods and develop process skills since they enable learners to interact and explore real world data, run their own experiments, engage in realistic scientific inquiry (Bush, 2016). Simulations used in CCE can help comprehend climate research procedures in the same manner that scientists do, but in most of the cases these types of technology enhanced inquiry learning curricula take place over longer periods of time.

Recently, another increased usage of technology in CCE appeared as educational games. The increasing number of studies about climate change games showed positive results as useful tools to sustain engagement in both cognitive, emotional, and behavioral dimensions for climate change (Fernández Galeote & Hamari, 2021; Ouariachi et al., 2019; Wu & Lee, 2015). With the provided immersion and interactivity, games enable users to test decisions, predict outcomes, and see their actions' effects immediately in future environments (Ouariachi Peralta et al., 2017). Several studies that assess the effects of educational games in CCE concluded that games could prepare learners for future world (Wu & Lee, 2015), engage them in climate learning (Flood et al., 2018; Ouariachi et al., 2019), enhance decision making (Flood et al., 2018), develop empathy for people living in climate vulnerable places (Koenigstein et al., 2020) enhance knowledge gains and problem solving related to climate change and (Leitão et al., 2021). A recent review of environmental education games and gamified apps for users has shown that these apps and games are effective for players to adopt more sustainable behaviors related to energy reduction, transportation, water conservation and waste management (Douglas & Brauer, 2021). As a new genre, climate change games are promising tools for climate change engagement and education since they can serve to simplify complex ideas and concepts in climate change topics.

Although research and practices on CCE have significantly developed together with the advances in educational technology in the last decades; positive results are mostly seen only in knowledge and awareness levels that do not guarantee a change in public attitudes and behaviors towards the issue (Flood et al., 2018; Reid, 2019).

Therefore, there is a need for CCE which engages the young in climate change by targeting to develop both a better understanding and positive emotional responses for climate change. For that purpose, virtual environments provided by educational technologies can be integrated into inquiry-based climate change learning. Virtual reality in environmental education has already seen an opportunity to allow learners to have experiences that are not available in daily life and increase connectedness (Taylor & Disinger, 1997). With increased immersion, presence, and embodiment it can be used to address the existing challenges of climate change education.

2.4 Virtual reality, immersive virtual reality and their affordances

As happened in other rapidly developing technologies, virtual reality (VR) created a new type of interaction between computers and humans. Depending on the goal, target consumers, setting, and technology, the sort of VR experience might vary in three types: (1) explorations, (2) games, and (3) simulations (Scurati et al., 2021). These VR technologies have been studied in several contexts for their benefits and applications showed great potential in education as they made new connections possible with the educational materials for learners. VR was initially characterized in terms of technology, as it linked with the usage of specific devices. Following that, the ideas of presence and telepresence were used to define it as a real or virtual setting in which a perceiver can experience telepresence (Steue, 1992). A mostly accepted definition for presence is “a psychological state in which virtual objects are experienced as actual objects in either sensory or nonsensory way” (Lee, 2004, p. 46).

When wearable hardware technologies that can generate direct experiences with the virtual environment developed, another affordance called immersion was added to VR in a computational environment. Immersion is differentiated from presence as a feature of technology delivery, and it is related to how well the technology represents motions and movement in the virtual 3D environment that surrounds the user (Cummings & Bailenson, 2015). Studies in the field showed that these affordances of VR, presence and immersion, are related (Cummings & Bailenson, 2015; Trindade et al., 2002). Therefore, IVR characterized with VR headsets offers stereoscopic displays and 3D sounds that give the feeling of depth and controllers can interact with the environment using hand movements, and sensors that track full body. As a results, the presence is more readily and strongly accomplished in IVR compared to desktop or mobile VR (Bryson, 1996). Another affordance of VR is the embodiment which means changing the representation of the body in virtual environments (Biocca, 1997). Embodiment involves the feeling of being present in a virtual environment where user can interact with the surrounding as if it is physically present (Schultze, 2010). Together with the effects of increased immersion, presence, IVR offers embodied experiences in realistic environments that users can see, hear and interact with.

The advancements in the hardware and software combinations such as better resolution or graphics also have made high fidelity possible for all three types of VR experiences. Fidelity is a notion related to the level of realism achieved by various components of VR that support a design with temporal and spatial accuracy: therefore, IVR with its affordances creates a higher fidelity compared to VR and higher fidelity also supports these affordances (Gilson & Glennerster, 2012). With the help of 360-degree visual environments and three-dimensional, realistic sound, people can easily internalise their virtual experiences and treat them as similar to the real thing, allowing IVR to be used in therapeutic applications (Sanchez-Vives & Slater, 2005). With the potential to present educational media that would otherwise be difficult or impossible to access, IVR can be seen as revolutionary for education. This is because IVR allows users to interact with virtual materials in a virtual environment, which is also useful for promoting interaction between content and learners in a unique way.

2.4.1 Immersive virtual reality and education

Numerous experimental educational research found out that VR used in desktop is successful to increase engagement and learning (Dede, 2009, 1996) however research that investigates the effects of immersive virtual reality (IVR) in learning is quite less when taking into account its potentials to create a stronger embodiment and immersion that will help learning. Since accessibility to IVR is increasing as head-mounted display devices that provide much more immersive VR experiences, getting cheaper, much research started to be done to see the challenges and potentials of IVR in training and education. IVR started to be used in science education, psychological treatments, tourism and virtual trips, medical treatment practices (e.g., Kilmon et al., 2010; Markowitz et al., 2018; Sacks et al., 2013).

Even though most of these studies stated improved engagement and learning gains, some of them have found no significant effect or sometimes even negative effects when IVR was compared to the desktop usage (e.g., Makransky et al., 2019; Moreno & Mayer, 2002, 2004). For example, in a recent research Parong and Mayer (2021) investigated the learning outcomes of a history lesson by comparing IVR and interactive video on the desktop. Results of the study showed that participants who used the video outperformed compared to the IVR group. Based on the multimodal data collected in the research, the authors argue that excessive cognitive processing and emotions negatively affected the learning performance. In another study, Parong and Mayer (2018) conducted two experimental designs to investigate the effectiveness of converting multimedia lessons into virtual reality environments. In the first experiment, college student participants are divided into groups. The first group used an interactive, immersive virtual reality trip to learn about the human bloodstream while the other group uses a self-directed slideshow to learn the same material. Results showed that although IVR group participants show higher interest, motivation, and engagement scores, their posttest results about the subject learning were significantly lower than the slideshow user group. These results show that desktop slideshows can be a better tool than IVR for teaching scientific knowledge. The second experiment aimed to assess the effectiveness of additional learning strategies in the IVR. For that, while one group used IVR as usual the other groups made a summary after each segment of the IVR. Results show the group that makes summarization outperformed in the posttest while both groups stated a similar level of interest, engagement, and motivation stated in each group. Results of these studies revealed that although VR can contribute to engagement and interest, these are not enough for learning gains, especially when the IVR application is not integrated with a learning experience designed in line with a pedagogy.

Many research that compares IVR with other types of learning environments stated improvement in cognitive gains (e.g., Allcoat & Mühlenen, 2018; Di Natale et al., 2020; Hsu et al., 2018; Markowitz et al., 2018; Mirauda et al., 2020). For example, Allcoat and Mühlenen (2018) compared the IVR condition with the video condition for a learning material about 3D interactive cell models. Results show that both engagement, understanding, and remembering were better for the participants in the virtual reality condition. When these knowledge gains are combined with the potentials of IVR as increasing presence, connectedness, emotions, and empathy, IVR can support climate change understanding while promoting hope and regulating worry which can bring changing behaviors and taking actions.

2.5 Immersive virtual reality and climate change education

The idea of using realistic visualization of a predicted future to raise public awareness in climate change and influencing environmental behaviors first started to be suggested by Sheppard (2005), and he argued that technology can be used to visualize information on climate change and as a result may help to communicate the issue. At those times, the idea of using virtual reality for education also started to gain importance. As stated earlier by Dede et al. (1996), this is due to the great potential of virtual reality technologies to promote effective and active learning of complex and abstract scientific concepts. Respectively, using VR in environmental education started to gain focus in recent decades with the call for innovative technological tools to facilitate learning about environmental and social issues. Firsthand experiences provided by VR make it possible to observe and get connected with environmental problems more closely.

The climate crisis is one of the most important global environmental issues that comprise various scientific and environmental topics. Therefore, using virtual environments in CCE also started to be studied in the area. According to recent reviews (Fauville et al., 2020; Queiroz et al., 2018), virtual reality can be a highly useful tool for CCE that aims not only to provide knowledge and awareness about the issue but also to engage users in changing behaviors and adopting pro-environmental actions. This is due to the potential of virtual reality to address the challenges in CCE with its interactive and immersive nature. For instance, for the challenges of invisible causes and distant consequences of climate change, emissions and their relationship with individual actions can be made visible with the help of a virtual reality simulation. In that way, individuals directly see the consequences of their actions or inactions in future scenarios modeled based on scientific evidence. Similarly, to that approach, in a recent study (Ke et al., 2019), immersive IVR was used to simulate extreme weather conditions in Hong Kong that are enhanced as a result of participants' electricity and energy consumption. In the interactive game, participants who perform their daily energy use first saw the effects of their usage on future virtual city environments in a personalized way.

Individuals who experience the IVR can directly interact with the created immersive environment which is otherwise impossible to do because it can represent a faraway place, an inaccessible place, or a place in the future. A recent empirical study confirmed that higher levels of immersion provided by virtual reality could enhance pro-environmental behaviors and be used to communicate environmental risks as it bridges the psychological distance of environmental problems for individuals (Breves & Schramm, 2021). Moreover, IVR is useful for providing a place for perspective-taking actions by changing the environment and the user's avatar easily. Studies have shown that with the help of this perspective-taking of someone else, IVR can contribute to the development of prosocial behaviors such as helping (Ahn et al., 2013), fostering empathy and connectedness to others like homeless people (Herrera et al., 2018), decreasing racism and ageism, (Hasler et al., 2017; Oh et al. 2016).

This potential of IVR in climate change education was investigated in many aspects in the literature, yet the majority of the empirical research does not directly state contributions to CCE but mostly focus on specific environmental issues related to climate change such as ocean acidification (Markowitz et al., 2018), deforestation (Ahn et al., 2014; Huang et al., 2021), energy consumption (Bailey et al., 2015), meat consumption (Fonseca & Kraus, 2016) plastic consumption (Chirico et al., 2021). This is due to the complexity of the climate change subject which includes many sub-titles to consider, and a learning module of the whole subject would take so long to assess its specific effects in a short-term empirical study. Still, this body of research is helpful in understanding the effects of IVR in climate change education. For the same reason, the current study was designed to focus on only one part of the learning about climate change, the phenomena of sea level rise, which is local, relevant to the learners, and critical consequence of climate change.

Most of the literature focuses on knowledge-based cognitive gains for climate change-related environmental concerns due to VR-used treatments (Fauville et al., 2020). This approach is widely used due to its ease to apply, and the research findings argue that relevant amounts of knowledge on the topic contribute to attitude and behavior change (Fabrigar et al., 2006; Ramsey & Rickson, 1976; Ranney & Clark, 2016). However, starting from the classical work by Hungerford and Volk (1990), studies also show that there is usually a knowledge-action gap in environmental issues (Kollmuss & Agyeman, 2002), which states that knowledge alone is insufficient to change individual or collective actions about environmental problems for pro-environmental behaviors. Therefore, environmental education focuses on other relevant factors such as emotions and their relationship with each other to better understand the adoption of pro-environmental behaviors. Since VR can offer special opportunities to investigate varying factors, several studies investigate changes in emotions, engagement, environmental literacy attitudes (Fonseca & Kraus, 2016; Markowitz et al., 2018) and behaviors (Ahn et al., 2014; Bailey et al., 2015; Fonseca & Kraus, 2016) with respect to VR usage for climate change education.

The affordances of IVR that contribute to greater interaction, engagement, and elaboration on the task which is stated as effects that last longer when compared to other experiences in the light of the elaboration likelihood model. According to this model, interacting and elaborating more on the task with careful considerations mostly results in a longer-lasting change of attitudes and persuasion (Petty & Cacioppo, 1986). Therefore, IVR experiences designed to support those affordances for the aim of promoting a willingness to act climate-friendly, can be expected to promote constructive hope and controlled worry which would produce long-term effects on individual's intentions as well.

Even though the potential of IVR for adopting actions in the long term, a limited number of research investigated this possible contribution, especially considering both cognitive and affective factors. For example, in the study conducted by Ahn et al. (2014), they compared an immersive virtual environment in head-mounted display usage with a video and a reading material about the same issue: paper consumption's effects on deforestation. While one group experiences cutting of the trees in IVR the other just read a passage about it. Results showed that in the short term, immersion had no significant effect because both groups showed a similar increase in the tendency to relate personal actions with environmental consequences. However, results from the second data collection which is one week later than the experiments show significant differences based on immersion as the group with head-mounted display used showed higher environmental behavior intention compared to video and paper groups. These results are consistent with arguments that immersion can improve learning by providing multiple perspectives, greater presence, and transfer from the learning environment to real life as stated by Dede (2009). Also, after the treatments, they compared the number of napkins used by the two groups to dry some water. They found that participants in the reading material treatment group used significantly more napkins than participants in the IVR condition. These results are considerable to show that when learning is supported by the emotional arousal created with IVR, a long-term contribution to the permanence of pro-environmental behaviors is possible.

Markowitz and her colleagues present another prominent study that focuses on the use of IVR in CCE. Markowitz et al. (2018) investigated the effectiveness of an immersive virtual reality for teaching the predicted consequences of climate change. In six months, researchers developed an IVR exercise focusing on four design goals, namely physical immersion, embodiment, natural interactions, and time travel, in collaboration with high school teachers. The developed IVR exercise focused on increasing students' knowledge about ocean acidification and changing their attitudes toward the issue. Four studies in the research investigated the effects of avatar change from scuba diver to coral and motion change from swimming with body movement or remote control. The results of those studies have shown significant knowledge gains for ocean acidification issues and some of them have resulted in positive changes in environmental attitudes. Also, findings from the data collected as time spent in VR and interaction by collecting marine objects showed a correlation with learning gains, indicating that visual and physical exploration during IVR resulted in increased learning in the subject. This recent research is unique in the research area since it is a large-scale, multi-study article with a variety of participants and a sample size of nearly 300; even though the results between conditions do not show a significant difference and the research does use a controlled setting to compare IVR exercises with different learning experiences or investigate affective contributions of this virtual experience.

Similarly, Bailey et al. (2015) used an immersive virtual reality environment with a head-mounted display to investigate the effects of personalization and vividness which is the degree of being realistic multisensory and motivationally engaging (Ganesh et al., 2019). In their research, participants washed their hands before and after the immersive virtual reality treatments that present consequences of using coal-originated energy for heating water and then asked users to take a virtual shower. Results of the 2x2 design research showed that after the treatment, participants used much colder water to wash their hands compared to their initial usage. Moreover, participants in the vivid treatment, which had three-dimensional realistic coals moving from one pile to another in every used significantly colder water compared to not vivid treatment that shows the numbers of used coals in a billboard sign in the virtual environment. This study contributes not only the literature about the effective usage of IVR in climate change education for behavior change but also presents the role of learning environment design using a virtual component (e.g., Chirico et al., 2021). Still, research neither provide information about emotions, motivations or understating behind participants' energy savings behaviors.

A more comprehensive approach should be adopted to understand IVR's possible role in CCE that uses emotional arousal and understanding of the issue to promote action. This can be possible by integrating virtual reality technology into learning environments where immersion is boosted with inquiry and collective meaning-making. In this way, CCE cannot only serve cognitive learning gains or short-term behavioral intention but also arouse constructive worry while enhancing hope.

2.6 Summary

As global temperatures rise and environmental problems resulting from climate change are increasing, there is an emergency to take action against climate change. Education has the potential to contribute to this by increasing knowledge, awareness and promoting behavioral changes. A way to address the challenges of climate change education is possible by using immersive virtual reality to increase both cognitive and affective factors that contribute to finding solutions and changing behaviors. This can help learners to understand the causes and consequences of climate change, like sea level rise, and foster their hope while controlling their worries. However, this research area is in its early stages with a limited number of research. Existing studies promise positive results for promoting climate-friendly actions with IVR. However, IVR should be integrated into a learning experience, especially inquiry-based learning for a better CCE that prepares the next generation for a future shaped by climate change.

Even though some recent studies assess the effects of IVR in climate education for cognitive (knowledge-level), affective (emotional-level) and behavioral change, their number is insufficient for such a potential present in the findings. It is obvious that IVR can contribute to climate change education, but more research is needed to understand how. The existing studies that investigate the effects of IVR on fostering pro-environmental behaviors showed positive results, but they are insufficient to present the overall picture of the learning environment and emotional responses from students.

This study aims to investigate the role of an IVR-integrated IBL environment on middle school students' worry and hopes about climate change and understanding of predicted consequences of sea level rise. The type of IVR examined is virtual field trips consisting of one 360-degree IVR documentary and one interactive IVR exploration environment.

Hopes and worry about climate change are related emotional responses that can promote adopting climate friendly actions. Understanding of impacts of sea level rise means the level of knowledge and ability to predict physical and human scale impacts of sea level rise on ecosystems and human communities.

2.7 Research questions

i. Do middle school students' level of understanding of impacts of sea level rise improve after participating in the immersive virtual field trips integrated inquiry-based learning (iVFTs-IBL) environment about sea level rise?

    i.i Is there a significant difference between sixth-grade students' pretest and posttest scores on sea level rise measured by the sea level rise learning progression instrument (ISLRAI) after participating in the iVFTs-IBL environment about sea level rise?

    i.ii How do students' understanding of sea level rise change as evident in their explanations written in the KLEW chart after participating in the iVFTs-IBL environment about sea level rise?

ii. Is there a significant difference between sixth-grade students' pretest and posttest scores on Climate Change Worry Scale after participating in the iVFTs-IBL environment about sea level rise?

iii. Is there a significant difference between sixth-grade students’ pretest and posttest scores on Climate Change Hope Scale after participating in the iVFTs-IBL environment about sea level rise?

CHAPTER 3

METHOD

This section presents the research design, context of the study and participants, data collection instruments and procedure, data analysis, and limitations of the study.

3.1 Research design

The study used a one-group pretest-posttest design supported by qualitative data (Chang et al., 2015) to provide a more comprehensive and in-depth understanding. For the quantitative data in the primary role, differences between students' pretest and posttest scores from the Impacts of Sea Level Rise Assessment Instrument (ISLRAI), Climate Change Worry Scale (CCWS) and Climate Change Hope Scale (CCHS) were examined. In this way, students' understanding of the impacts of sea level rise, and their worries and hopes regarding climate change were evaluated in two data points, before and after the IVR integrated inquiry-based learning experience. In addition to that, qualitative data collected through writing prompts in the KLEW (Know-Learn-Evidence-Wonder) chart lesson material from students was used to support and expand on the quantitative findings regarding students' understanding of the impacts of sea level rise.

3.2 Variables

The independent variable in the study is a treatment of immersive virtual reality integrated inquiry-based learning experience about sea level rise, which is a part of the global climate change problem. Dependent variables include the scores from two scales measuring climate change worry and climate change hope constructs and the score for the understanding of impacts of sea level rise as measured by the Impacts of Sea Level Rise Assessment Instrument.

3.3 Context and participants

The study was conducted as an after-school activity in the virtual reality lab of a private school in Istanbul. The study was organized in the context of a virtual reality workshop on climate change. The research population consists of sixth-grade students from private schools in Istanbul. After reviewing the existing primary and secondary school curricula and assessing the essential abilities, it was determined that 6th-graders are the best fit for this study because they have limited prior knowledge about the topic, but still have a basic scientific understanding of the phases of water and temperature.

The sample of the study includes 38 sixth-grade students who volunteered to participate in the study. The students participated in the workshop in groups of 8 to 13 students each. Participants were selected using a purposeful sampling method based on several criteria. The primary purpose was to conduct the study with students who are initially familiar with virtual reality technology in order to minimize the novelty effect that can be experienced when using it for the first time. Students at the school are actively using the virtual reality lab that has been set up in the current academic year. According to the information collected from the participants through the demographic form (Appendix A and Appendix B), all participants have used a VR headset before. 13% of the participants used the VR headset once, 56% of them used it a couple of times, and 27% of them used it 3-4 times or more. One student reported that he owns a VR headset and uses it very often at home.

Another aim was to minimize students' prior knowledge about climate change and sea level rise. Therefore, this school was selected because it does not offer an environmental education and climate change course, which is included in the national curriculum as an elective course for grades 6, 7, and 8 in the 2022-2023 school year. Participants were also asked about their previous experience of environmental education or climate change. 73% of participants reported that they had never attended a course, lesson or workshop on environmental education or climate change. Similarly, 82% said they had never joined or been a member of an environmental group or organization.

3.4 Data sources

The data for this study was gathered using the Impacts of Sea Level Rise Assessment Instrument (ISLRAI), the KLEW chart used in the lesson, the Climate Change Worry Scale, and the Climate Change Hope Scale.

3.4.1 Impacts of sea level rise assessment instrument (ISLRAI)

To empirically examine participants' understanding about sea level rise before and after the learning experience, an adapted version of the Sea Level Rise Assessment Instrument (Breslyn et al., 2016) with items related to the impacts of sea level rise was used. The SLRAI is developed by four researchers from the University of Maryland to provide data for their research aiming to develop a learning progression on the sea level rise topic (Breslyn et al., 2016). Each item of the instrument is related to concepts in the learning progression which has three components: causes and mechanism, scale and representation, and impacts of sea level rise. After content experts and science teachers reviewed the instrument, it was used together with a sea level rise activity course to measure student understanding of sea level rise. The instrument went through an iterative revision process, each time the course is applied to middle school and university students. The final version of the instrument includes 16 multiple-choice items accompanied by a writing prompt “Why do you think this is the best response?” to uncover the reasoning behind selected choices with open-ended responses. Therefore, the instrument is useful for uncovering the complexity of a student's thinking and could indicate different progression levels for each component. This assessment instrument provided both quantitative and qualitative data for investigating the levels participants holds in the sea level rise learning progression.

In this study, the learning experience only focuses on one of the components of this learning progression, which is “impacts of sea level rise”. Therefore, only the five related items with this construct (item numbers 5, 9,11, 13, and 16) were selected from the SLRAI and adapted to Turkish for this research. These five items about the impacts of sea level rise were translated to Turkish and two content experts evaluated this translated version for its suitability to middle school students in Turkey. Final adjustments were completed based on their feedback. For example, the predicted “4 feet” sea level rise translated into “about one meter” since the metric system is commonly used in Turkey. Similarly, since the word “contributing” (*katkı yapmak*) is strongly considered as positive in Turkish, the experts suggested using “caused” (*sebep oldu*) sea level rise, instead of “contributing” to it.

This adapted version of the instrument was named as Impacts of Sea Level Rise Assessment Instrument (ISLRAI) (see Appendix C and Appendix D) and was used in the present study to investigate students’ understanding of sea level rise- both initial levels in the learning progression related to impacts of sea level rise, and also after the intervention. Two-tiered tests like ISLRAI are especially useful for overcoming limitations of multiple-choice items including guessing or correct responses with wrong conceptions (Adadan & Savasci, 2012; Pesman & Eryılmaz, 2010).

For analyzing the written explanation of student's answers to 'Why is this the best explanation' question followed by each multiple-choice item, the ISLRAI Rubric (Appendix C) was developed by the researcher. Designing a rubric requires a clear understanding of the expected student learning outcomes and how these will be achieved (Luft, 1999). Therefore, the scoring rubric was developed based on the levels of the sea level rise learning progression and the student thinking described for each level by Breslyn et al. (2016) (Figure 1 & 2). In the ISLRAI Rubric, the level of understanding is described in detail for each scoring band, and examples of student responses are provided for clear scoring using the rubric. As suggested by Allen and Tanner (2006), 'no response' was scored as 0 and 'incomplete' responses were coded as 1 for clarity in the coding of the rubric. For each item, the explanation section was scored from 0 to 5 and summed with the multiple-choice scores (1 or 0) to give the total score for the item.

To indicate the internal consistency of the ISLRAI, the instrument was given to 154 6th and 7^{th}-grade students in a private school (different than the study school). The test scores of these students were used to calculate Cronbach's alpha which was .79. In most cases, Cronbach's alpha between 0.7 and 0.8 is reported as acceptable, although it is expected to be higher for cognitive tests (Field, 2018). However, it is also argued that since Cronbach's alpha value is highly dependent on the number of items, the internal consistency of scales with fewer than ten items may be underestimated by this number (Herman, 2015). In addition, the interpretation of Cronbach's alpha needs to be considered for broad knowledge domains and diagnostic instruments. As the ISLRAI assesses the understanding of the impacts of sea level rise with different items focusing on relocation (item 1), ecosystems (item 2), coastal flooding (item 3), global warming (item 4), and storm surge (item 5), this reliability value was considered as acceptable for the test.

3.4.2 The know, learn, evidence, and wonder (KLEW) chart

The KLEW chart is a valuable teaching tool for active learning and formative assessment. The four letters in the abbreviation come from the initials of Know, Wonder, Evidence, and Learn. Originally the graphic organizer chart was used as a teaching tool with three letters: K, W and L; for the "K", students answer the question of "What do I already know?" at the beginning. Then for the letter "W" they write down what they wonder about the lesson topic, in the "L" they reflect on what they learned. As students participate in a course or learning experience students may use this graphic organizer to activate past knowledge, create learning goals, and arrange new information (Ogle, 1986). In this study, a developed version of the KWL chart that includes the question of "What is my evidence) was used; therefore, it is called as the KLEW chart. With this version of the tool, students are able to link their evidence from the investigation with their previous knowledge and claims (Hershberger et al., 2006). In this study, the KLEW chart (Appendix E and Appendix F) was used to collect data on students' understanding of sea level rise in the context of IBL.

3.4.3 Climate Change Worry Scale

One of the dependent variables of the study is students' climate change worry was measured by the adopted version of the Climate Change Worry Scale (CCWS) developed by Stewart (2021) (Appendix G and Appendix H). This five-point Likert scale (1: *Never* to 5: *Always*) consists of ten items that assess participants' proximal worry about climate change. This self-report psychometric measure shows people's level of worrying and frightening thoughts regarding climate change. The developed scale was used with 600 university students and reported as internally consistent, temporarily stable (r = .91), and correlated with existing similar measures. The scale was adapted to Turkish by Gezer and Ilhan (2021) and used with a sample of 236 pre-service teachers. In the adoption of the scale to Turkish, the authors used a two-factor structure in the validity analysis: feelings of helplessness and anxiety. They calculated the Cronbach's alpha reliability coefficient as .83 and .87, respectively, for these sub-dimensions and .91 for the whole scale. An example item from the scale is "I worry that outbreaks of severe weather may be the result of a changing climate."

3.4.4 Climate Change Hope Scale

Another construct that was measured in the study is the student's hope about climate change. For that, the Turkish-adopted version of the Climate Change Hope Scale (CCHS) developed by Li and Monroe (2018) was used (Appendix I and Appendix J). The scale developed for high school students has 11 items, each still being ranked from 1 to 5 (1: *strongly disagree*, 5: *strongly agree*). It has three factors: willpower and waypower for personal-sphere (1), for collective-sphere (2) and lack of willpower and waypower. The first factor which in the personal-sphere covers the individual willingness to take action. While creating this scale, Li and Monroe (2018) adopted item that cover both individual readiness to hope and belief in society to create and apply solutions. Therefore, the scale presents a more comprehensive and accurate measurement for hope about climate change. Developers stated the reliability and validity of the scale through a three-phase study conducted with 1902 students. They confirmed the content validity with experts and verified the internal consistency and convergent validity with trust and self-efficacy scales; the overall scale has an acceptable reliability (the Cronbach's alpha was .76). Gezer and Ilhan (2020) adopted the scale to Turkish through a study carried out with 453 university students. The exploratory and confirmatory factor analysis showed that the three-dimensional structure of the Turkish version was valid. The item analysis and Cronbach alpha calculation, which is .74 for the overall scale, confirmed the reliability of the adopted version. An example item from the scale is "If everyone works together, we can solve problems caused by climate change."

Given that the Turkish adaptation processes of the Climate Change Hope Scale and Climate Change Worry Scale were originally completed with university students, the scales were given to two middle school students (not study participants) for the present study. Students were asked to answer the scales while thinking aloud. Both students found the scales easy to answer without reporting any misunderstandings. Since CCHS and CCWS are affective measure instruments that score worry and hope, their reliability score is considered as high for affective instruments (Gay et al., 2012), and, therefore acceptable for use in this study. They are found suitable to be used for this research purpose since the investigated constructs are the same. Also, they are considered valid for the present context and participants.

3.5 Data collection

This study was carried out at the virtual reality laboratory of a private middle school in Istanbul as an after-school workshop activity. Before the study, three pilot study was conducted. The pilot studies were conducted as weekend workshops in the virtual reality laboratory of a public research university. Ten middle school students from 5th to 7th grade participated in pilot studies. The participants were from public schools around the university and were enrolled in the free course center organized by volunteer university students. Each pilot application mainly helped to iteratively design one of the used iVFT, VR-Boat Sea-Rise Experience, by the researcher. Also, some revisions to the design of the learning environment, activities, and lesson materials were done based on the observations in these pilot studies.

For the study, a workshop called “Climate Change with VR” was announced to all sixth-grade students in the private middle school. Then, volunteer students enrolled for the workshop and the number of participants was determined. Teachers and administrators were informed about the workshop and the study. They also help to get consent from students’ parents and organize the time schedule for the workshop after school. Due to the physical boundaries and sources (size of the virtual reality laboratory, number of available VR headsets) in the research site, and the design of the intervention as a classroom activity, students participated in the study in groups. The workshop was held five times, each session consisting of up to 13 students and each session conducted with the same procedure. The total duration of the intervention was about 2 hours and was implemented at once. The data collection and treatment process were completed in two weeks in total, as seen in Table 1.

Before data collection students were informed about the process and their parents were asked to sign a written consent for students’ participation (See Appendix K for the permission letter). One week before the intervention, participants were gathered and they completed the demographic form and pretests: Climate Change Worry Scale (CCWS), Climate Change Hope Scale (CCHS), and the Impacts of Sea Level Rise Assessment Instrument (ISLRAI).

Table 1. Data Collection and Implementation Schedule

Weeks	Study Activity	Instruments	Duration
Week 1	Pretest	Demographic form, CCWS, CCHS, ISLRAI	20 minutes
Week 2	Intervention (iVFTs-IBL)	KLEW Chart	2 hours
	Posttests	CCWS, CCHS, ISLRAI	15 minutes

During the 2-hour intervention of iVFTs-IBL experience, students completed KLEW Chart, the formative assessment instrument. After the intervention, the same instruments (CCWS and CCHS, and ISLRAI) were given to students as posttest (see Table 1).

3.5.1 The immersive virtual field trips integrated inquiry-based learning environment

In this study, an immersive virtual field trips integrated inquiry-based learning (iVFTs-IBL) environment is designed to elevate students' understanding of impacts of sea level rise. As part of the present research, a lesson plan (see Appendix L) consisting of engagement, exploration, explanation, elaboration, and evaluation stages has been prepared with the 5E model of inquiry-based learning approach. Immersive virtual reality component is integrated into this learning experience in the exploration phase to provide students with virtual field trips where they can observe the current problems, interact and predict future consequences related to sea level rise, one of the most dramatic consequences of climate change.

This learning experience is designed by targeting to bring students into Level 3 in the learning progression about impacts of sea level rise, created by Breslyn et al. (2016). Two immersive virtual field trips, the VR documentary (This is Climate Change: Melting Ice) and VR-Boat Sea-Rise Experience integrated into the explore part of this lesson. The VR-Boat Sea-Rise Experience is specially developed for the iVFTs-IBL environment to elevate student understanding to level 3 described in the sea level rise learning progression. Also, the lessons include other types of media including images and the interactive sea level rise map (see Table 2 and Appendix L for details). The first three levels in this learning progression are matched by the lesson activities that target to move student understanding in this level (Table 3).

Table 2. 5E Lesson Plan Activities, Related iVFTs and Other Media Components

Phase	Activity	Media Component	Time
Engage	Discussion about ice on Earth and the change in its amount	Photos revealing melting glaciers	10 min
Explore	Observation through immersive virtual field trips	This is Climate Change: Melting Ice (*iVFT)* VR-Boat Sea-Rise Experience (*iVFT)*	45 min
Explain	Discuss the predicted impacts of sea level rise on Earth.	(no media)	40 min
Elaborate	Experimentation with the interactive map.	Interactive Sea Level Rise Map	20 min
Evaluate	KLEW chart and worksheets and discussions for self-evaluation.	(no media)	5 min

Table 3. Learning Progression Levels by Breslyn et al. (2016) and Activities in the Lesson Plan Targeting Three Levels.

Level	Targeting Lesson Activity
1	Students observe flooding at the end of the VR Documentary and in sea level rise the VR-Boat Sea-Rise Experience as a consequence of melting glaciers.
2	The VR-Boat Sea-Rise Experience shows the predicted sea level rise in 2050. Students examine the interactive sea-level rise map for various cities.
3	At the end of the VR documentary , students see a storm and flooding showing the local consequences of rising sea levels. In the lesson, students discuss the possible consequences of such storms on people's lives. In the VR-Boat Sea-Rise Experience students observe the habitat loss for arctic animals. In the interactive sea level rise map, students interpret the future consequences of sea level rise for different cities.
4	The learning experience does not target this level due to the targeted group's limited pre-knowledge level and the study's limited time.

3.5.1.1 The immersive virtual field trips on sea-level rise

In the explore phase of the lesson plan, students experienced two immersive virtual reality experiences using Meta Quest-2 VR headsets. One is an existing documentary, and the other is an interactive experience designed by the researcher.

This is Climate Change: Melting Ice

The first virtual field trip is a 10-minute long 360-degree VR documentary titled “This is Climate Change: Melting Ice” directed by Dennis and Strauss (2018). 360-degree video documentaries in VR are a form of immersive media that provides a realistic experience. They enable viewers to examine a scene from every aspect and experience it as if they were physically present in the scenario. This documentary offers a journey to Greenland’s melting ice sheet with Former US Vice President Al Gore and scientist Dr. Konrad Steffen to witness glaciers melting into rivers as icebergs disappear into the ocean (see Figure 3). In the first scenes, viewers are immersed in the trip by landing with a helicopter to Greenland with Al Gore. Then, in the third scene, they watch Al Gore getting information from scientist Dr. Konrad Steffen in the research camp. In the following scenes (4 to 9), they observe different glacier areas in Greenland. In the last scene, (scene 10) the documentary shows a flood disaster that happened in Florida in 2015. A scene-by-scene image map that gives details about the storyline in the documentary can be found in Appendix M.

This is Climate Change: Melting Ice documentary provides an immersive experience for users as they can look around and explore the environment by turning their heads or moving their gaze in different directions. However, the user cannot physically walk or move around in the space as in real life. Even though it may create an illusion of movement through the use of the camera, interacting with the surrounding is not possible in this pre-recorded immersive media.

Figure 3. A captured scene from the This is Climate Change: Melting Ice documentary

Source: [Dennis &Strauss, 2018]

VR-Boat Sea-Rise Experience

The second virtual field trip is the "VR-Boat Sea-Rise Experience," designed by the researcher and developed in collaboration with a graduate student from the computer science department. Unity 3D virtual reality development software was used to create a realistic virtual field trip in three connected areas. The users take a trip by driving a boat through controllers in Meta Quest 2 VR headset device. This virtual field trip enables users to observe the consequences of melting ice and sea level rise, including loss of habitat for living things and effects on coastal communities.

VR-Boat Sea-Rise Experience is a self-paced exploratory virtual trip experience that takes about 20 to 30 minutes to complete. The experience is designed to target the learning objectives of the iVTTs-IBL experience, which aims to upgrade students' understanding of the impacts of sea level rise to the third level described in the sea level rise learning progression (Breslyn et al., 2016). It enables users to take two trips and visit three areas today and in the future. The first area is the glacier area, which includes icebergs, glaciers, a research station, and many young and adult polar bears. Second is the coastal forest area that includes various plants and animals such as deer, rabbit, square, and many trees. Lastly, the low-lying coastal town area has several buildings, a kiosk, and some plants and sheep. These zones are designed to represent different areas on Earth that will be affected by melting ice and sea level rise. To provide a realistic experience as much as possible, used three-dimensional animal models designed from real images and movement animations were added to some of them. Also, the experience has been enriched with several sound effects, like water, the boat engine, animals, and the crashing sound when the ship hits something.

Two minutes after the user enters all three areas, they give a short break in an empty black scene. After the break, users will take another trip in the same area in the future when the sea level has risen about 1-2 meters in the following century, as projected for the high emission scenario (IPCC, 2023). In this way, they observe the differences in these regions for today and the future. Figure 4 shows screenshots from the designed environment, and Figure 5 shows screenshots for today and future scenarios in the coastal town area in the experience. The experience was also published in the SideQuest platform [https://sidequestvr.com/app/16835/vr-boat-sea-rise-experience] and available as open access for users with Meta Quest devices.

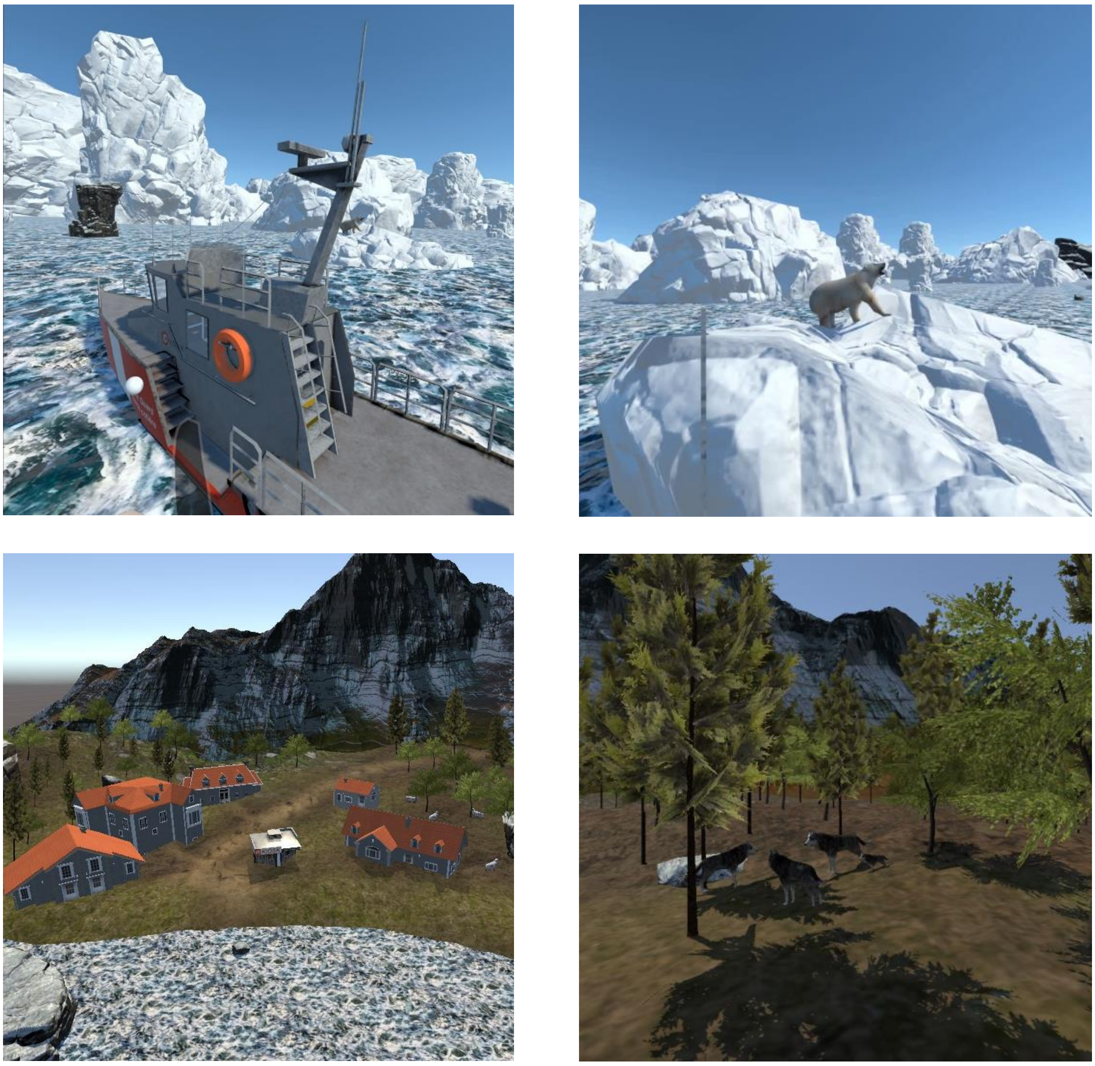

Figure 4. Screenshots from the VR-Boat Sea-Rise Experience

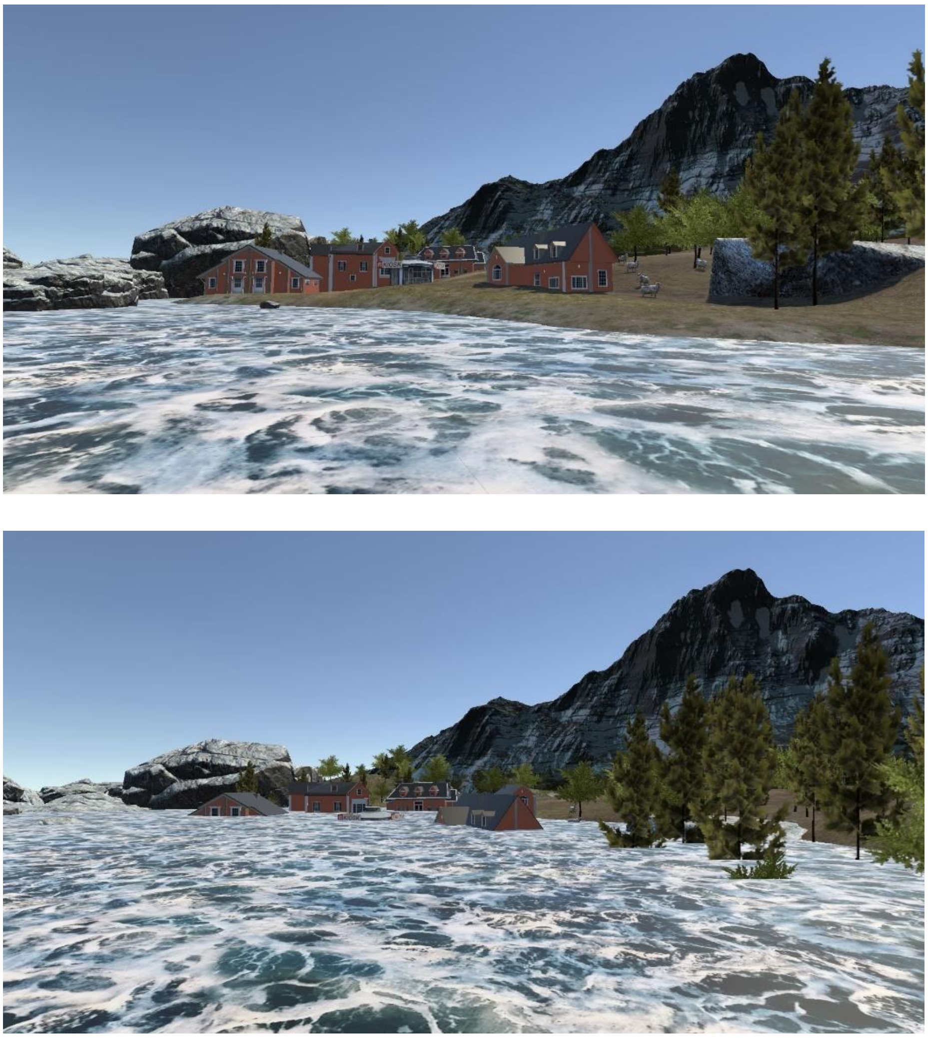

Figure 5. Screenshots from today and future scenarios in the coastal town area from the VR-Boat Sea-Rise Experience

3.5.1.2 Other media components

The prepared lesson aims to support learners with the most suitable and accessible educational materials in the inquiry-based learning process. While the iVFTs are appropriate to create connectedness and enable users to experience the impacts of sea level rise firsthand in the virtual environment, other media components are also integrated into the phases of iVFTs-IBL. These include photos and an interactive sea level rise map.

Interactive sea level rise map

For students to examine the local effects of sea level rise an interactive sea level rise map (https://coastal.climatecentral.org) was used in the elaboration part of the learning experience. Using this map, students can observe different scenarios about sea level rise in various cities (see Figure 6). The map was created by Climate Central which is a non-profit organization comprised of independent scientists and communicators who research and report about climate change. This risk visualization tool was created based on the scientific projections and shows the water levels and impacted coastal areas on the map.

Figure 6. A screenshot from the interactive sea level rise mapSource: Climate Central, (n.d) [https://coastal.climatecentral.org]

The photos

In the engagement part of the lessons, photos showing the change in climate were shown to students to engage them with the sea level rise topic (see Figure 7). Students were asked to answer some guiding questions while looking at these photos. This engagement activity helped students to predict the reason for sea level rise and got them started to think about the consequences of melting glaciers. More detail about the lesson can be seen in Appendix L.

Figure 7. Examples of photos used in the elaboration part of the lesson

Source: Jurkštaitė, 2022 [https://www.boredpanda.com/]

3.6 Data analysis

The first research question (1.Do sixth-grade students' level of understanding of sea level rise improve after participating in iVFTs-IBL experience about sea level rise?) was explored in two parts through the i.i and i.ii sub-questions.

For answering research question i.i (Is there a significant difference between sixth-grade students' pretest and posttest scores as measured by the learning progression instrument about impacts of sea level rise (ISLRAI) after participating in the iVFTs-IBL experience?), items in the ISLRAI were scored using the ISLRAI

Rubric which developed based on the sea level rise learning progression. For each correct answer to the multiple-choice part of the item, students received 1 point, and for the explanation part of the item, students received 0 to 5 points. Total item scores for every five items were calculated accordingly. Scores obtained from each item were added to calculate a total score for the ISLRAI. The lowest possible score that can be obtained from the instrument is 0, and the highest possible score is 30.

Descriptive statistics summarizing the data set for students' pretest and posttest scores from ISLRAI were calculated and tabulated. Obtained data were initially checked for the assumptions of the statistical parametric test to compare test scores to answer research questions. For the assumption of normality, histograms and normal Q-Q plots were visually examined, skewness and kurtosis z-values were calculated, and the Shapiro–Wilk test was used for the ISLRAI differences scores. Since the assumption of normal sampling distribution of the differences between scores for paired samples t-test was met, the test was performed using IBM SPSS Statistics SPSS to compare the mean pretest and posttest scores. Then, the effect size for the paired samples t-test was calculated as Cohen's d and reported.

For research question i.ii (How students' understanding of sea level rise change as evident in their explanations written in the KLEW chart after participating in the iVFTs-IBL environment about sea level rise?), the qualitative data collected through the KLEW chart worksheet, which was used as an formative assessment throughout the lesson, systematically organized by giving a participant identifier code consisting of the workshop session number, small group number and participant number.

The organized data was analyzed with content analysis to support the quantitative data and to examine the development of students' understanding of sea level rise in detail. Main emerging concepts in written responses of students were determined. For the “know” and “learn” parts, the frequencies an percentages of these concepts were calculated and tabulated. For each emerging concepts in these parts representative quotes were given. Students' responses to the "What I know" part represent their initial level of understanding about sea level rise, compared with their "What I learned" responses which represent their level of understanding after the lesson.

To answer the second research question (Is there a significant difference between sixth-grade students’ pretest and posttest scores on Climate Change Worry Scale after participating in the iVFTs-IBL environment about sea level rise?), both pretest and posttest data were tabulated, and total scores were calculated for analysis. The CCW scores were assigned as 1: *Never*, 2: *Rarely*, 3: *Sometimes*, 4: *Often*, 5: *Always*. The normality assumption was checked with histograms, z-scores for the skewness and kurtosis, Q-Q plots, and the Shapiro–Wilk test for climate change worry score differences The assumption of normal distribution was met for CCW differences; therefore a paired samples t-test test was performed and effect size was calculated and reported as Cohen’s d.

Lastly, for the third research question (Is there a significant difference between sixth-grade students’ pretest and posttest scores on Climate Change Hope Scale after participating in the iVFTs-IBL environment about sea level rise?), CCH scores for the pretest and posttest were calculated with a similar scoring, 1 = *strongly disagree* to 5 = *strongly agree*, and CCH difference scores were computed. The z-scores for the skewness and kurtosis computed, the Shapiro–Wilk test was conducted for the normality hypothesis, and histograms and normal Q-Q plots were examined visually. After concluding that the normality assumption for the sampling distribution of differences between test scores was met, a paired samples t-test was conducted with the IBM SPSS Statistics SPSS. The effect size for the paired samples t-test was calculated as Cohen’s d and reported.

CHAPTER 4

RESULTS

This chapter includes answers to the research questions of the study.

4.1 Understanding of impacts of sea level rise

Research Question i.i: Is there a significant difference between sixth-grade students' pretest and posttest scores as measured by the learning progression instrument about impacts of sea level rise (ISLRAI) after participating in the iVFTs-IBL experience?

Descriptive statistics for students' pretest and posttest scores from ISLRAI were calculated and tabulated (see Table 4). To examine the assumption for normal distribution of the differences between pretest and posttest scores, ISLRAI differences scores were computed. Shapiro-Wilk test was conducted for the score differences ($p > .05$) (see Table 5), and histograms and Q-Q plots were examined. The results showed that differences between pretest and posttest scores were normally distributed, with a skewness of -.349 (*SE* = .383) and kurtosis of -.194 (*SE* = .750) (see Table 6). Thus, it was concluded that the assumptions for using paired sample t-test were met.

Table 4. Descriptive Statistics of ISLRAI Scores

	N	*M*	*SD*	*Mdn*	Min	Max	Skewness	Kurtosis
ISLRAI Pretest	38	17.82	3.85	18.0	6.0	25	-1.069	1.821
ISLRAI Posttest	38	22.63	3.52	24.00	13	28	-1.115	1.088

Table 5. Shapiro-Wilk Test Result for the Differences Between ISLRAI Scores

	W	*df*	*p*
ISLRAI Differences	.977	38	.607

Table 6. Descriptive Statistics for the Differences Between ISLRAI Scores

	N	*M*	*SD*	*Mdn*	Skewness	Skewness z-value	Kurtosis	Kurtosis z-value
ISLRAI Differences	38	4.82	3.86	5	-.349	-.911	-.194	-.258

A paired samples t-test was conducted and revealed that the posttest scores of ISLRAI were significantly higher (*M* = 22.63, *SD* = 3.52) than the pretest scores (*M* = 17.82, *SD* = 3.85), $t(38) = -7.68$, $p < .001$. Therefore, it is concluded that participants' understanding of sea level rise has significantly improved after participating the iVFTs-IBL intervention with a very strong effect size (*r* = -1.25) as measured by Cohen's d (Sawilowsky, 2009).

Research Question i.ii: How do students' understanding of sea level rise change as evident in their explanations written in the KLEW chart after participating in the iVFTs-IBL environment about sea level rise?

Students' responses to the KLEW chart (N= 38) were analyzed for each part of this worksheet (know, wonder, learn, and evidence) with content analysis by identifying mentioned concepts in the written responses. Frequencies of the emerging concepts in the responses to the "what I know" part and the "what I learned" part were identified, and the percentage of the total mentioned concepts were calculated. Also, students' written responses to "what I wonder" and "what is my evidence" parts are analyzed for each student to reveal more about their understanding before and after the lesson.

Part 1: What I know

Students mainly stated some key issues related to melting ice and sea level rise in the "Know" section of the chart. Five main concepts emerged in the analysis of the student's responses to the "what I know" part. Table 7 shows these concepts' frequency and percentage in students' written responses.

Table 7. Frequency and Percentage of Mentioned Concepts in the "Know" Part of the KLEW Chart.

Concept	n	%
Melting glaciers results in sea level rise	28	74
As temperature increases, ice melts and turns into water	15	39
Global warming/climate change causes sea level rise	8	21
Sea level rise affects communities and living things	8	21
There are other reasons for sea level rise, such as changes in seasons, tides, rain, earthquakes	5	13

Note. N = 38

Most of the students (28 out 38) related sea level rise with melting glaciers by writing that melting ice phenomena results in rising sea levels. Two representative quotes are:

> Student 1d-7: The glaciers are melting, and the melting glaciers flow into the sea and so the sea level is rising.
>
> Student 2b-15: Sea level rise is caused by melting glaciers.

Many students (15 out 38) mentioned their pre-knowledge about phases of water by stating a relationship between temperature, ice melting and water. One student said:

> Student 1b-4: As the temperature rises, the glaciers cannot stand the heat and they melt.

Another one mentioned the same thing to explain sea level rise:

> Student 2d-18: Since ice is made up of water when the ice melts, it turns into water, raising the sea level.

Some students related melting ice to climate change and/or global warming. For example, Student 4b-35 wrote that “Sea level has risen due to global warming.”. Similarly, Student 1a-1 wrote “I know that climate change causes the melting of glaciers.”. Another student connected global warming with both melting ice phenomena and sea level rise by writing: “I know that the ice sheets melt and turn into water due to global warming, and this water flows into the oceans, increasing the water level.” (Student 3b-28).

One-fifth of students wrote about possible consequences of sea level rise, such as flooding or habitat loss. Some representative quotes:

> Student 1c-5: If the sea level rises, events such as flooding will occur.

> Student 2c-17: Coastal life may be endangered when the sea rises.

> Student 3c-43: As the temperature rises, the glaciers melt and raise the sea level. As the sea level rises, some places become submerged.

A small number of students (5 out 38) wrote other reasons than melting glaciers for sea level rise. These include changes in seasons, tides, floods, tsunamis, rainfall, and earthquakes. For instance, Student 3c-30 said that “Events such as earthquakes increase the water level.” and Student 1b-3 said that “Events such as the tsunami will also raise the sea level.”. Some student responses showed misunderstandings about sea level rise caused by rain. These are some representative quotes:

> Student 4b-34: The sea level rise happens due to excessive precipitation and the melting of glaciers.

> Student 1e-11: I know it happens as a result of events such as melting glaciers and rain.

Part: 2 What I learned

The analysis of the student responses to "what I learned" part revealed four main concepts emerging in their written responses. The frequencies and percentages of these concepts were presented in Table 8.

Table 8. Frequency and Percentage of Mentioned Concepts in the “Know” Part of the KLEW Chart.

Concept	n	%
Sea level rise does not happen due to rain	13	34
Melting land ice causes sea level rise, not sea ice	12	32
The impacts of sea level rise related to altitude	11	29
Sea level rise affects communities and living things	10	26

Note. N = 38

Many students (13 out 38) stated that they learned that rain does not affect sea level rise. For example, Student 2a-12 wrote that “Rainwater doesn't actually change sea level.”. Similarly, Student 2b-14 wrote that “Rain does not raise the sea level because rain is already formed from the evaporation of water in the sea.”

Nearly a third of the students stated responses that underline that only the melting of land ice contributes to sea level rise, not the sea ice. Therefore, compared to their answers in the “know” part about melting glaciers and sea level rise, they detailed their understanding by differentiating land ice and sea ice. Several representative quotes are:

> Student 3b-27: I learned that glaciers on land affect the sea level.

Student 3b-28: In order for the sea level to rise, an ice mass on land, which is outside the sea, must melt.

Student 4a-32: Water level increases when the glaciers on land thaw, water level does not change when the glaciers on the water melt.

Student 5a-41: Glaciers on land raise the sea level while glaciers above the sea do not affect the sea level.

Another prominently mentioned learning gain that appeared in the "Learn" part was about the impacts of sea level rise. Just under a third of students clearly stated that the impacts of sea level rise would be different for regions with different altitudes. Here are some examples from student answers:

Student: 3a-27: I learned that altitude and being closer to the sea affect submersion.

Student 5a-39: The lower a region is, the more it will be affected by sea level rise.

Student 4c-37: If the sea level rises, it will affect not only the coastal areas but also, low-lying inland regions. In other words, being affected is not only related to the region but also to the altitude.

About the impacts of sea level rise, one in four students wrote about predicted consequences of sea level rise in the future. For instance, Student 4b-36 wrote, “I learned how the lives of people and animals will change and what kind of differences will be in the future.”. One student wrote that “Rising sea level increases flooding and erosion.” (Student 2e-21) while another one mentioned that low-lying areas would be flooded when the sea level rises (Student 3a-25).

Part 3: What I wonder

The responses to what is my wonder and my evidence parts of the worksheet were not the subject of this research. Still, the “wonder” part was useful as it showed missing pre-knowledge about the lesson topic started by some students. Some students wondered about the reason behind sea level rise and what can be done to stop this. Some representative quotes are:

> Student 2c-26: I wonder why the glaciers are melting.
>
> Student 1a-1: Why is the sea level rising, and how can we prevent it?
>
> Student 1c-5: If I can't prevent the glaciers from melting, how can I reduce the amount of melting ice?

Some other students mentioned that they wonder about the impacts of sea level rise. Student 4c-37 wrote, “I wonder what will happen if sea level rises.”. Another student asked if rising sea level is a good thing (Student 3b-28).

Part 4: What is my evidence

In the evidence part, instead of giving scientific evidence, students mainly stated the lesson activities that they learned from. Their responses were helpful as they showed the main components of the iVTF's-IBL environment, such as virtual field trips, the interactive map, and other media components. Here are some examples of student responses to the “Evidence” part:

> Student 3c-43: We experienced it live on the trip we watched, and so we learned how this happened.
>
> Student 4b-35: When we were having a trip in VR, glaciers on land were falling into the water.
>
> Student 5a-40: I experienced it as virtual reality.
>
> Student 5a-39: I learned them using VR glasses, using maps, and video.

Also, some students mentioned their small group's discussion as evidence for the things they learned:

> Student 1c-5: Discussions with my groupmates
>
> Student 1c-6: In the worksheet, I learned from another group that precipitation does not affect sea level.
>
> Student 3c-30: I learned from my friend.

4.2 Climate change worry

Research Question 2: Is there a significant difference between sixth-grade students' pretest and posttest scores on Climate Change Worry Scale after participating in the iVFTs-IBL environment about sea level rise?

Descriptive statistics for student's pretest and posttest scores for Climate Change Worry Scale were used to summarize the variable (see Table 9). CCW difference scores were computed and Shapiro-Wilk test was performed to examine the distribution of the differences between pretest and posttest scores ($p > .05$) (see Table 10). These results and visual examination of histograms and normal Q-Q plots showed that the distribution of the differences between climate change worry pretest and posttest scores were normally distributed, with a skewness of -.097 (*SE* = .383) and kurtosis of -.687 (*SE* = .750) (see Table 11).

Table 9. Descriptive Statistics of Climate Change Worry Scores

	N	*M*	*SD*	*Mdn*	Min	Max	Skewness	Kurtosis
CCW Pretest	38	38.3	6.30	38.0	21	50	-.132	.248
CCW Posttest	38	40.1	7.00	42.5	21	50	-.929	.452

Table 10. Shapiro-Wilk Test Result of the Differences Between Climate Change Worry Scores

	W	*df*	*p*
CCW Differences	.974	38	.520

Table 11. Descriptive Statistics for the Differences Between Climate Change Worry Scores

	N	*M*	*SD*	*Mdn*	Skewness	Skewness z-value	Kurtosis	Kurtosis z-value
CCW Differences	38	1.82	6.12	1	.097	.253	-.687	-.916

Descriptively, there was a slight increase in the mean of the climate change worry posttest scores (M = 40.2, SD = 7.00) of the sample, compared to pretest scores (M = 38.3, SD = 6.30). The paired samples t-test revealed that the pretest scores of the Climate Change Worry Scale were not significantly different from the posttest scores, $t(38) = -1.828$, $p > .05$.

4.3 Climate change hope

Research Question 3: Is there a significant difference between sixth-grade students' pretest and posttest scores on Climate Change Hope Scale after participating in the iVFTs-IBL environment about sea level rise?

For the third research question, descriptive statistics for students' pretest and posttest scores from the CCHS were calculated (see Table 12). For the normality assumption for the sampling distribution of differences between posttest and pretest scores, CCH difference scores were computed and Shapiro-Wilk test was conducted ($p > .05$) (see Table 13). Together with a visual examination of histograms and normal

Q-Q plots, the results showed that the differences between CCH posttest and pretest scores were normally distributed with a skewness of -.750 (*SE* = .383) and kurtosis of -.007 (*SE* = .750) (see Table 14). Thus, it was concluded that the assumptions for using paired sample t-test were met.

Table 12. Descriptive Statistics of Climate Change Hope Scores

	N	*M*	*SD*	*Mdn*	Min	Max	Skewness	Kurtosis
CCH Pretest	38	42.8	5.73	43.0	29	51	-.254	-.558
CCH Posttest	38	44.71	5.06	45.00	33	55	-.082	-.394

Table 13. Shapiro-Wilk Result of the Differences Between the Climate Change Hope Scores

	W	*df*	*p*
CCH Differences	.943	38	.053

Table 14. Descriptive Statistics for the Differences Between Climate Change Hope Scores

	N	*M*	*SD*	*Mdn*	Skewness	Skewness z-value	Kurtosis	Kurtosis z-value
CCH Difference	38	1.92	5.28	3	.750	-1.958	-.007	.009

A paired samples t-test was conducted to determine the effect of the iVFTs-IBL environment on students' climate change hope scores. Results showed that there was a significant difference between participants' CCH pretest scores (*M* = 42.79, *SE* = .930), and CCH posttest scores (*M* = 44.71, *SE* = .820), $t(38) = -2.24$, $p<.05$. Specifically, the CCH scores increased after participating in the iVFTs-IBL environment with a medium effect size (r = .36) as measured by Cohen's d (Cohen, 1992).

CHAPTER 5

DISCUSSION AND CONCLUSION

This study investigated the use of immersive virtual reality in an inquiry-based learning environment. Immersive virtual field trips, including a 360-degree documentary, and the interactive VR boat sea level rise experience, designed by the researcher, were integrated into an inquiry-based lesson about sea level rise. One purpose of the study was to investigate whether sixth-grade students' understanding of the impacts of sea level rise changed after participating in this iVFTs-IBL experience. The results show a significant improvement in students understanding scores after they were involved in two hours long iVFTs-IBL experience. Also, students' perceived pre-knowledge and learning gains were visible in their KLEW chart responses. While students' scores of climate change worry did not change the iVFTs-IBL, their climate change hope scores significantly increased right after the intervention. This section discussed the results of three research questions, with the study's limitations and implications and further study suggestions.

5.1 Cognitive aspect: Understanding of sea level rise

The results of this study showed that students who participated in a two-hour inquiry-based lesson, which included immersive virtual field trips, improved their understanding scores related to the impacts of sea level rise. Despite the short period of the implementation time, the iVFTs-IBL experience was effective in improving students' understanding described in LP about sea level rise (Breslyn et al., 2016). The cognitive gains shown in this study are parallel to the previous research that uses immersive technology for climate change learning (Allcoat & Mühlenen, 2018; Di

Natale et al., 2020; Hsu et al., 2018; Markowitz et al., 2018; Mirauda et al., 2020). Also, using immersive virtual reality in inquiry-based climate change education can be quite effective as it offers virtual field trips related to the climate crisis (Petersen et al., 2020).

Since the understanding scores were given by a rubric also designed based on the levels in this learning process, the incase in the means scores from 17.82 to 22.63 can be interpreted as about one level movement in LP levels. Because according to the developed ISLRASI Rubric, Level 1 understanding corresponds to test scores of 20, and Level 2 corresponds to 25. This finding is consistent with the findings of other research investigating short-term learning progressions and learning trajectories, such as what happens over a course or an instructional unit (Merritt et al., 2008; Steedle & Shavelson, 2009). Similarly, this study utilized only one part of a conditional sea level rise learning progression, impacts of sea level rise, and did not focus on the causes and mechanisms or scale and representations parts, which are the subsets of this LP. This study improved students' understanding after the iVFTs-IBL experience, which was designed based on an LP, supported by other researchers that suggest LPs can be used to develop instructional approaches, materials, and assessment practices (Alonzo & Gearhart. 2006; Sztajn et al., 2012; Langbeheim et al., 2022).

Even though the duration of the learning experience was relatively short, students also showed learning gains in their responses to the KLEW chart, despite their limited pre-knowledge about the reasons and consequences of sea level rise. Several previous studies already showed the effectiveness of the KWL chart, the initial version of KLEW, as it positively affects students' achievement (Alsalhi, 2020) and improves student learning (Siribunnam & Tayraukham, 2009). In this study, the KLEW chart was a valuable scaffold for learners to aid in developing understanding. It helped to link previous knowledge through the "know" part while gaining learning through the wonder and evidence parts (Ogle, 1986). Moreover, the "learn" part was useful for tracing student understanding in a self-reflective form. Student responses to "what I learned" showed more focus on the causes and impacts of sea level rise phenomena than their answers about what they already know. This result was predictable as the learning objectives of the lesson was focused on impacts of sea level rise. The evidence part enabled learners to link the inquiry-based learning activities with their previous knowledge (Hershberger et al., 2006) and their perceived learning gains. Analyzing the student responses to the KLEW worksheet for how evident their understanding of the chart served as supportive information for the pretest-posttest comparison to explore change in their understanding of the sea level rise topic.

5.2 Affective aspect: Climate change worry and hope

This study also examined the climate change worry and climate change hope scores of middle school students, before and after they attend the iVFTs-IBL. The results showed that there was no significant change in the pretest and posttest score for climate change worry while for climate change hope, student’s scores increased. These findings are parallel with the claim of learning climate change and its mechanism is not just a cognitive activity, but also includes feelings brought on by learning how serious and difficult the problem it is (Ojala, 2012, 2015).

There was a small increase in the climate change worry scores which can be due to the emotional connectedness that immersive experiences can provide with high levels of presence (Diemer et al., 2015; Markowitz & Bailenson, 2021). Considering that the used immersive virtual field trips were integrated into an inquiry-based classroom learning, limited emotional arousal would be understandable as participants complete the questionnaire at the very end of the lesson, not right after the IVR experiences. Also, working in groups and discussing about what they observe in the environment after each trip may help them to regulate their worries. This finding is significant considering the climate change anxiety, which is a recently emergent issue for psychological well-being and mental health and called for urgent clinical attention (Clayton, 2020). According to recent research (Hickman et al., 2021) 84% of children and youths are moderately or extremely worried about climate change. Although climate anxiety is not yet seen as pathology but rather a rational response, extreme levels of climate change worry can threaten people's ability to comprehend information and make judgments due to being too much concerned (Clayton et al., 2017). Integrating iVFTs into learning environments can help to manage these negative emotions while teaching climate change.

The result of increasing climate change hope scores after the intervention showed that iVFTs-IBL experience improved students' belief that they, and society as a whole, can create and carry out solutions to issues caused by climate change (Li & Monroe, 2018). Hopelessness about climate change associated with pessimistic views and not taking actions related to climate change mitigation (Ratinen, 2021). The findings of this study about climate change hope support previous research that argues meaning-making enables maintaining hope and developing coping strategies (Sangervo et al., 2022). This is a particularly important result as climate hope has a role to motivate pro-environmental behaviors (Ojala, 2012). Therefore, this study reveals that the use of immersive VR for climate change education needs to consider the affective aspects of the results of these learning experiences. This would serve to inhibit the possible negative impacts on the attitudes and behaviors of adults in the future (Jones & Davison, 2021).

5.3 Implications and recommendations

This study successfully integrated immersive VR into learning experiences, as similar to previous research (e.g., Han, 2020; Petersen et al., 2020; Makransky & Mayer, 2022). Therefore, it provides information for educators to design inquiry-based learning experiences with immersive technology in classrooms. Also, the applied practice of using learning progressions to design the immersive field trip and the 5E lesson activities can help researchers and educational content developers to use existing learning progressions in their designs or design-based research. Studying smaller-scale issues in short time frames can help to validate hypothetical learning progressions and empirically support them, as happened in this example. For further research, the effect of various components of the iVFT-IBL environment can be examined by analyzing worksheets or additional sources of data. Most of the research about use of VR in education does not provide theoretical or implicational background for the development of used VR (Radianti et al., 2020) while this study used a learning progression and inquiry-based learning to provide a solid foundation for the development of learning experience and the virtual field trips. As practical implications, this study suggest using virtual field trips which are the affordable alternative to real field trips, especially when they make invisible things visible or provide unique opportunities which real- field trips cannot offer (e.g. driving boat in glaciers, visiting a research center in Greenland with scientists, moving back and forth in time)

5.4 Limitations of the study

The duration of the intervention is a limitation for this study since it is only two hours. VR time is also limited since longer VR experiences can be uncomfortable for children even if they are used to them. A longer intervention wouldn't be used in this study due to the limited capacity of the VR lab for equipment and the lack of available time for participants to attend the study. Also, a longer intervention would overlap with their informal learning through media sources or school.

This study only focuses on the integration of IVR field trips to a lesson on sea level rise and investigates the student learning in the experience. The lack of a control group could be regarded as a limitation of the study; however, qualitative data with a KLEW chart was collected to minimize this limitation by providing a detailed deep understanding of students' learning through the iVFTs-IBL experience. The one-group design is preferred due to the fact that IVR experiences are quite unique in their nature. For that reason, designing a similar experience to IVR with traditional multimedia tools or other instructional methods was hard to accomplish in scope of this study. Also, the number of accessible participants was limited to create a control group.

Another thing to consider is the effect of differing participants' performance in the IVR environment. For example, some participants may be more comfortable with using the VR headset and touch controllers which may affect their performance in IVR and as a result affect their gains from IVR. However, since the resources of the virtual reality laboratory are limited to measure the real-time performance of users in the VR experience, this study assumes similar VR performances by users. Additionally, students worked in groups and shared their experiences with their peers during the iVFTs-IBL, which can serve to close this gap.

APEENDIX A

DEMOGRAPHIC FORM

Following questions are designed to get information about who participated in this survey. Start by filling out the student number given to you for the study.

1. Student Number: ....
2. How old are you? ....
3. Which grade student are you? ....
4. Have you taken a course on environmental education or climate change?

   ☐ Yes ☐ No

   If yes, please specify the course(s) / course(s): Where did you take it? How long did it take? Who gave?

   ………………………………………………………………………………………
   ………………………………………………………………………………………
5. Have you joined or ever been a member of an environmental group or organization?

   ☐ Yes ☐ No

   If yes, please indicate the name(s) of the institution(s): How long did you attend? What activities did you do?

   ………………………………………………………………………………………
   ………………………………………………………………………………………
6. Have you used virtual reality glasses before?

   ☐ Yes ☐ No

   If yes, where did you use it? How long did you use? Please explain.

   ……………………………………………………………………………………
   ……………………………………………………………………………………

APEENDIX B

DEMOGRAPHIC FORM (TURKISH)

Aşağıdaki sorular, bu ankete kimin katıldığı hakkında bilgi almak için tasarlanmıştır. Çalışma için size verilen öğrenci numarası doldurarak başlayın.

1. Öğrenci Numarası: ....
2. Kaç yaşındasınız? ....
3. Kaçıncı sınıf öğrencisisiniz? ....
4. Çevre eğitimi ya da iklim değişikliği ile ilgili bir ders aldınız mı?

   ☐ Evet ☐ Hayır

   Cevabınız evet ise, lütfen ders(ler)i / kurs(lar)ı belirtiniz: Nerde aldınız? Ne kadar sürdü? Kim verdi?

   ……………………………………………………………………………………

   ……………………………………………………………………………………
5. Bir çevre grubuna veya kuruluşuna katıldınız mı veya hiç üye oldunuz mu?

   ☐ Evet ☐ Hayır

   Cevabınız evet ise, lütfen kurum(lar)ın isim(ler)ini belirtiniz: Ne kadar süre katılım gösterdiniz? Hangi aktivitelerde bulundunuz?

   ……………………………………………………………………………………

   ……………………………………………………………………………………
6. Daha önce sanal gerçeklik gözlüğü kullandınız mı?

   ☐ Evet ☐ Hayır

   Cevabınız evet ise, Nerede kullandınız? Ne kadar süre kullandınız? Açıklayınız.

   ……………………………………………………………………………………

   ……………………………………………………………………………………

APPENDIX C

IMPACTS OF SEA LEVEL RISE ASSESSMENT INSTRUMENT AND RUBRIC

Question 1

Description of situation	Sea level is projected to rise several feet in the future.
Question	What are the most likely impacts to humans in a coastal community if sea level rises 4 feet (1.2 m)?
Select the ***best*** response.	***There will be***: **A**. An increase in home values farther inland because they will be closer to the beach. **B**. A need for people to move and relocate structures further inland to adapt to flooding. **C**. Few impacts since 4 feet is not a significant increase in sea level. **D**. No serious impact since a new coastline would be established.

Why is this the best explanation?

Answer: B

Score	**Understanding**	**Description**	**Sample Responses**
0	No Answer	Blank responses	
1	Irrelevant	Unrelated responses	Because I think so This is the most logical answer Other options are illogical
2	Flawed	Related to the impacts on people but scientifically unsound explanations or too general and not linked with questions.	1 meter rise would not hurt Nobody builds their house one meter from the sea anyway. People adapt to nature
3	Limited	General statement about the impact(s) on people without elaborating on reasons or details	There will be loss of life Houses can be demolished They can die
4	Complete	Identify a limited number of specific consequences of seal level rise for people, gives reasons for relocation of people	They take precautions in case the waters increase more in the long term. Because if the water rises 1 meter, the first flood will be in the coastal houses

5	Advanced	Detailed explanation links reasons of relocation of people with specific consequences of sea level rise such as, property loss, in-land flooding during storms and erosion.	People need to relocate their homes closer to inland areas to be protected from sea level rise. Because sea level rise can result in floods which would harm their properties and life will be in danger. Also, people can lose their yard, animals, jobs due to increasing coastal flooding.

Question 2

Description of situation	Sea level is projected to rise several feet over the next hundred years.
Question	What are the most likely impacts to a coastal ecosystem if sea level were to rise 4 feet (1.2 m)?
Select the ***best*** response.	***Many plants and animals would***: **A**. Benefit from the change and increase in numbers. **B**. Move further inland and establish new ecosystems. **C**. Quickly adapt to the changes caused by sea level rise. **D**. Die off but some would be able to adapt or move inland.

Why is this the best explanation?

Answer: D

Score	**Understanding**	**Description**	**Sample Responses**
0	No Answer	Blank responses	
1	Irrelevant	Unrelated responses	Because I think so This is the most logical answer Other options are illogical
2	Flawed	Related to the impacts on people but scientifically unsound explanations or too general and not linked with the question.	They have always migrated They can make changes on their own Since the sea will rise one meter, it will not affect the animals much They choose to live not die
3	Limited	Explanation focusing on one impact on coastal ecosystems (adaptation or die off)	They can mitigate Cause they evolve Some non-swimmers can drown Animals cannot breathe underwater Because too much water kills plants.

4	Complete	Explanation focusing on both impacts on coastal ecosystems (adaptation and die off)	Some animals can adapt to change, some can't plants probably die but animals can adapt
5	Advanced	Detailed explanation links several impacts on coastal ecosystems due to sea level rise for some animals and plants	Sea level rise causes habitat loss and displacement of plant and animals. Coastal erosion destroys nesting sites and root systems, affecting birds, sea turtles, and plants. Saltwater intrusion harms freshwater ecosystems, disrupting the balance and leading to the loss of sensitive species

Question 3

Description of situation	The overall, or average, sea level is rising. However, sea level varies with tides, lunar cycles, and weather events.
Question	How would sea level rise affect a weather event, like a hurricane or tropical storm?
Select the ***best*** response.	***A rise in sea level would***: **A**. Only affect people living right next to the sea. **B**. Increase the frequency and amount of coastal flooding. **C**. Absorb and dissipate the energy from the hurricane or storm. **D**. Cause no changes in the nature of a hurricane or storm.

Why is this the best explanation?

Answer: B

Score	Understanding	Description	Sample Responses
0	No Answer	Blank responses	
1	Irrelevant	Unrelated responses	Because I think so This is the most logical answer Other options are illogical
2	Flawed	Related to the impacts on people but scientifically unsound explanations or too general and not linked with the question.	As water overflows, it enters the soil and productivity increases. I don't think it has anything to do with hurricanes or storms. Surely there will be side effects. Because it absorbs energy. It dissipates energy and harms us.

3	Limited	States a relationship between weather events and sea level rise. Explanation states increase in coastal flooding due to rise in baseline sea level or storms and hurricanes caring water	As the hurricane pushes the waters, the frequency of flooding increases to the shores. Because there will be waves and the water level will rise As the seas increase, more water goes to land.
4	Complete	Explanation states both increase in coastal flooding due to rise in baseline sea level and storms and hurricanes caring water to costs	If natural events such as wind happens the sea will fluctuate and the water will overflow even more. If the sea level rises, storms and hurricanes carry more water and this harms the environment.
5	Advanced	Detailed explanation of storm surge with sea level rise impacts on coastal ecosystems with reasons	Sea level rise intensifies the impacts of hurricanes or storms by because it amplifies storm surge and raises the baseline sea level, so extends coastal flooding, inland areas with low elevation are also affected.

Question 4

Description of situation	Scientists have found a warming trend in average global temperatures on Earth.
Question	Which of the following is an impact of the global warming trend? ***Global warming causes***:
Select the ***best*** response.	**A**. Increased evaporation of oceans, contributing to sea level decline. **B**. Increased precipitation, which contributes to sea level rise. **C**. Increased ice on land melting, which contributes to sea level rise. **D**. The oceans to become warmer but nothing else changes.

Why is this the best explanation?

Answer: C

Score	Understanding	Description	Sample Responses
0	No Answer	Blank responses	
1	Irrelevant	Unrelated responses	Because I think so This is the most logical answer Other options are illogical

2	Flawed	Related to global warming, sea level rise or melting ice but scientifically unsound explanations, or too general and not linked with the question.	Because the precipitation increases and this causes the sea level to rise As the water heats up and evaporates, it causes the sea level to decrease It is already happening Even if the temperature of the world rises even by 1 degree, the end of the world may come.
3	Limited	Correct statements about global warming related to melting ice or sea level rise.	Because as the glaciers melt, the water mass increases The water in the ice will melt and there will be more water Because glaciers are melting due to global warming
4	Complete	Responses that focus on the cause-effects relationship between all three: global warming, melting ice and sea level rise. (not distinguishing between terrestrial and sea ice)	Global warming causes ice to melt. Melting ice become water and increase sea level As the glaciers melt with global warming, the volume of water naturally increases.
5	Advanced	Detailed explanation by mentioning cause-effects relationship between increasing temperatures, melting terrestrial -ice and sea level rise	Sea level rises only when land glaciers melt. Global warming causes ice on the land to melt. This ice becomes water and water flowing into the oceans causes sea level rise.

Question 5

Description of situation	The picture is an aerial view of a coastal town.	
Question	As sea level rises, one impact on coastal areas, as shown in the picture above, could be:	 [Color figure can be viewed at wileyonlinelibrary.com]
	If sea level rise occurred in this area, what would be a likely consequence during storms?	
Select the ***best*** response.	**A**. Only areas on the coast would experience increased flooding. **B**. Only area further inland would experience increased flooding. **C**. Both coastal and inland areas would experience increased flooding **D**. Storms do not affect sea level, so there would be no change.	

Why is this the best explanation?

Answer: C

Score	**Understanding**	**Description**	**Sample Responses**
0	No Answer	Blank responses	
1	Irrelevant	Unrelated responses	Because I think so This is the most logical answer Other options are illogical
2	Flawed	Related to the impacts of sea level rise but scientifically unsound explanation, or too general and not linked with the question.	It won't come inland area Flooding occurs only in inland areas I have seen such an event before, there is no problem in the sea Because the storm affects everywhere Everywhere is damaged, everyone becomes homeless Affects everyone, storms can be dangerous It is hard to stop flooding It affects inland areas too because these places are a whole.

3	Limited	Correctly states the possible impact(s) of sea level rise, flooding or storms carrying water.	Storms cause sea level rise in both areas Effect the level of sea more Flooding happen if sea rise Cause storm effect both areas Flooding increased in both areas
4	Complete	Explanation focusing on rise in the baseline sea level will cause storm-induced flooding to affect both areas. States a uniform, static understanding of sea level rise	If sea level rise since storms carry water there can be flooding in inner regions as well Storms and water level related stuff. The amount of flood increases as they carry more water when sea level rised
5	Advanced	Detailed explanation links sea level rise with both increasing storm-induced flooding and low-lying landforms of the coastal town. Understand local variations and attribute this to topography.	Since the sea level is high, the storm will affect the coastal and inland areas more than before because the altitude is low and close to the sea and as it is flat, the water will spread all over.

APPENDIX D

IMPACTS OF SEA LEVEL RISE ASSESSMENT INSTRUMENT (TURKISH)

Aşağıdaki her soru için, soruya en iyi cevap olduğunu düşündüğünüz şıkkı daire içine alarak işaretleyin. Lütfen yanıtınızın gerekçesini verilen boşluğa detaylı bir şekilde açıklayın.

Soru 1: Durum: Deniz seviyesinin gelecekte birkaç metre yükselmesi bekleniyor.
Soru: Eğer deniz seviyesi en az 1 metre yükselirse, bunun kıyı kenarında yaşayan insanlar üzerindeki en olası etkilerinden biri aşağıdakilerden hangisidir?
En iyi yanıtı seçin.
A. İç kesimlerde evler artık sahile daha yakın olacakları için evlerin fiyatlarında artış olacaktır.
B. İnsanların sellere uyum sağlamak için yapıları daha iç kesimlere taşıması ve yeniden yerleşmeleri gerekecektir.
C. Deniz seviyesindeki 1 metrelik artış önemli bir artış olmadığından az bir etki olacaktır.
D. Yeni bir kıyı şeridi kurulacağı için ciddi bir etki olmayacaktır.

Neden en iyi açıklama budur?

Soru 2: Durum: Deniz seviyesinin önümüzdeki yüz yıl içerisinde birkaç metre yükselmesi bekleniyor.
Soru: Deniz seviyesinin en az 1 metre yükselmesi durumunda kıyı ekosistemi üzerindeki en olası etkilerinden biri aşağıdakilerden hangisidir?
En iyi yanıtı seçin.
Birçok bitki ve hayvan:
A. bu değişimden yararlanacak ve sayıları artacaktır.
B. daha iç kesimlere taşınacak ve yeni ekosistemler kuracaktır.
C. deniz seviyesinin yükselmesinin neden olduğu değişikliklere hızla uyum sağlayacaktır.
D. ölecektir, bazılarıysa suda yaşama uyum sağlayabilecek veya iç bölgelere taşınacaktır.

Neden en iyi açıklama budur?

Soru 3: Durum: Genel olarak veya ortalamada deniz seviyesi yükseliyor. Fakat, deniz seviyesi gelgitlere, ay döngülerine ve hava olaylarına göre değişir.
Soru: Deniz seviyesinin yükselmesi kasırga veya tropik fırtına gibi bir hava olayını nasıl etkiler?
En iyi yanıtı seçin.
Deniz seviyesinin yükselmesi:
A. Sadece denizin hemen yanında yaşayan insanları etkiler.
B. Kıyılara su taşmasının sıklığını ve miktarını artırır.

C. Kasırga veya fırtınadan gelen enerjiyi emer ve dağıtır.
D. Kasırga veya fırtınaların doğasında hiçbir değişikliğe neden olmaz.

Neden en iyi açıklama budur?

Soru 4: Durum: Bilim insanları, Dünya'daki ortalama küresel sıcaklıklarda bir ısınma eğilimi buldular.
Soru: Aşağıdakilerden hangisi küresel ısınma eğiliminin etkilerinden biridir?
En iyi yanıtı seçin.
Küresel ısınma:
A. Okyanuslardaki buharlaşmanın artmasına ve bu da deniz seviyesinin alçalmasına neden olur.
B. Yağışın artmasına neden olur ve bu da deniz seviyesinin yükseltir.
C. Karadaki buz kütlesinin erimesine neden olur ve bu da deniz seviyesinin yükseltir.
D. Okyanusların ısınmasına neden olur ama başka hiçbir şey değişmez.

Neden en iyi açıklama budur?

Soru 5: Durum: Aşağıdaki resim, bir sahil kasabasının havadan görünüşüdür.
Soru: Bu bölgede deniz seviyesi yükselirse, fırtınaların muhtemel sonuçları ne olur?

Bu bölgede deniz seviyesinin yükselirse, fırtınaların muhtemel sonuçları ne olur?
En iyi yanıtı seçin.
A. Yalnızca kıyıdaki alanlarda sel baskınları artar.
B. Yalnızca daha iç kesimlerde sel baskınları artar.
C. Hem kıyı hem de iç kesimlerde sel baskınları artar.
D. Fırtınalar deniz seviyesini etkilemediği için herhangi bir değişiklik olmaz.

Neden en iyi açıklama budur?

APPENDIX E

THE KLEW CHART

Start by filling out this worksheet by writing down what you know and wonder about sea level rise.

Continue to fill in the table, writing down any new questions that came to mind during the lesson, what you learned, and where you learned them (evidence).

Sea Level Rise			
What I know?	What am I wondering?	What I learned?	What is my evidence?

APPENDIX F

THE KLEW CHART (TURKSIH)

Bu çalışma kağıdını deniz seviyesinin yükselmesi ile ilgili bildiklerinizi ve merak ettiklerini yazarak doldurmaya başlayın.

Ders boyunca aklınıza gelen yeni soruları, öğrendikleriniz, ve bunları nereden öğrendiğinizi (kanıt) yazarak tabloyu doldurmaya devam edin

Deniz Seviyesinin Yükselmesi			
Ne biliyordum?	Neyi merak ediyorum?	Ne öğrendim?	Kanıtım nedir?

APPENDIX G

ITEMS OF THE CLIMATE CHANGE WORRY SCALE

Please read the statements below carefully and tick the appropriate option for you.

Never (1) Rarely (1) Sometimes (3) Often (4) Always (5)

1. I worry more about climate change than other people.
2. Thoughts about climate change make me worry about what the future will bring.
3. I tend to look for information about climate change in the media (e.g. TV, newspapers, internet).
4. Even if the impacts of climate change may seem distant, hearing about them worries me.
5. The idea that severe weather events are caused by climate change worries me.
6. I realized that my concerns about climate change are not new.
7. I worry about how the people I care about will be affected by climate change.
8. I'm so worried about climate change that I feel helpless because I can't do anything about it.
9. I worry that I will not be able to cope with climate change.
10. Once I start worrying about climate change, I have a hard time stopping my anxiety.

APPENDIX H

ITEMS OF CLIMATE CHANGE WORRY SCALE (TURKISH)

Aşağıda yer alan ifadeleri dikkatli okuyarak, sizin için uygun olan seçeneği işaretleyiniz.

Asla (1) Nadiren (1) Bazen (3) Sık sık (4) Her zaman (5)

1. İklim değişikliği kon usunda diğer insanlardan daha fazla endişeleniyorum.
2. İklim değişikliği ile ilgili düşünceler, geleceğin neler getireceği konusunda endişelenmeme neden oluyor.
3. İklim değişikliği hakkında medyada (örneğin tv, gazeteler, internet) yer alan bilgileri arama eğilimindeyim.
4. İklim değişikliğinin etkilerinin ortaya çıkması uzak görünse bile bunları duymak beni endişelendiriyor.
5. Yaşanan şiddetli hava olaylarının iklim değişikliğinden kaynaklandığı düşüncesi beni endişelendiriyor.
6. İklim değişikliği konusundaki kaygılarımın yeni olmadığını fark ettim.
7. Değer verdiğim insanların iklim değişikliğinden nasıl etkileneceği konusunda endişeleniyorum.
8. İklim değişikliği konusunda o kadar endişeliyim ki bu konuda hiçbir şey yapamadığım için kendimi çaresiz hissediyorum.
9. İklim değişikliğiyle baş edemeyeceğimden endişe duyuyorum.
10. İklim değişikliği konusunda bir kez endişelenmeye başlayınca yaşadığım endişeyi durdurmada güçlük çekiyorum.

APPENDIX I

ITEMS OF THE CLIMATE CHANGE HOPE SCALE

Please read the statements below carefully and tick the appropriate option for you.

Strongly disagree (1) Disagree (2) Neither agree nor disagree (3) Agree (4)

Strongly agree (5)

1. I am willing to help solve problems arising from climate change.
2. I know that there is something I can do to solve the problems caused by climate change.
3. I know what to do to help solve the problems caused by climate change.
4. If everyone works together, we can solve the problems caused by climate change.
5. I believe that scientists can find ways to solve the problems caused by climate change.
6. I believe that people can solve the problems caused by climate change.
7. I believe that more people want to take action to solve the problems caused by climate change.
8. I know that even if some people give up, there will be others who will try to solve the problems caused by climate change.
9. Climate change is beyond my control, so I won't even bother trying to solve the problems caused by climate change.
10. The actions I can take are too small to solve the problems caused by climate change.
11. Climate change is so complex that we cannot solve the problems caused by climate change.

APPENDIX J

ITEMS OF THE CLIMATE CHANGE HOPE SCALE (TURKISH)

Aşağıda yer alan ifadeleri dikkatli okuyarak, sizin için uygun olan seçeneği işaretleyiniz.

Kesinlikle katılmıyorum (1), Katılmıyorum (2), Ne katılıyorum ne de katılmıyorum (3), Katılıyorum (4), Kesinlikle katılıyorum (5)

1. İklim değişikliğinden kaynaklanan problemlerin çözümüne yardım etmede istekliyim.
2. İklim değişikliğinden kaynaklı problemlerin çözümü için yapabileceğim bir şeyler olduğunu biliyorum.
3. İklim değişikliğinin neden olduğu sorunları çözmeye yardımcı olmak için ne yapacağımı biliyorum.
4. Herkes birlikte çalışırsa iklim değişikliğinden kaynaklanan problemleri çözebiliriz.
5. Bilim insanlarının iklim değişikliğinden kaynaklı orunları çözmenin yollarını bulabileceklerine inanıyorum.
6. İnsanların iklim değişikliğinden kaynaklanan sorunları çözebileceklerine inanıyorum.
7. İklim değişikliğinin neden olduğu sorunları çözmede daha fazla insanın harekete geçmek istediğine inanıyorum.
8. Bazı insanlar pes etse bile, iklim değişikliğinden kaynaklanan sorunları çözmeye çalışacak başka insanlar olacağını biliyorum.
9. İklim değişikliği kontrolümün ötesinde, bu yüzden iklim değişikliğinin neden olduğu sorunları çözmeye çalışmakla bile uğraşmayacağım.
10. Yapabileceğim eylemler iklim değişikliğinin neden olduğu sorunları çözmek için çok küçük.
11. İklim değişikliği o kadar karmaşık ki iklim değişikliğinin yol açtığı sorunları çözemeyiz.

APPENDIX K

PERMISSION LETTER

BOĞAZİÇİ ÜNİVERSİTESİ

Sosyal ve Beşeri Bilimler İnsan Araştırmaları Etik Kurulu

KATILIMCI BİLGİ ve ONAM FORMU

Araştırmayı destekleyen kurum: Boğaziçi Üniversitesi

Araştırmanın adı: İklim Değişikliği Eğitiminde Sürükleyici Sanal Gerçekliğin Kullanımı

Proje Yürütücüsü: Prof. Diler ÖNER

E-mail adresi:

Telefonu:

Araştırmacının adı: İpek PAKSOY

E-mail adresi:

Telefonu:

Sayın Veli,

İklim değişikliği eğitiminde sanal gerçeklik teknolojisinin kullanımını araştırmak için bir çalışma gerçekleştiriyoruz ve bu çalışmaya öğrencinizin katılımı için sizi davet ediyoruz.

Proje Konusu:

Bu bilimsel araştırma Boğaziçi Üniversitesi Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü öğretim üyesi Profesör Diler ÖNER danışmanlığında ve yüksek lisans öğrencisi İpek PAKSOY tarafından "İklim Değişikliği Eğitiminde Sürükleyici Sanal Gerçekliğin Kullanımı" adıyla yürütülmektedir. Bu araştırmanın amacı, iklim değişikliği ve deniz seviyesinin yükselmesi ile ilgili sürükleyici sanal gerçeklik kullanılan sorgulamaya dayalı bir öğrenme deneyimin ortaokul öğrencilerinin deniz seviyesinin yükselmesinin öngörülen sonuçlarını anlamaları ve iklim değişikliği konusundaki endişeleri ve umutları üzerindeki etkisini araştırmayı amaçlamaktadır. Çalışma Boğaziçi Üniversitesi etik kurulu onayı ile yapılacaktır.Sizi bu araştırmaya velisi olduğunuz öğrencinizin katılımı ile bize yardımcı olmaya davet ediyoruz. Kararınızdan önce araştırma hakkında sizi bilgilendirmek istiyoruz. Bu bilgileri okuduktan sonra öğrencinizin araştırmaya katılmasını onaylarsanız lütfen bu onam formunda bulunan "EVET" ibaresini işaretleyin.

Onam

Bu araştırmaya katılım tamamen gönüllülük esaslıdır ve katılım karşılında herhangi bir ödül verilmeyecektir. Kabul ettiğiniz takdirde öğrencinizin sanal gerçeklik gözlüğü kullanımını öğrendikleri 15 dakikalık bir deneyime katılmaları, iklim değişikliği ile ilgili yine sanal gerçeklik kullanılan bir derse katılıp gerekli veri toplama formlarını doldurmaları beklenecektir. Araştırmaya başlamadan önce öğrencinin demografik form ve 3 ön-test formu doldurmasını rica edeceğiz. Demografik formda öğrenci numarası yalnızca ön-test ve son-test karşılaştırması yapabilmek amacıyla istenmiştir. Ek olarak formda yaş, iklim değişikliği ile ilgili bir ders almış olma gibi sorular yer almaktadır. Bu sorular katılımcı profili hakkında genel bilgi sahibi olmak amacıyla istenmektedir. Ön test olarak 10 maddeden oluşan İklim Değişikliği Endişesi Ölçeği, 11 maddeden oluşan İklim Değişikliğinin Önlenmesine Yönelik Umut Ölçeği ve 5 maddeden oluşan Deniz Seviyesi Yükselişinin Etkileri Değerlendirme testi uygulanacaktır. Bu ölçekler, sanal gerçeklik teknolojisinin kullanıldığı dersin öğrencilerin konuyu anlamalarına, ve iklim değişikliği ile ilgili umut ve endişelerine etkisini anlamamıza yardımcı olacaktır. Ölçekleri doldurmak en çok 15 dakika sürecektir.

İklim Değişikliği temalı 2 saatlik bir ders sürecinde öğrencilerin bireysel olarak dolduracakları KWEL şablonu ile nitel veriler toplanarak öğrencilerin ön bilgileri, merak ettikleri, kanıtları ve öğrendikleri bilgiler takip edilecektir. Bu ders içerisinde 15 dakikalık bir sürede Oculus Quest 2 sanal gerçeklik gözlüğü öğrenciler tarafından kullanılacaktır ve Grönland'da sanal bir alan gezisi gerçekleştireceklerdir. Ders süreci tamamlandığında ön-test ile aynı içerikteki son-testler bireysel olarak uygulanacaktır. Bu araştırma bilimsel bir amaçla yapılmaktadır ve katılımcı bilgilerinin gizli tutulmaktadır. Uygulanan veri toplama araçlarında çocukların ismi yerine bir numara kullanılacaktır. Kişisel bilgi istenmeyecektir.

Bu araştırmaya katılmak tamamen isteğe bağlıdır. Öğrenciniz çalışmaya katıldığınız takdirde çalışmanın herhangi bir aşamasında herhangi bir sebep göstermeden onayınızı çekme hakkına da sahipsiniz. Aynı şekilde öğrenci çalışmaya devam etmek istemediği takdirde herhangi bir sebep göstermeden çalışmadan ayrılabilir. Katılımcılar araştırmadan çekildikleri takdirde tüm veriler silinecek ve herhangi bir araştırmada kullanılmayacaktır. Bu araştırmada öğrencileri birbirleriyle ya da başka bir öğrenci grubuyla karşılaştırılmayacaktır.

Araştırmanın sizin ya da velisi olduğunuz öğrenciniz için bir risk oluşturması beklenmiyor. Araştırmada kullanılan VR gözlükleri uzun süre takıldığında baş ağrısına neden olabildiği belirtildiğinden bu çalışma sırasında gözlük kullanımı 15 dakika ile sınırlandırılmıştır. Bazı katılımcılar sanal gerçeklik kullanırken taşıt tutması ve mideleri bulantısı yaşadıklarını belirtmişlerdir. Bu çalışmada kullanılan içerik hızlı hareket içermediği için ve sabit bir kamera ile hazırlandığı için böyle bir sorun yaşanması beklenmiyor. Deney sırasında katılımcılar herhangi bir zamanda herhangi bir rahatsızlık hissederlerse çalışmayı durdurabilirler. Görme engeli, kalp rahatsızlığı veya diğer ciddi tıbbi durumları olan veya tıbbi cihazlar kullanan çocuklar bu çalışmaya katılmayacaklardır.

Araştırma çerçevesinde toplanan verilerden ulaşılan sonuçlar yüksek lisans tez çalışması için kullanılacaktır. Katılımcı bilgilerinin gizliği esastır ve sizin ve velisi olduğunuz öğrencinin bilgileri tamamen gizli tutulacaktır. Araştırma projesi hakkında ek bilgi almak istediğiniz takdirde lütfen Boğaziçi Üniversitesi Eğitim Teknolojisi programı yüksek lisans öğrencisi İpek PAKSOY ile iletişime geçiniz (Telefon: , Email:). Araştırma katılımcısının ve velisinin hakları konusunda daha fazla bilgi almak için Boğaziçi Üniversitesi Sosyal ve Beşeri Bilimler Yüksek Lisans ve Doktora Tezleri Etik İnceleme Komisyonu'na (SOBETİK) mail adresinden ulaşarak ( ) danışabilirsiniz.

Yukarıdaki açıklamaları okudum ve anladım. EVET ☐ HAYIR ☐

Velisi olduğum öğrencinin görme engeli, kalp rahatsızlığı, ciddi tıbbi durumu yoktur ve tıbbi cihaz kullanmamaktadır. EVET ☐ HAYIR ☐

Velisi olduğum öğrencinin bu çalışmaya gönüllü olarak katılmasını onaylıyorum. EVET ☐ HAYIR ☐

Formun bir örneğini aldım / almak istemiyorum (bu durumda araştırmacı bu kopyayı saklar).

Katılımcının ve Velisinin Adı-Soyadı:..

İmza:.. Tarih (gün/ay/yıl):........./.........../..............

Araştırmacının Adı-Soyadı: İpek PAKSOY

İmzası:.. Tarih (gün/ay/yıl):...../......./..............

APPENDIX L

LESSON PLAN ON SEA LEVEL RISE

1. Topic: Melting Ice and Impacts of Sea Level Rise
Grade: 6th and 7th grade
Duration: 120 minutes

2. Expected pre-knowledge about topic:
Students already know how ice forms from water, the melting point temperature of ice. They may know little about global warming, melting ice and sea level rise.

3. Objectives:

- Explain ice melting phenomena in Greenland by observing the environment in an immersive virtual field trip.
- Relate melting ice with the rise in global temperature and sea level.
- Describe consequences of sea level rise on humans and coastal ecosystems by observing them in an immersive virtual field trip.
- Predict consequences of storms and hurricanes on coastal towns when sea level rise

4. Science Practices:

- Analyzing and interpreting data
- Constructing explanations
- Asking questions and defining problems
- Obtaining, evaluating, and communicating information

5. Materials Needed:

- Images of Change - Arctic Glaciers
- Immersive Virtual Field Trip -1:This is Climate Change: Melting Ice
- Immersive Virtual Field Trip -2: VR Boat Sea-Rise Experience
- Interactive sea level rise and coastal flood risk map

6. Body of the Lesson

Engagement (15 min)

1- Students engage in the discussion about ice on Earth and change its amount with the help of the guiding questions.

- How does ice occur?
- At what temperature does water normally freeze?
- Where can ice be found on Earth? In which forms? (Glacier / Sea Ice)
- How does the amount of Glaciers on Earth change?

2- Students examine photos of Arctic glaciers and describe the differences that they see. Then they dissues reasons and consequences of this change with the guiding questions. They write their ideas on the KLEW chart.

- What may be the reason for that change?

- What happens when it changes?
- What are the down three things (or more) you already know about sea level rise (e.g., why it is happening, factors causing it, impacts on communities and ecosystems)
- Why sea level is rising and what are the impacts of sea level rise?

Exploration-1 (15 min)

Students take two immersive virtual field trips (IVFTs) about melting ice and sea level rise. They observe their surroundings and try to find answers to the guiding questions in the engagement part. First IVFT is a 10 minutes documentary about melting ice in Greenland. The second is an interactive boat experience in Greenland with three exploration areas: glacier area, forest area and coastal town area. Students visit and explore these areas two times by driving the boat: first in current time, second in 2050 when sea level rises.

IVFT- 1
This field trip is a 10 minutes-long 360° immersive documentary, This is Climate Change: Melting Ice directed by Danfung Dennis and Eric Strauss.

3- Teacher introduce the first immersive virtual field trip activity to students as follow:
Would you like to go to Greenland and make some observations to learn more about melting ice? If so, now you can Travel to Greenland with former US vice president Al Gore and meet there with Dr. Konrad Steffen, who is an Arctic scientist, studying 30 years of Greenland's ice sheet.

4- Students list the things they want to learn with this immersive field trip to the KLEW chart (Worksheet-1).

5- Students are asked to carefully observe their surroundings and try to find answers to their questions, or think about new questions while they watch the 360° immersive documentary.

Explanation-1 (20 min)

6- After the field trip, students share their experience with the documentary in groups of two to three. As a group they discuss questions in the Worksheet – 2 and complete it by taking notes

7- Each student group pairs with another group and shares their ideas by comparing their worksheet - 2 responses to each other.

8- They write down things they learned and their new questions after the field trip to the KLEW chart.

Exploration-2

IVFT- 2 (15+15 minutes)
This IVFT experience enables users to see the predicted future of Greenland due to melting glaciers in 2050. Students are able to interact with the boat by driving it through controllers. They can take a trip and observe the melting ice, sea level rise and loss of habitat for living things.

9- The teacher introduces the second immersive virtual field trip which is the "VR-Boat Sea-Rise Experience" to students as follow:

*Now, you will travel back to Greenland and explore three different areas in this country, during two different time periods. First 2023, and then in 2050. You will drive a boat while observing and interacting with your surroundings. Try to see the consequences of melting ice in the ar*ea.

10. Students are asked to think about some questions throughout the trip.

- What kind of natural environment are you in?
- What living things are around you?
- What are the possible consequences of sea level rise in these areas?

Explanation-2 (20 min)

11- After the field trip, students share what changes they observed in these three regions when sea level rose. They share their experiences with class.

12- Students complete worksheet-3 about the experience by answering the relevant questions as a group. They reflect on the IVFT based on what they observed on the virtual field trips they discuss predicted impacts of sea level rise on the human and ecosystems.

13- They write down things they learned and their new questions after the field trip to the KLEW chart.

Elaboration (20 min)

14- Students are asked “What about other places on Earth, how these impacts may be different or similar in various places?”

15- In the interactive predicted sea level rise map interactive predicted sea level rise map, students in groups manipulate the meter of projected sea level rise. And interpret the consequences of sea level rise up to 10 meters in different areas.
Local Areas: İzmir/ Antalya/ Samsun vs Trabzon, Sinop / Mersin vs Adana
Other Areas: Miamı / Bangladesh / Manila, Philippines / Shanghai, China

Evaluation

16. Students fill out the KLEW Chart at the end of the lesson as they did throughout the lesson. Student worksheets and communication will be used as a formative assessment. Impacts of Sea Level Rise Assessment Instrument (ISLRAI) will be used to assess understanding of impacts of sea level rise.

7. Worksheets

1. Worksheet -1 KLEW Chart
2. Worksheet - 2 Melting Glaciers
3. Worksheet - 3 Impacts of Sea Level Rise

8. References

Jurkštaitė, D. (2022, December 11). 7 Shocking Photos Reveal What 100 Years Of Climate Change Has Done To Arctic Glaciers. Bored Panda. https://www.boredpanda.com/climate-change-pictures-arctic-greenpeace-christian-aslund/?utm_source=google&utm_medium=organic&utm_campaign=organic

Dennis, D., & Strauss, E. (2018). This is climate change: Melting ice. Retrieved from https://www.youtube.com/watch?v=MwSLTGjPqG8

VR-Boat-Sea-Rise-Experience on SideQuest (Oculus App Lab). (n.d.). https://sidequestvr.com/app/16835/vr-boat-sea-rise-experience

Climate Central (n.d.) Coastal Risk Screening Tool: Sea level rise map and coastal flood. Retrieved from https://coastal.climatecentral.org/map/

Worksheet -1

The KLEW Chart

Start by filling out this worksheet by writing down what you know and wonder about **sea level rise**.

Continue to fill in the table, writing down any new questions that came to mind during the lesson, what you learned, and what is your evidence.

Sea Level Rise			
What did I know?	What did I learn?	What is my proof?	What am I wondering?

Worksheet -1 Turkish

KLEW Şeması

Bu çalışma kağıdını **deniz seviyesinin yükselmesi** ile ilgili bildiklerinizi ve merak ettiklerini yazarak doldurmaya başlayın.

Ders boyunca aklınıza gelen yeni soruları, öğrendikleriniz, ve kanıtlarınızı yazarak tabloyu doldurmaya devam edin

Deniz Seviyesinin Yükselmesi			
Ne biliyorum?	Neyi merak ediyorum?	Ne öğrendim?	Kanıtım nedir?

Worksheet – 2

Melting Glaciers

Discuss the following questions with your group mates. Take a brief note of your answers as a group.

1	What have you observed about the melting of glaciers? What happens to the melting glaciers?
2	Why does sea level rise?
3	How does sea level rise affect regions at different altitudes?
4	How is sea level rise different from flooding?
5	How does rising sea level affect natural disasters such as floods?

Worksheet – 2 Turkish

Buzulların Erimesi

Aşağıdaki soruları grup arkadaşlarınız ile tartışınız. Grupça ulaştığınız cevaplarınızı kısaca not alınız.

1	Buzulların erimesi ile ilgili neler gözlemlediniz? Eriyen buzullara ne oluyor?
2	Deniz seviyesi neden yükselir?
3	Deniz seviyesinin yükselmesi farklı yükseltideki bölgeleri nasıl etkiler?
4	Deniz seviyesinin yükselmesi sel olayından nasıl farklıdır?
5	Deniz seviyesini artması sel, gibi doğal afetleri nasıl etkiler?

Worksheet - 3

Impacts of Sea Level Rise

Discuss the following questions with your group mates for each area. Take a brief note of your answers as a group.

Based on your observations on the trip where the sea level rose, interpret the results that can be experienced in these three regions.			
	1- Glacier Area	2- Coastal Forest Area	3- Costal Town Area
People How are people affected by this change?			
Ecosystem How were the plants and animals living in the region affected by this change?			
Storm What will be the consequences if there is heavy rain and storm in these regions while the sea level has risen?			

Worksheet - 3 Turkish

Deniz Seviyesinin Yükselmesinin Sonuçları
Aşağıdaki soruları her bölge için grup arkadaşlarınız ile tartışınız. Grupça ulaştığınız cevaplarınızı kısaca not alınız.

Deniz seviyesinin yükseldiği gezideki gözlemlerinizden yola çıkarak bu üç bölgelerde yaşanabilecek sonuçları yorumlayınız.			
	1- Buzul Bölgesi	2- Orman Bölgesi	3- Sahil Kasabası
İnsanlar İnsanlar bu değişimden nasıl etkilenirler?			
Ekosistem Bölgede yaşayan bitkiler ve hayvanlar bu değişimden nasıl etkilenmiştir?			
Fırtına Bu bölgelerde deniz seviyesi yükselmişken bir de aşırı yağış ve fırtına yaşanırsa nasıl sonuçlar olur?			

APENDIX M

IMMERSIVE 360° VR DOCUMENTARY SCENES

"This is Climate Change: Melting Ice" documentary.

YouTube Link: https://www.youtube.com/watch?v=MwSLTGjPqG8

Genre: 360° documentary video

Country: USA

Year: 2018

Duration: 9:47 min

Director: Danfung Dennis, Eric Strauss

Scenes:

Figure M1. Scene 1: Arriving to Greenland by helicopter

Figure M2. Scene 2: Helicopter is landing and bringing US vice president Al Gore

Figure M3. Scene 3: Al Gore is getting information from scientist Dr. Konrad Steffen in the research camp

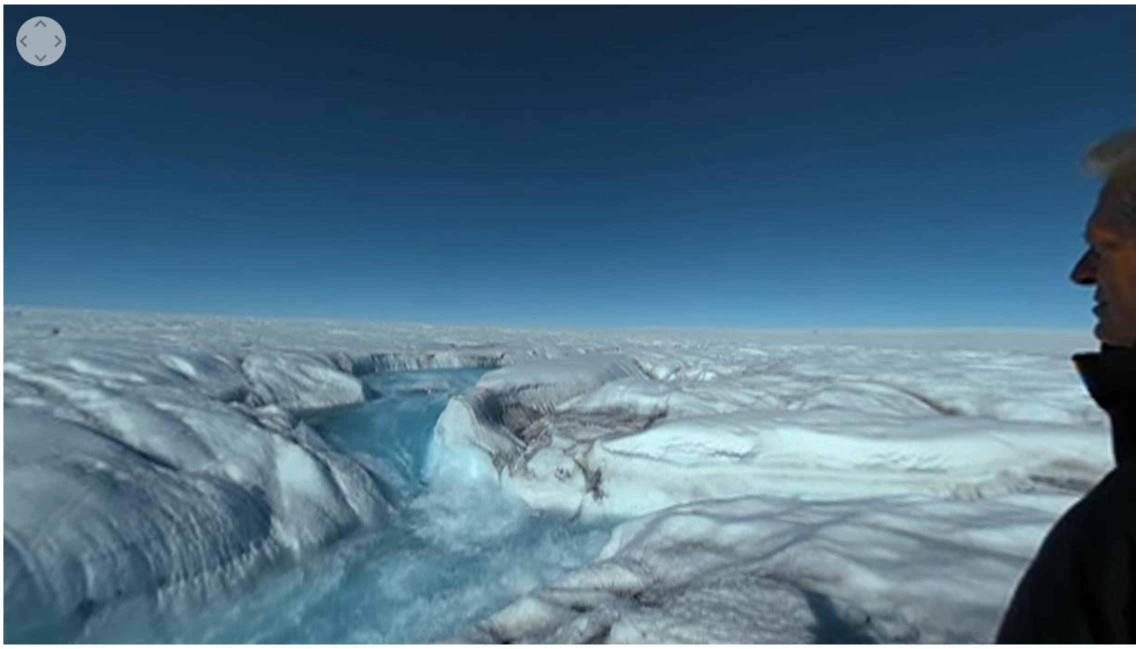

Figure M4. Scene 4: Al Gore is observing river formed by melting glaciers

Figure M5. Scene 5: Melting glaciers are falling apart and collapsing

Figure M6. Scene 6: A river formed by melting glaciers

Figure M7. Scene 7: The boat is moving in the arctic sea

Figure M8. Scene 8: A look through melting glacier

Figure M9. Scene 9: The view from the ice floe in the middle of the glacial sea

Figure M10. Scene 10: The flood disaster happened in Florida in 2015

APPENDIX N

ETHINCS COMMITTEE PERMISSION

Evrak Tarih ve Sayısı: 23.03.2023-119242

T.C.
BOĞAZİÇİ ÜNİVERSİTESİ
SOSYAL VE BEŞERİ BİLİMLER YÜKSEK LİSANS VE DOKTORA TEZLERİ ETİK İNCELEME KOMİSYONU
TOPLANTI KARAR TUTANAĞI

Toplantı Sayısı	:	42
Toplantı Tarihi	:	22.03.2023
Toplantı Saati	:	14:00
Toplantı Yeri	:	Zoom Sanal Toplantı
Bulunanlar	:	Prof. Dr. Feyza Çorapçı, Doç.Dr. Arhan S. Ertan, Doç. Dr. Senem Yıldız, Dr. Öğr. Üyesi Yasemin Sohtorik İlkmen, Dr. Öğr. Üyesi Ayşegül Metindoğan
Bulunmayanlar	:	

İpek Paksoy
Bilgisayar ve Eğitim Teknolojileri Eğitim Bölümü

Sayın Araştırmacı,

"Using Immersive Virtual Reality in Climate Change Education" başlıklı projeniz ile ilgili olarak yaptığınız SBB-EAK 2023/31 sayılı başvuru komisyonumuz tarafından 22 Mart 2023 tarihli toplantıda incelenmiş ve uygun bulunmuştur.

Bu karar üyelerin toplantıya çevrimiçi olarak katılımı ve oy birliği ile alınmıştır. Onay mektubu üye ve raportör olarak Yasemin Sohtorik İlkmen tarafından toplantıya katılan bütün üyeler adına e-imzalanmıştır.

Saygılarımızla, bilgilerinizi rica ederiz.

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