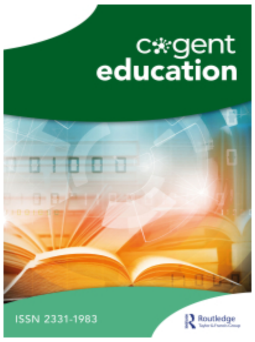

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Contextual structure as an approach to the study of virtual reality learning environment

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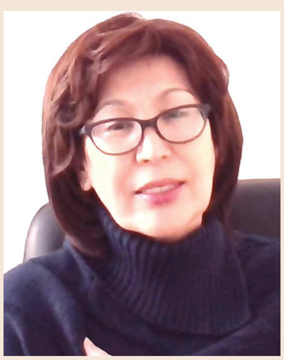
Abstract: This study aims to offer a contextual framework for a virtual reality learning environment (VRLE) that would assist in interpreting students' and teachers' expectations on how to use VR in the learning process. Due to the current lack of unified recommendations and principles, as well as framework methods, the structure of VRLE, consisting of 4, pedagogical, technological, social and health-preservation contexts may be one approach to the study of VR in education. The study involved 53 school students aged 10–16 years and 49 teachers of various subjects at schools. The participants' opinions were assessed after the immersion into the VR. The results showed that 79,2 % of learners agreed to learn in school using VR, and 77,5 % of teachers expect to use it in the next five years. A quarter of



Manargul Mukasheva

ABOUT THE AUTHORS

Virtual reality (VR) can have a significant impact on learning in school. The Virtual Reality Learning Environment (VRLE) framework we developed consists of four contexts: pedagogical, technological, social, and health preservation. The contextual structure can act as one approach to the study of virtual reality in education, and we used it to study students' and teachers' attitudes toward VR. Students and their teachers believe that VR shapes a new way of looking at learning in school, promotes constructivist, student-centered learning, and has many educational benefits. However, students and teachers do not rule out the possible social and health risks of excessive use of VR.

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the learners believe that VR promotes independent and comfortable learning outside the classroom. However, half of the participants are concerned about the possible undesirable health effects of VR. The prospects for further research lie in defining the criteria and designing VR models for each context including technological, pedagogical, social, and health-preservation contexts.

Subjects: Legal, Ethical & Social Aspects of IT; Computer Graphics & Visualization; Educational Research; Middle School Education; ICT; Research Methods in Education; Secondary Education

Keywords: virtual reality (VR); virtual reality learning environment (VRLE); contextual structure; health-preservation context; school; student-centered learning

1. Introduction

Many studies devoted to VR issues report the absence or underdevelopment of unified guidelines and principles, framework methodologies for crowdsourcing, and other research on VR use, although the potential of this technology is enormous for many areas of human activity (Mottelson et al., 2021). A systematic reviews of immersive VR applications for K-12 and higher education (Di Natale et al., 2020; Radianti et al., 2020) shows a significant increase of interest in VR applications for educational purposes. However, the research results also state a very low maturity of research works in this direction. The authors believe that VR theory for educational applications is not sufficiently developed to enable a uniform and clear understanding of its terms and main concepts.

The researchers are right in calling VR a "mosaic of science and technology" as it simultaneously encompasses many areas, primarily computer science, engineering, education, and neuroscience (Cipresso et al., 2018) and can provide many immersive and interactive experiences in virtual 3D space (Mikropoulos, 2006). The most modern research on VR use in training is still focused on technological aspects and more accurate measurement of the dynamics of individual parameters and qualities of learning in a VR environment (W. Huang et al., 2020; Mulders et al., 2020; Radianti et al., 2020). Large-scale implementations of VR learning increasingly use technological rather than learner-centered approaches (Makransky et al., 2019). Perhaps a pure "technological approach" to "virtual reality" as noted in the studies by Mikropoulos and Natsis (2011), alone cannot provide a conceptual framework for the use of VR for social purposes, including educational one. Researchers, in a general context, have noted the broad potential of VR to implement constructivist learning, which is based on the idea that new knowledge is formed based on the students' personal experience, implying conceptual and strategic thinking skills (Dalgarno & Lee, 2009; Dede, 1995; Feyzi Behnagh & Yasrebi, 2020; Di Natale et al., 2020). A VR application with advanced interfaces provides direct interaction with objects in the learning environment individually or in a group, as in real life (Chacon, 2018; The Stanford Ocean Acidification Experience on Steam. The Stanford Ocean Acidification Experience on Steam, 2016). In doing so, learners can act and experiment independently without outside assistance. The Repeated action on mistakes and the quest approaches (prompts) of the environment itself promote learning in one's own experience and intuition. Perhaps, this is the difference between 360-degree video and real VR in learning. The possibilities of VR to implement the main principle of constructivism—student-centered learning are obvious and real. However, according to Feyzi Behnagh and Yasrebi (2020), VR has potential for building constructivist learning if it is used productively, otherwise it becomes nothing more than entertainment and distractions in the learning environment. Furthermore, now when VR has become available and a mass adoption is expected in such areas as education and training, there is a need to think about the social and health-preservation aspects of VR (Bailenson, 2019; Kamińska et al., 2019).

The findings of all these studies point to the multidimensionality of VR and the need to study VR learning in a variety of contexts. We believe that the most acceptable way to structure educational, technological, social, and other opportunities provided by a VR learning environment is a contextual approach which is widely used in pedagogical research (Marishane, 2020; Springer, 2010). The contextual approach has predictive potential and allows us to identify opportunities of integrating or borrowing new learning technologies, including VR learning. The contexts are one of the most important factors in designing and evaluation learning environments with different characteristics and capabilities. The authors of the studies recommend taking into account contextual factors in the design and implementation of the learning environment since the introduction of innovations in education without taking into account necessary physical, organizational, and cultural contexts would not lead to desired outcomes (Jonassen, 1999; C.J. Chen, 2010; Mulders et al., 2020). We suppose such a structural representation of the VR learning environment and the description of its structural components in a specific context would contribute to solving some crucial problems in the design and assessment of the effectiveness of the VR learning environment. The purpose of this study is to propose a contextual framework for a VR learning environment (VRLE) that will help interpret students' and teachers' expectations how to use VR in learning process. Our proposed VRLE contextual framework was used to investigate the following hypotheses:

H1: VR is shaping a new way of looking at learning in school

H2: Participants believe that VR promotes student-centered learning

H3: Participants believe there are undesirable effects of VR on health.

Students and teachers from three general education schools in the western and central regions of the Republic of Kazakhstan participated in the study.

Considering the virtual reality environment in four: technological, pedagogical, social and health-preservation contexts contributes not only to a better understanding of virtual reality as a new learning technology with promising possibilities, but also allows to explore its learning capabilities and impact on education in a broader context.

2. Theoretical foundations. Literature review

2.1. Virtual reality and learning

VR capabilities will bring the following most essential and global changes to learning process:

- obtaining non-symbolic experience from the first person (Winn, 1993) and providing educational materials and situations that are unable or challenging to be implemented in reality. For example, to study the ocean acidification process or hieroglyphs from a tomb on the Giza plateau (Chacon, 2018; The Stanford Ocean Acidification Experience on Steam. The Stanford Ocean Acidification Experience on Steam, 2016)
- provision of favorable conditions for independent and easy learning. For example, using the concept of avatars to reduce psychological stress, social barriers, or the ability to implement the seven principles of constructive learning (Bailenson & Segovia, 2010; Dalgarno & Lee, 2009; Dede, 1995; Mikropoulos & Natsis, 2011; Unruh et al., 2021)
- gamification of learning that promotes exciting and committed learning rather than traditional learning. At the same time, studies note the need and usefulness of further research for this possibility using 3D immersive games in virtual worlds with avatars and detailed environments (Checa & Bustillo, 2020; Dede, 1995; Hamari et al., 2016; Papastergiou, 2009)
- promoting the study of a foreign language and reducing the language barrier, since VR applications enable students to interact with their environment in a different format (autonomously, with a team, with a teacher, or without a teacher) and have different language settings. In addition, students who are not native speakers of the development language can entirely focus on the reality

where they are and get the most out of these activities, without making much effort to understand the language (Chen, 2016; Kozlova, 2019; 2019 Wang et al., 2020; Parmaxi, 2020; Lynch, 2020).

Therefore, VR learning environment as an alternative approach to traditional classroom learning can increase motivation and interest in learning, encourage new knowledge acquiring by presenting the attractiveness of science and STEM education, which will improve learning outcomes. However, a number of studies confirm that the use of VR in learning does not lead to improved learning outcomes because the perceptual realism inherent in IVR (immersive VR) is distracting: overly emotional, and increases cognitive load by processing extraneous information not relevant to the learning goal (Makransky et al., 2019; Parong & Mayer, 2020). The results of these studies are attributed to the novelty effect, as virtual reality is a new and massively uncommon technology for many students, they lack the good familiarity and automatism of managing a VR environment that comes with practice and experience.

2.2. Virtual reality learning environment or Virtual learning environment?

The purpose of this section is to show that there are different perceptions of VR and correspondingly different understandings of VRLE in learning theory and practice. As noted in the research of Radianti et al. (2020), there is still ambiguity and heterogeneity in the understanding of technology that can be attributed to "immersive technologies," including VR. Since the 1990s, most of the definitions of "virtual reality" have been presented through a specific technological system or equipment (Steuer, 1992), 3D graphics, or 3D modeling (Levis, 1997; Mazuryk, 1999). However, at that time, the authors noted that there was no clear boundary between 3D graphics and VR (Mazuryk, 1999). In this regard, one of the leading developers of VR applications, the Unity platform (Unity & VR, 2020), reports that computer-generated stereo images surround the user to replace the natural world around him/her. This definition displaces 360-degree video from actual VR. The complete description of VR, contributing to a broad understanding of VR as a universal technology of the future, is presented by the Unity platform (Unity & VR, 2020) in a technological and social context.

Researchers who explore the VR training possibilities point to a significant advantage of an actual head-mounted display (HMD) VR over desktop VR (DVR) or 360-degree video in teaching (Dalgarno & Lee, 2009; Jacobson & Reimann, 2010; Klingenberg et al., 2020; Mikropoulos & Natsis, 2011; Winn, 1993). As Dede (1995) claimed, "Inducing a sense of physical immersion involves manipulating human sensory systems (especially the visual system) to enable the suspension of disbelief that one is surrounded by a virtual world. The impression is that of being inside an artificial reality rather than looking through a computer monitor 'window' into a synthetic environment: the equivalent of diving rather than riding in a glass-bottomed boat." Considering abovementioned descriptions and the social orientation of educational activities, we consider VR as an artificial or simulation learning environment that ensures human interaction with the surrounding virtual environment in real-time.

In most studies on the VR use in education, this technology is considered as a learning environment and has various names: educational VR applications (Winn, 1993); synthetic constructivist environment (Dede, 1995); MUVE—Multiuser Virtual Environment (Dede et al., 2005); VLE—virtual learning environment (Bailenson et al., 2008); 3D VLE—three-dimensional virtual learning environment (Dalgarno & Lee, 2009), virtual worlds for learning (Jacobson & Reimann, 2010), IVE—immersive virtual environments, educational IVE, IVE classes (Blascovich & Beall, 2010), EVE—educational virtual environment or VLE (Mikropoulos & Natsis, 2011), IVR—immersive VR, lessons in IVR (Klingenberg et al., 2020; Parong & Mayer, 2020), VRLE—VR learning environment (H.M. Huang et al., 2009; W. Huang et al., 2020; Ip & Li, 2015; Singh et al., 2021; Vogt et al., 2021). All these studies relate to VR and its use for education. Therefore, the question arises whether these terms can convey the uniqueness of VR as a new learning environment when in ordinary practice, "virtual learning," "virtual education," "virtual learning environment," or "learning virtual environment" have been associated with online learning without students' physical presence for many years. Moreover, now these terms are used everywhere. Further we will use the term "VRLE, a virtual reality learning environment" because it more accurately conveys that we consider virtual reality as a learning environment with a contextual structure as technological, pedagogical, social and health-preservation contexts.

2.3. Structure of the virtual reality learning environment

The VRLE means the digital virtual space where training takes place and many other conditions related to the methodological, psychological, pedagogical, and technological aspects of learning by using VR. The researchers consider the constructivist paradigm as the theoretical basis for learning in the VRLE since many of the characteristics and learning capabilities of VR are compatible with constructivist learning and support their implementation (Bailenson et al., 2008; C.J. Chen, 2010; Dalgarno & Lee, 2009; Dede, 1995; Mikropoulos & Natsis, 2011; Winn, 1993). Several studies on the design and assessment of VRLE and digital learning objects with practical results highlight the following contexts:

- the pedagogical context that determines the relevance of the environment to the objectives and expected learning outcomes, the content of teaching materials, and the corresponding teaching methods (Akhavan & Arefi, 2014; Allcoat et al., 2021; Mikropoulos & Papachristos, 2021; Radianti et al., 2020)
- the technological context that implies the availability of technical equipment and appropriate software for the functioning of the environment (technical equipment includes VR headset, additional equipment for a VR headset, network equipment, equipment for broadcasting VR sessions, VR application software, or VR content, VR development platforms), as well as its economic and language accessibility for mass learning (Dalgarno & Lee, 2009; Kurilovas & Dagiene, 2009)
- the social context significantly influences an individual's cognitive processes and relationships with his/her environment and society (Bailenson, 2019; Bailenson et al., 2008; Vogt et al., 2021).

The Constructivist Learning Environments design model also supports these contexts for the VRLE. The studies of Jonassen (1999) and Pantelidis (2009) noted that VR was not suitable for all educational purposes and proposed a model of its use in teaching. However, the VRLE of such platforms as on Steam (2018) and Spatial on Oculus Quest. Oculus (2020), etc. provide excellent opportunities to implement various approaches to learning, teaching methods that can also initiate the improvement of the theoretical model of the constructivist learning environment. At the same time, the VRLE ensures the preservation of the main principle of constructivism—student-centered learning.

In the context of widespread digitalization of education, new approaches and forms of learning are often accompanied by an increase in the learning load and worsening the health of students (Diachenko-Bohun et al., 2019; Mukhametzyanov et al., 2018). Besides, the researchers also point out the need to study the effect of VR on the health of school-age children, their physiological and psychological development (Kamińska et al., 2019). Findings from research by Aubrey et al. (2018) showed that VR use raises some questions for parents of students: how does VR differ from other media tools? What is the influence of VR on children's development? Are there any cognitive implications of prolonged immersion in VR? What characteristics of the content presented in VR change children's attitudes and behavior? In this regard, it will be appropriate to include a health-preservation context that studies the effect of VR on the physical and psychological health of the learner. Health-preservation context implies learning safety and promotes the creation of comfortable conditions aimed at preserving, developing, and strengthening the personal health of participants in the VRLE.

Thus, the structure of the VRLE suggested by us may contain structural components of the pedagogical, technological, social, and health-preservation context. Each of these components is a set of more specific and non-specific properties, characteristics of VR that reveal their purpose and function. Perhaps these properties and characteristics of the learning environment can be

Table 1. Content of VR applications of the VRLE for HTC VIVE Pro Full Kit

Name	Content summary
The Stanford Ocean Acidification Experience	Due to atmospheric pollution, the oceans will absorb too much carbon dioxide and become more acidic. A VR headset enables the user to descend to the bottom of the ocean watch and feel the destruction of ocean flora and fauna from air pollution, such as how the acidity of the ocean has corroded the shell of a sea snail.
Rumii	The content presents a classroom with appropriate virtual teaching equipment and thematic resources for individuals or groups of users. Interaction between the teacher and students takes place online, in real-time. With the help of avatars, they solve problems on the board together, do laboratory experiments, and discuss problematic issues on the spot. There are also various 3D models of numerous objects for training, including training in elementary school.

supplemented and changed along with new possibilities of VR that we do not yet know. In this regard, the structure of the VRLE proposed by us is not categorical; it can be a primary approximation of the consolidation and systematization of the VR training possibilities.

3. Materials and methods

3.1. Research tools and content of materials

The study has been conducted by using the HTC VIVE Pro Full Kit and the Oculus Quest 2. In our study, two VR applications were chosen as the VRLE for the HTC VIVE Pro Full Kit headset: The Stanford Ocean Acidification Experience on Steam. The Stanford Ocean Acidification Experience on Steam (2016) and ; Appendix 1). The National Geographic Explore VR on Oculus quest. Oculus (2019) application with two thrilling journeys to the ancient Inca city of Machu Picchu and icy Antarctica was used for Oculus Quest 2 (Table 1 and 2).

3.2. Methods

This study used a mixed-methods approach: a multiple-choice questionnaire and open-ended questions with free responses (for teachers only). This approach allows the collection, analysis, and interpretation of both quantitative and qualitative data to gain a deeper understanding of the

Table 2. Content for VR applications of the VRLE for Oculus Quest 2

Name	Content summary
National Geographic Explore VR: The Machu Picchu	The educational and cognitive content is developed in the form of a quest. A student wearing a VR headset helmet finds himself in the ancient Inca city of Machu Picchu. As a traveler who completes simple tasks, the user will get acquainted with the history and culture of the Incas, visit their homes, and take beautiful photos with the alpaca. You can hang your favorite photos in photo frames on the wall of the room or share them on social networks.
National Geographic Explore VR: The Antarctica	The content enables you to travel across Antarctica between huge icebergs on a large boat called a kayak. Whales and seals (fur seals) swim around the kayak. Penguins walk not far from you, sounds are heard. The high level of visualization, tactile feedback, and real vibration when paddling provide a good effect of presence and convey the feeling of the cold, harsh climate of territories covered with ice and snow.

phenomenon of interest (Leech & Onwuegbuzie, 2009). The questionnaire we developed includes 8 questions on the four contexts of VRLE (technological −3, pedagogical—2, social—2, and health-preservation −1, Appendix 1). The guidelines suggested by Alexandrovsky et al. (2020) related to VR questionnaires' reliability, validity, and reproducibility were used to develop the questionnaire. The questions designed by the authors were aimed at obtaining information about the experience in the virtual world, the comfort of learning in a VRLE, the expectations of students and teachers from VR as a new learning environment. The topics that are not highlighted in the option questions but assist the in-depth interpretation of teachers' expectations from VR are included in the open-ended questions:

- How do you see the role of a teacher in a VRLE?
- Can VR help narrow the education quality gap between urban and rural schools?
- Can VR have a significant influence on the psychology of a student?
- Can VR help children with special needs, low achievers, and excellent students achieve the same learning outcomes?

This questionnaire structure enabled the respondents to express their opinions and visions of the questions asked in a free and specific way. Teachers' answers to open-ended questions were manually analyzed regarding text content.

3.3. Participants and data collection

The study involving 53 students and 49 teachers at the school was conducted from February to April 2021. There were no criteria when a school or respondents were chosen, except for the student's age. Students and teachers from two schools in Aktobe (Western Kazakhstan) and one school in Nur-Sultan (Central Kazakhstan) took part in the study. Since 2016, schools in Kazakhstan are legally allowed to employ virtual reality glasses and content for them in school subjects (""On approval of norms of equipment and furniture," 2016). However, the schools that took part in the study do not have VR headsets. We used VR headsets from our research lab, HTC Vive Pro Kit and Oculus Quest 2. Of the 53 students, 28 (52.8%) were middle school students at the age of 10–14 years, 25 (47.2%) were senior students at the age of 15–16. The number of boys was 28 (52.8%), of girls was 25 (47.2%). Out of 49 responding teachers, 13 (26.5%) persons were at the age of 20–29, 11 (22.4%)—30-39 years old, 16 (32.7%)—40-49 years old, and 9 (18, 4%) participants were 50–59 years old. Besides, 30 (61.2%) persons had a bachelor's degree, 14 (28.6%)—a master's degree, 5 (10.2%)—a Ph.D. degree. The survey involved 22 (34.8%) teachers of STEM subjects, 11 (22.5%) teachers teaching languages and literature, 5 (10.2%) teachers of history, geography, and art, 2 (4.1%) physical education teachers and 9 (18.4%) teachers who work in the management area of the school. 47.3% of teacher respondents had more than two years of experience in a rural school.

Survey questions and answers were offered in the language of instruction of the respondent, in Kazakh or Russian. Students answered the multiple-choice questions. Along with multiple choice questions, teachers answered open-ended questions.

The studies were conducted in small groups with safety precautions due to the Covid-19 pandemic. Researchers held presentations using the HTC VIVE Pro Full Kit and Oculus Quest 2. After the presentation, students and teachers in groups of 5–6 persons were able to work with the VR headset. Each respondent was given the opportunity to immerse himself/herself in VR at least three times. The session duration depended on the VR application but did not exceed 5–7 minutes. After these sessions, they were asked to answer the questionnaire and write their impressions and visions of the VR used for teaching at school.

4. Results

In this study, a 4-point Likert scale was used to evaluate questions with four answers (Q1, Q2, Q3, and Q5) according to 1- (a), 2—(b), 3—(c), and 4- (d). In questions Q4, Q6, Q7, and Q8, one or more answers can be selected. This multiple-answer format is useful when you want to ask the respondent what is more important to them. To assess multiple-choice (or multiple-answer) questions we used a modified Likert scale for determining the level of understanding of a problem (Vagias, 2008): if only one answer is chosen, it means 1—Not at all a problem, to choosing two answers means 2—Minor problem, choosing three answers is defined as 3—Moderate problem, and choosing four or more answers 4—Serious problem. To check the reliability to determine the internal consistency of questions and answers to the questionnaire we developed, we calculated the values of Cronbach's alpha (α), widely used in pedagogical research. Its values were 0.65 for students and 0.46 for teachers, respectively. As the authors note, one should not always expect high internal consistency from a scale to diagnose motive or emotion, which are themselves highly dynamic (Berger & Hänze, 2015; Mitina, 2015; Nehring et al., 2015; Taber, 2018). We also believe that for this study, values of $\alpha = 0.65$ and $\alpha = 0.46$ are considered acceptable given the limited number of items (8 questions) and the wide range of questions tested, including primary perceptions and expectations in four different contexts. The mean values (M) and standard deviations (SD) for each question are shown in Table 3.

We analyzed the results in four contexts and in terms of responses to each question. Presenting the results in the form of a bar chart allows a wide range of readers to easily understand the essence of the contextual-structural approach to the study of VR as a learning environment.

4.1. Significance of the technological context for the VRLE

In this research, the technological context of the VR learning environment is characterized by (Appendix 1: Q1, Q2, Q3):

- participants' awareness of VR, reflecting the availability of VR devices and educational VR contents
- perception of VR as the achievement of scientific and technological progress
- satisfaction with the interaction with the learning environment provided by VR technology.

According to participants' responses, the first noticeable thing was the lack of awareness of VR technology among students and teachers. Awareness among students was 45.3%, while a significant number of respondents (54.7% of students and 57.1% of teachers; Figure 1, (a; b)) had only a general idea or had heard about VR for the first time. At the same time, students were 2.4% more aware than their teachers (Figure 1, (c; d)).

Table 3. Mean values (M) and standard deviations (SD) obtained from an 8-question questionnaire

Contexts	Questions	Students		Teachers	
		M	SD	M	SD
Technological	Q1	2,25	0,99	2,51	0,82
	Q2	2,66	0,75	2,92	0,57
	Q3	2,62	1,24	3,06	1,03
Pedagogical	Q4	1,66	0,89	1,69	1,05
	Q5	3,21	1,09	3,31	0,71
Social	Q6	1,38	0,66	1,57	0,74
	Q7	1,26	0,65	1,45	0,68
Health-preservation	Q8	1,09	0,30	1,27	0,64

Figure 1. Survey Results for Technological Context: Q1

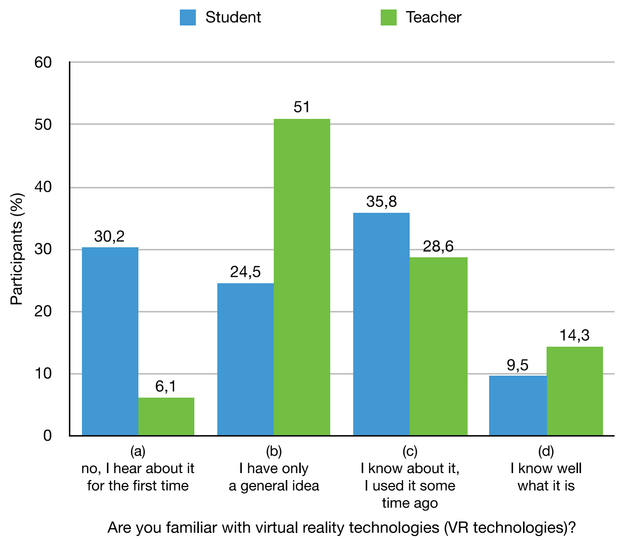
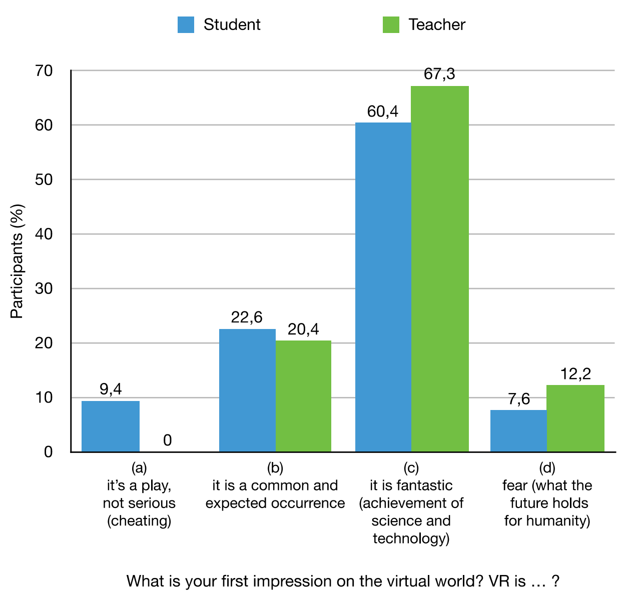


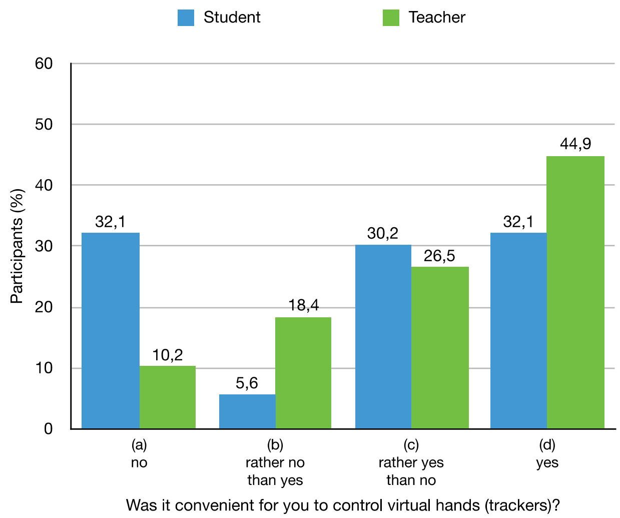
Figure 2. Survey Results for Technological Context: Q2



Nevertheless, most respondents in both groups, 60.4% of students and 67.3% of teachers believe VR is a high technology achievement and perceive it as a fantastic opportunity for humanity (Figure 2, (c)). Of the 32 students who perceive VR as a technology achievement, 50% are elementary school students, the share of girls and boys being 43.7% and 56.3%, respectively. 80% of students (4 out of 5) who consider VR immersion a game or not a serious activity are in basic school and all four are boys. 12.2% of teachers who are concerned about "what the future holds for humanity" are over the age of 40, and of the students, the majority (75%, 3 out of 4) are female.

In our research, the available control device of the virtual environment were trackers, which provide navigation, movement in the environment, and interaction with its objects. 62.3% of students and 71.4% of teachers believe that control and interaction with the help of virtual hands are quite acceptable (Figure 3, (c; d)). In the VR environment, the trackers are displayed as left and right hands that can be used to perform various actions with the objects of the environment, such as picking up a camera and taking pictures of Antarctica or Machu Picchu,

Figure 3. Survey Results for Technological Context: Q3



holding oars and leading a kayak, putting dishes, a lamp, flags, or other things in the right places. After doing all of these activities, 62.3% of the students and 71.4% of the teachers felt that controlling and interacting with virtual hands was acceptable (Figure 3, (c; d)). Uncomfortable control of virtual hands was felt by 37.7% of the learners, of which 55% (11 out of 20) were high school girls.

Additionally, in a technological context, 77.5% of teachers expect that schools will have VR headsets and use them in the teaching process in the next five years: 4.1% of teachers believe that schools already use them; 26.5% believe that VR will be widely used in schools in a year or two, 46.9%—in 3–5 years.

4.2. How is the pedagogical context of the VRLE perceived?

Students and teachers have a good perception of VR as a learning environment and understand the educational opportunity of it. Participants were able to select several answers to pedagogical context of the question, “What kind of changes do you expect from the implementation of VR in learning?” (Appendix 1: Q4). The responses presented in Figure 4 show that the majority of respondents believe that the implementation of VR allows a new view of the learning in school (b) and increases the level of motivation and interest of students in learning (c). Answers (a), (b), (e), and (f) reflect that teachers are more interested in the impact of VR on the quality of learning, and students in approaches to personalize (individualize) learning according to chose of answers (c) and (d).

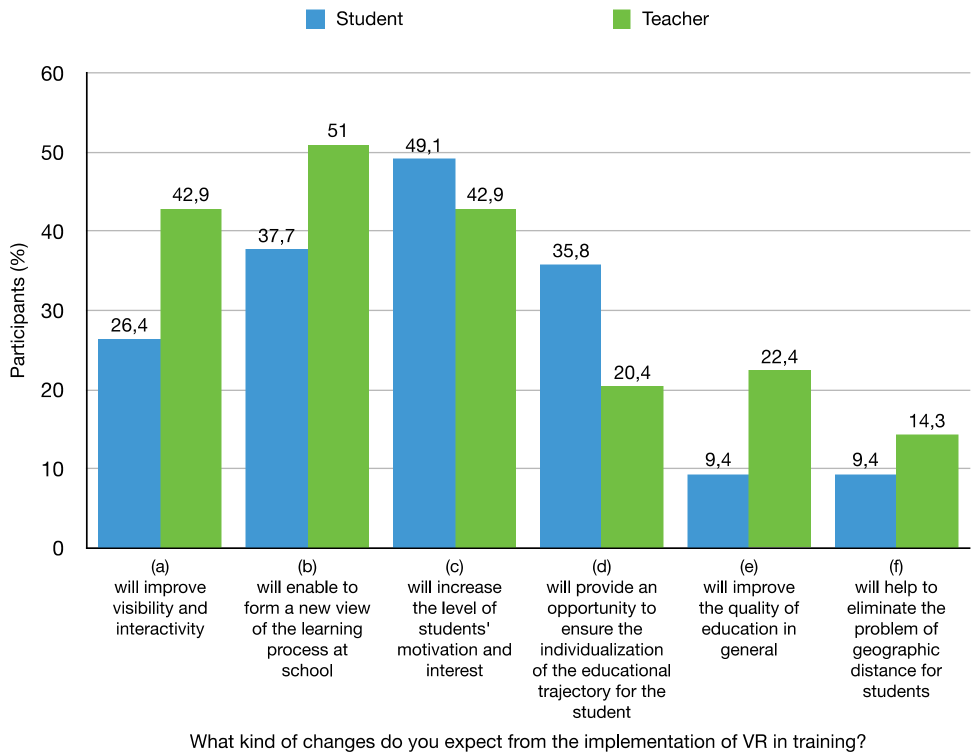
Despite the low level of awareness of VR, participants show a high level of interest in VR education. A crosstabulation of Q1 and Q5 obtained with SPSS shows well that there is a significant relationship between awareness of VR and its use (Table 4).

An analysis of technological and pedagogical contexts on the crossing confirms that almost all participants who are familiar with VR or who know it well agree with the use of VR in school (Table 4, Q1(c; d), Q5(c)(d)). Additionally, 79.2% of students agree to study at school using VR, and 20.4% of teachers believe that VR can be used to teach from an early age in primary grades, and the majority of 61.2% agree with teaching children in the VRLE in middle school, starting from the age of 10.

4.3. Understanding the social context and health risks

The research participants assume that learning in the VRLE has its pros and cons in the social context. The freely formulated questions of our questionnaire and the possibility to choose several

Figure 4. Results of the Pedagogical Context Survey: Q4



answers by them allowed us to highlight important social and health-preservation aspects of the VRLE learning that attract the attention of students and teachers (Appendix 1: Q6, Q7, Q8). In Figure 4 (c) and Figure 5 (b), with a slight deviation, students confirm previous results "on increased motivation to learn." Students think that using VR in school can make the teacher's job easier and facilitate free and comfortable learning outside the classroom (Figure 5, (a; c)). When using VRLE, teachers are most interested in the capabilities of the learning environment to improve motivation for learning, the strength of knowledge acquired, and open access to various educational resources (Figure 5, (b; d)(e)).

The analysis shows that study participants who have only recently been immersed in VR and have been to the bottom of the ocean, the ancient city of Machu Picchu, or icy Antarctica, consider the imbalance of real-world perception as the most significant risk in learning in a VRLE (Figure 6, (c)). 15.1% of students, including 75% of those students—boys in the main school think that there may be risks of reducing the quality of education. Among the students who are concerned about the impact of VR on health (b) 66.7% (12 out of 18) are high school students. All but 2 of these students also disagreed with the answer (e). Teachers and learners with a slight difference of 3.9% do not exclude the risk of isolation from the outside world, with 44.9% of teachers believing there would be no risk with moderate use of VR at school.

The participants in both groups are also concerned about the undesirable health effects of VR, and their worries have a basis, as 63.3% of learners and 49% of teachers felt at least one discomfort when immersed in VR. At the same time, some teachers are confident that there is no risk with moderate and competent use of VR in school (Figure 7). Three students (5.7%) who feel confused (c) are male high school students (a), and all four (7.5%) who feel nauseous (c) are male high school students. Dizziness when immersed in VR (d) is observed in 6 students (11.3%) of which 4 (67.7%) are female and are in elementary school. Of the teachers who noted signs of dizziness 58.3% (7 of 12) were over the age of 40. Of all the teachers immersed in VR, only three (0.06%) confirmed having more than one discomfort at a time and overall, more than half of the teachers felt comfortable (h) in the VR

Table 4. Table of conjugacy of issues of technological and pedagogical contexts

Q1: Are you familiar with VR technologies (VR technologies)?			Q5: How do you feel about using VR in school?			
			(a) no	(b) rather no than yes	(c) rather yes than no	(d) yes
(a) no, I hear about them for the first time	Student	N	3	0	3	10
		%	18,8%	0,0%	18,8%	62,5%
	Teacher	N	0	1	2	0
		%	0,0%	33,3%	66,7%	0,0%
	Total	n	3	1	5	10
		%	15,8%	5,3%	26,3%	52,6%
(b) I have only a general idea	Student	n	3	2	4	4
		%	23,1%	15,4%	30,8%	30,8%
	Teacher	n	0	5	12	8
		%	0,0%	20,0%	48,0%	32,0%
	Total	n	3	7	16	12
		%	7,9%	18,4%	42,1%	31,6%
(c) I know them, I used formerly	Student	n	2	1	3	13
		%	10,5%	5,3%	15,8%	68,4%
	Teacher	n	0	1	5	8
		%	0,0%	7,1%	35,7%	57,1%
	Total	n	2	2	8	21
		%	6,1%	6,1%	24,2%	63,6%
(d) I know well what they are	Student	n	0	0	2	3
		%	0,0%	0,0%	40,0%	60,0%
	Teacher	n	0	0	1	6
		%	0,0%	0,0%	14,3%	85,7%
	Total	n	0	0	3	9
		%	0,0%	0,0%	25,0%	75,0%

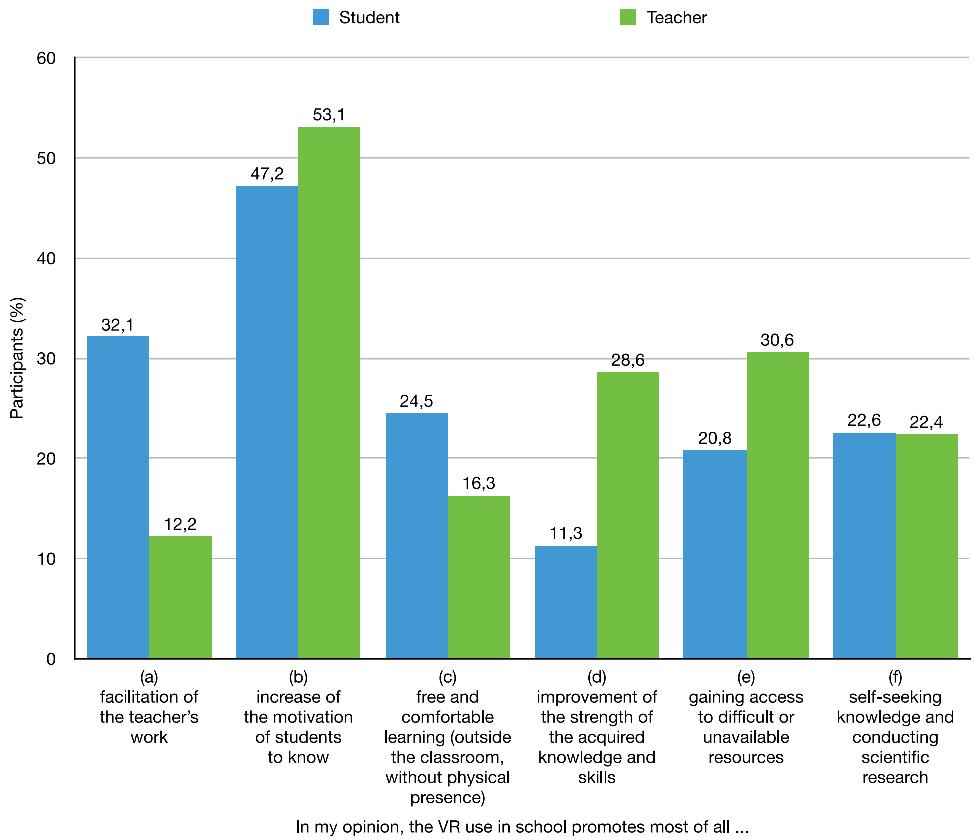
environment. The discomfort associated with nausea, dizziness, and fear of falling was largely due to the quality of the VR content navigation interface. The apps we used for this study have fairly comfortable navigation interfaces in the form of teleportation (Table 1, 2).

The extreme importance of social and health-preservation contexts of the VRLE is also confirmed by the teachers' answers to the open-ended questions of our questionnaire.

4.4. Interpretation of open-ended questions

Out of 49 teachers, 35 (71.4%) persons answered the open-ended questionnaire. For the first question, "How do you imagine the role of a teacher in a VRLE?" the teachers' responses were divided into two groups. The first group, consisting of 13 of teachers (37.1%), wrote that the importance of the teacher's role in a VRLE would be the same high as before implementing it. The teacher determines the content of training, provides practical assistance, organizes feedback, and ensures training safety. The second group, consisting of 22 teachers (62.9%), suggests that the teacher's role in the VRLE will become guiding since the student controls his/her learning in VR. The teacher plays the role of a navigator and coordinator of students' research, promotes the development of imagination, gives advice, reminds us that there are virtual and real worlds.

Figure 5. Social Context Survey Results: Q6



For the question "Can VR help children with special needs, low achievers, and excellent students achieve the same learning outcomes?" the following responses were received:

- "All students will have the same conditions and access to educational resources. Interest and motivation to study will be very high"—6 (17.1%)
- "Perhaps VR will help students achieve the same learning outcomes. However, this will depend on the wishes of the students. VR will help children with special needs achieve high results"—20 (57.2%)
- "No, the results will not be the same. It requires the same level of motivation and ability. It is unrealistic. Unsuccessful students are less interested"—6 (17.1%)
- "I do not know. I am at a loss to answer. I do not divide children by academic performance"—3 (8.6%).

All 35 teachers who answered the question "Can VR have a significant impact on a student's psychology?", confirmed the influence of VR on students' psychology. Of these, 10 persons (28.6%) expect more benefits than harm to human psychology from VR use at school if all the norms are observed. 9 teachers (25.7%) believe that VR use in school significantly influences the students' psychology, especially on cognitive processes. It can develop or decline abstract thinking and spatial orientation. This aspect requires further study. A significant part of teachers, 16 persons (45.7%), fear the negative influence of VR, and there should be restrictive measures for its use. They believe that it is best not to use it for children under 15, as they cannot control their emotions.

The next open-ended question, "Can VR help narrow the education quality gap between urban and rural schools?" was formulated considering our region's existing problems, where 71.2% of schools are rural (Nurbayev, 2021). 57.1% of teachers are confident that VR contributes to improving the education quality in a rural school where there are not enough teachers of STEM

Figure 6. Social Context Survey Results: Q7

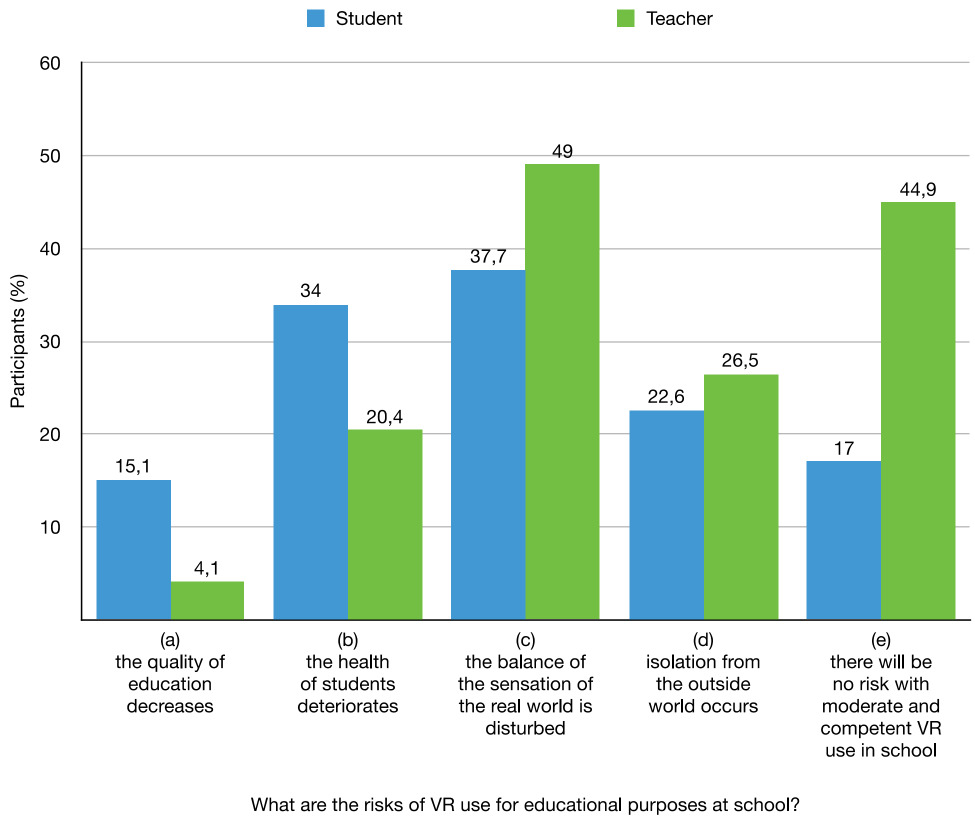
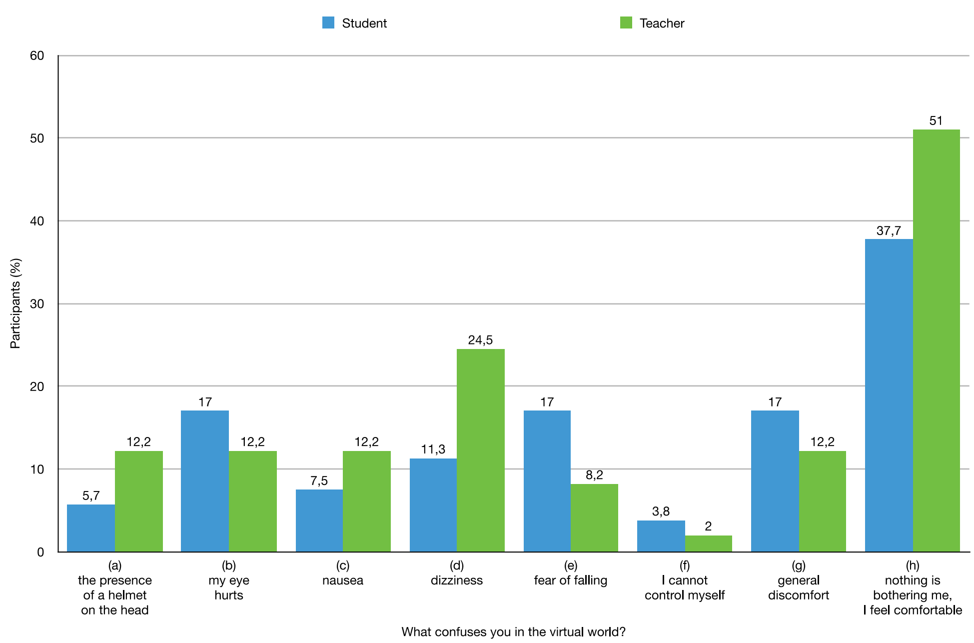


Figure 7. Health-preservation Context Survey Results: Q8



and English. 22.9% of participants are less sure that it requires good high-speed Internet, appropriate equipment, and VR. 20% of respondents consider this project a utopia since they do not believe in VR availability for a rural school.

5. Discussion and conclusion

In accordance with the purpose of the study we considered VR as a structured learning environment, consisting of four contexts: technological, pedagogical, social and health-preservation. The proposed structure of VRLE was defined as one of the approaches to the study of VR in education. The results of the study, based on the data of self-reports of the participants, allowed to interpret the expectations of students and teachers from using VR in terms of four contexts.

In the *technological context*, it was established that Kazakhstani students and teachers, while not highly aware of VR (54.7% and 57.1%) perceive it as a high achievement of science and technology (60.4% and 67.3%). The expectation of the teachers (77.5%), that in the next five years schools will use VR in teaching, shows their acceptance of this technology for use in school. However, teachers' uncertainty about the future prevalence of VR in schools is related to the technical and digital divide that have become major educational issues due to the COVID-19 pandemic (Celik et al., 2022; Suraci et al., 2022). Teachers are concerned about the availability of VR technology for rural schools in Kazakhstan, as the effectiveness of VR education is directly related to the quality of the Internet connection, VR headset and VR -contents.

In a *pedagogical context*, more than half of the teachers (51%) agree with the statement "VR will enable to form a new view of the learning process at school. A half of students and teachers (49.1% and 42.9%) believe that VR increases motivation and interest in learning, while having no significant impact on the quality of learning (9.4% and 22.4%; Figure 4). In this regard, participants' responses are consistent with the findings of Makransky et al. (2019) and Parong and Mayer (2020), who state that a sense of presence and positive emotion in VRLE increases motivation but does not necessarily contribute to improved learning outcomes. The possibilities of VRLE for the implementation of constructivist learning centered on self-experience, which are examined in studies by Dede (1995), Dalgarno and Lee (2009), Di Natale et al. (2020), and Feyzi Behnagh and Yasrebi (2020) are confirmed in the self-reports of the study participants. The increased motivation and interest in learning, the provision of individualized education that students and teachers expect from VR, and teachers' responses to an open-ended question about the teacher's role in VRLE indicate that VRLE is student-centered. In addition, 62.9% of teachers wrote in responses to the open-ended question "How do you imagine the teacher's role in VRLE?" that the teacher's role in VRLE would be guiding or coordinating as the student directs his or her own learning.

The results of this study also confirmed the importance and interconnectedness of *social and health-preservation contexts* in VRLE research. Answers to the questions "What are the risks of VR use for educational purposes at school?" and "What confuses you in the virtual world?" show that there is reason to support the hypothesis on undesirable health effects of VR. Students cite "the health of students deteriorates" (34%), "the balance of the sensation of the real world is disturbed" (37.7%) and "isolation from the outside world occurs" (22.6%) as undesirable risks in VRLE (Figure 6). Teachers also considered the greatest social risk from VR to be the imbalance between the virtual and real world. In addition, most learners and half of teachers feel uncomfortable physically (Figure 7). Although these data are answers to self-report questions, they point to the need for new research in this direction. As noted by Kamińska et al. (2019) VRLE learning scenarios especially for children or people with disabilities, should be carefully studied and evaluated, consulted with professional psychologists and educators.

The difference between student and teacher responses to some of the questions in the technological context (Figure 1, (b); Figure 3, (a)) and the social context (Figure 5, (a); Figure 6, (e)) makes one wonder: Is there any reason why these responses are related? Perhaps students in the school have more practice in VR and VR-like technologies than their teachers? Why are students (17%) more cautious about the risks from VR than their teachers (44.9%)? These questions open new line of thoughts and require additional research.

Generalization of the results of the study of VRLE in four: technological, pedagogical, social and health-preservation contexts allowed us to obtain the following conclusions:

- students and teachers of Kazakhstani schools despite the low level of awareness and experience in VR have a great interest in its use in education
- most teachers expect VR to be implemented in schools in the next 5 years
- VRLE presents a new perspective on learning: high motivation and interest in learning, constructivist experiential learning, real help in learning for children with special needs, improving the quality of education in a rural school
- VRLE has many benefits for learning, but it is not without social risks and undesirable health effects.

In the theoretical part of the study, we also discussed the lack of consistency and homogeneity in the definition of "virtual reality" and the name VRLE, which are basic concepts for this and other research on the use of VR in education. Our findings on the definition of "virtual reality" are consistent with those of Radianti et al. (2020), who refer to 360-degree video, Desktop VR, CAVE, and panoramic videos as technologies without immersion. Using a consistent understanding and common name for VRLE would also contribute to a better perception of VR as a learning environment for further research. The findings of this study may be meaningful when deciding to implement VR in Kazakhstani schools and in other countries. In addition, the results of the study confirm the conclusions of previous research on VRLE and supplement them with 4 contexts.

6. Limitations and future directions

The most significant limitations of this study were the following:

- the quantitative data from the study are self-reported by the learners and teachers who participated in the survey
- difficulties in selecting quality educational content appropriate to the age, language of instruction, and other individual needs of students
- severe limitations in contact with students and teachers at school in the face of the COVID −19 pandemic.

Despite these limitations, our research reveals a number of issues related to the consideration of VRLE in different or combined contexts and which may be a reference for future research on the use of VR educations. It would be helpful if future research defines criteria and develop VR models for each of the technological, pedagogical, social, and health-promoting contexts. VRLEs (educational VR applications) must be designed and evaluated in terms of technical feasibility and software engineering, pedagogy (Radianti et al., 2020), medicine (Kamińska et al. (2019), and the needs of both teachers and students. The differences in students' and their teachers' perceptions of VRLE raise questions such as "Do students have more technological and social experience with VR than their teachers and how would this affect student-teacher interaction?" that would not arise in a traditional classroom environment. The large contrast between the perception of VR as a potential technology for learning (77.5% of teachers expect schools to have VR headsets and use them in the classroom in the next five years) and its actual use in school (4.1%) also shows the importance of addressing issues such as increasing VR use in schools and training teachers to use VR.

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Correction
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Appendix Survey questions

Table A1. Questions and answer choices for 4 contexts of VRLE

Contexts	Questions	Answers
Technological	Q1: Are you familiar with VR technologies (VR technologies)?	(a) no, I hear about it for the first time (b) I have only a general idea (c) I know about it, I used it some time ago (d) I know well what it is
	Q2: What is your first impression of the virtual world? VR is:	(a) it's a play, not serious (cheating) (b) it is a common and expected occurrence (c) it is fantastic (achievement of science and technology) (d) fear (what the future holds for humanity)
	Q3: Was it convenient for you to control virtual hands (trackers)?	(a) no (b) rather no than yes (c) rather yes than no (d) yes
Pedagogical	Q4: What kind of changes do you expect from the implementation of VR in learning?	(a) will improve visibility and interactivity (b) will enable to form a new view of the learning process at school (c) will increase the level of students' motivation and interest (d) will provide an opportunity to ensure the individualization of the educational trajectory for the student (e) will improve the quality of education in general (f) will help to eliminate the problem of geographic distance for students
	Q5: How do you feel about using VR in school?	(a) no (b) rather no than yes (c) rather yes than no (d) yes

(*Continued*)

Contexts	Questions	Answers
Social	Q6: In my opinion, the VR use in school promotes most of all …	(a) facilitation of the teacher's work (b) increase of the motivation of students to know (c) free and comfortable learning (outside the classroom, without physical presence) (d) improvement of the strength of the acquired knowledge and skills (e) gaining access to difficult or unavailable resources (f) self-seeking knowledge and conducting scientific research
	Q7: What are the risks of VR use for educational purposes at school?	(a) the quality of education decreases (b) the health of students deteriorates (c) the balance of the sensation of the real world is disturbed (d) isolation from the outside world occurs (e) there will be no risk with moderate and competent VR use in school
Health-preservation	Q8: What confuses you in the virtual world?	(a) the presence of a helmet on the head (b) my eye hurts (c) nausea (d) dizziness (e) fear of falling (f) I cannot control myself (g) general discomfort (h) nothing is bothering me, I feel comfortable