Research Article

Teaching the Seasons of the Year to Kindergarten Students Using Desktop Virtual Reality: A Comparative Study

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Teaching concepts related to the natural environment in early childhood education significantly impacts cognitive development and corrects misconceptions. Technological advancements have introduced innovative educational tools such as virtual reality (VR). Among the various forms of VR, desktop VR (dVR) is the most practical for use in a school setting, as it requires no specialized equipment other than computers. With this in mind, a project was implemented to examine the impact of a dVR application on kindergarten students' learning. A total of forty-five students participated in a within-subjects research design, studying the seasons of the year. The learning outcomes were then compared with those produced by conventional materials. Furthermore, students' feelings and attitudes were also analyzed. The results showed that when using the dVR application, students performed significantly better in terms of learning, immersion, motivation, enjoyment, and ease of use. Factors such as students' gender and prior knowledge did not have any significant effect. The study's implications for research and education are also discussed.

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1. Introduction

The learning requirements for students aged between 4 and 6 years (typically referred to as kindergarten students) differ significantly from those of other age groups. The learning process of these students is an adventurous journey where they quench their ever-lasting thirst for understanding how things work. It stems from their innate curiosity which perpetually prompts them to inquire about the origins, fabrication, operation, as well as the application of different objects and phenomena. During their "encounters" with various elements and phenomena of their environment, kindergarten students interpret the events with their own way of thinking in an effort to understand what is happening around them. Predominantly, these young learners center their attention on acquainting themselves with the natural environment encompassing them. Their interest gets piqued by numerous elements within their surroundings, such as weather phenomena, fauna, flora, and the forces of nature (Fokides & Zachristou, 2020). On the basis of their experiences, explorations, and interactions, children have formed a body of ideas and interpretative models, before they even enter formal education (Driver, et al., 2014). As kindergarten students attempt to make sense of events through sensory observations, they often do so without having developed a comprehensive understanding of these events (Paik et al., 2004), it is not uncommon their body of knowledge to be saturated with misconceptions, misinterpretations, and wrong ideas (Trundle, 2010).

In this regard, it becomes apparent that the introduction of concepts pertaining to the natural environment within early childhood education is of significant importance, as this exposure contributes to the cognitive development of very young students and the rectification of their misconceptions (Harlen, 2018; Trundle, 2010). Essentially, within the realm of early childhood education, the study of the environment serves as a framework, wherein students interact and engage with their surroundings. This model is inherently tied to their prior experiences. The pedagogical interventions designed and executed within this framework draw from the pre-existing cognitive structures, specific needs, and individual characteristics of students. The underlying objective is to stimulate children, instigate their creativity, foster the exchange of ideas, and, consequently allow the acquisition of new knowledge (Fokides & Zachristou, 2020).

Teachers possess a wide range of tools that can effectively be used to teach kindergarten students subjects associated with the natural environment. These tools, however, are predominantly "conventional," incorporating printed materials, songs, music, videos, images, paintings, toys, and physical materials. In contrast, technology offers innovative solutions laden with significant educational potential. One such tool is Virtual Reality (VR). VR is a computer-generated simulation of a 3D environment that users can interact with in a manner that mimics real-life experiences. Among the various forms of VR, desktop VR (dVR) is the most practical for use in a school setting, as it necessitates no specialized equipment other than computers. However, as will be detailed in a forthcoming section, the use of dVR is not a standard practice at the kindergarten level. This underutilization leaves a significant scope for investigation into its educational potential and impacts on the learning outcomes of students in this age group.

Considering the imperative role that understanding concepts related to the natural environment plays in the education of kindergarten students, and acknowledging that the utilization of dVR as a teaching tool for the teaching of such subjects (or any other subjects) for this age group is currently underexplored, it was decided to embark on a project aiming to investigate the potential effectiveness of dVR in teaching subjects related to the natural environment to kindergarten students. The following sections present and analyze the rationale behind this decision, the methodology that employed, and the results that were obtained from the project.

2. Related work

2.1. Considerations regarding the teaching of the natural environment at the kindergarten level

The pedagogical content at the kindergarten level is essentially an extension of what pupils already have knowledge of, thus teachers' efforts focus on establishing the conditions that will facilitate successful future learning. In teaching these students, it is imperative that the learning process is organized in a manner that caters to each child's unique attributes and promotes overall development and growth (Anning, 2015). Young learners tend to thrive when the subjects they are learning have a direct relation to their personal experiences beyond the school environment (Wilson, 2018). In essence, the process of learning at the preschool level is a product of the alignment of diverse learning experiences: personal experiences, which even though potentially unsystematic -and in several instances enclosing various misconceptions- are invaluable, and educational experiences which are structured and have a defined set of objectives originated from the teacher (Smidt & Rossbach, 2016).

As the children interact with these facets of their surroundings, they engage in several processes. These encompass playful activities, explorations aimed at comprehending how the world functions, observations of objects and explorations of their characteristics, as well as the conceptualization and execution of research to validate or debunk different phenomena (Kangas, 2009).

In this context, sensory perceptions perform an instrumental function, forming the basis on which children seek to recognize and make sense of the world around them. They are directed to identify the ubiquitous elements as well as the distinctive features within their environment. Moreover, they try to understand relationships, and undertake the challenge of interpreting the phenomenological experiences and transformative processes they witness in their surroundings (Smutny & Von Fremd, 2010). Subsequently, the propagation of the newly obtained knowledge to others becomes the next phase of the learning process. It is this exact process that induces the exchange of impressions and a resultant transformation in opinions among the learners. This approach is pivotal in facilitating a dynamic and

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iterative learning process where novel insights are continually produced and shared, contributing to the enrichment of the overall learning experience (Cakir, 2008).

In teaching subjects associated with the natural environment, the kindergarten teacher should foster student engagement in issues pertaining to the natural world (Samarapungavan et al., 2011). The subsequent logic employed in resolving these problems either assimilates into an existing rule or, if repudiated, formulates a new one. Kindergarten educators are advised against implementing rigid scientific language. In lieu of this, a more colloquial approach is suggested, utilizing descriptive and less scientific terminology (Menninga et al., 2017). Furthermore, a commendable approach for educators aiming to teach natural phenomena is to prompt students to document observations pertaining to a phenomenon and delineate these observations utilizing simple language (Garba et al., 2015). In addition, children are encouraged to categorize materials and situations and to explore and contrast varying classifications. They grapple with questions, formulating responses via predictions, hypotheses, and definitions. Pupils learn to deliberate on the genesis of a phenomenon or condition rather than focusing exclusively on its justification (Paris et al., 2001). However, it is emphasized that habitual experiences and the inherent curiosity of kindergarten students do not suffice in instigating cognitive conflicts, critical for the development of scientific conceptualizations. Pupil's nascent perceptions of their surroundings can serve as an invaluable springboard for the designing of activities. Nonetheless, it is crucial that, should there be any misconceptions about natural phenomena, these be addressed using scientific reasoning, otherwise, these misconceptions could potentially persist into adulthood (Cuzzolino, 2017).

2.2. Virtual reality in kindergarten level

VR, as previously noted, denotes computer-generated 3D environments that empower users to engage in a variety of activities and interact with virtual elements (Smith, 2015). Immersion stands out as a pivotal characteristic of VR, describing the capacity of a system's technical features to create an experience that convincingly mimics reality (Rasimah et al., 2015). Within educational spheres, VR's adoption is rapidly increasing due to its ability to render environments with a degree of realism unattainable through traditional textbooks, while simultaneously omitting elements that could obstruct the learning process (Blascovich et al., 2002). Furthermore, VR transcends the spatial and temporal limitations inherent in education, thereby facilitating experiential learning (Cambra & Viniegra, 2016). The deployment of VR in children's education offers a myriad of potential benefits. Not only does it expand their intellectual frontiers and foster imagination, but it also has been shown to enhance learning outcomes and equip students with the capacity to apply knowledge within real-world contexts (Schmitz et al., 2020). VR transforms students into active participants in their own learning journey, enabling them to independently conduct explorations and interactions (Martín-Gutiérrez et al., 2017). An additional merit of VR is its provision of access to learners, allowing them to comprehend events and phenomena within scenarios or locales that are otherwise beyond their reach. This affords students the unique opportunity to observe, examine, and delve deeply into microcosms and macrocosms in otherwise inaccessible environments (Pajorova & Hluchy, 2016). It's important to recognize that a diverse array of factors can significantly affect learning outcomes when utilizing VR. These include the individual's computer experience, cognitive profile, learning style, as well as characteristics related to the technology itself, such as the level of immersion offered by the VR system (Southgate et al., 2019). Therefore, it is essential to consider these variables when implementing VR technology in educational settings to maximize its effectiveness.

Research in the realm of kindergarten education has yet to extensively explore the utility of VR. Despite numerous literature reviews and meta-analyses corroborating the advantages of VR across a spectrum of educational settings (e.g., Luo et al., 2021; Merchant et al., 2014; Tilhou et al., 2020), these studies rarely differentiate among distinct educational levels. The notable exception is the work of Villena-Taranilla et al. (2022), which posits that positive learning outcomes via VR are consistent regardless of the educational level. Moreover, scholarly interest in the pedagogical applications of VR in early childhood settings can be traced to the advent of the technology. Pioneering initiatives such as the NICE project (Johnson et al., 1998) allowed children aged six to ten to collaboratively interact within virtual ecosystems, signaling early recognition of VR's potential in education. Similarly, Gabrielli et al. (2000) designed a dVR application that simulated a virtual farm to examine the development of spatial cognition in six-year-old students. Their findings suggest that VR not only enhances spatial abilities and representation in young learners but also fosters their enthusiasm for pursuing novel forms of play and computer interaction.

The implementation of VR) has been shown to exert a favorable influence on the promotion of healthy and environmentally sustainable dietary habits among children aged six to 13 years, as evidenced by the findings of Smit et al. (2021). Furthermore, there appears to be an enhancement in the children's awareness of the consequences their actions have on personal health and the environment. Kusuma et al. (2018) reported that the use of a VR application significantly improved learning outcomes among kindergarten students in lessons pertaining to various fish species. The immersive nature of VR also made the educational experience more engaging and enjoyable compared to traditional teaching methods.

Extending beyond environmental education, Passig and Schwartz (2014) have proven that VR tools are effective in facilitating kindergarten students' comprehension of concepts such as proportions and analogies. Another compelling application of VR was demonstrated in a study by Bakr et al. (2018), in which children ranging from three to six years of age were actively engaged in the design process of their school, contributing to decisions regarding building layout and wall colors. The immersive experience provided by VR led to heightened interaction and engagement with the virtual environment, almost paralleling real-world interactions. The study concluded that VR serves as a valuable visualization tool.

The influence of VR on young learners extends to their perception of reality, as Schmitz et al. (2020) observed that VR impacts children's discernment between possible and improbable events. From a neurological perspective, VR not only enhances learning but also appears to contribute positively to the overall construction of an educational framework within students' minds. Lorusso et al. (2020) noted that virtual activities are easily comprehensible, enjoyable, and foster strategic behavior, interaction, and collaboration, all with minimal need for instructor intervention. Judging by the results, the authors suggested that VR holds the potential to become a key tool to promote the cognitive and social development of infants and to improve the daily educational process of kindergartens.

In light of the above findings, it can be supported that VR technology possesses the potential to become an instrumental tool in fostering cognitive and social development in young children. Moreover, it promises to enhance the daily educational processes in kindergartens, revolutionizing the standard pedagogical approaches with its interactive and immersive capabilities. The incorporation of VR in early childhood education is poised to significantly contribute to the enrichment of learning experiences and outcomes.

3. Method

Reflecting on the research presented in the preceding sections, it can be concluded that the study of the natural environment is a crucial learning subject at the kindergarten level. Furthermore, the use of dVR across varied learning domains offers an intriguing educational potential. However, it has to be acknowledged that the pertinent research at a kindergarten level remains somewhat unsystematic. In light of these observations, it was deemed necessary to conduct a study, aimed at examining whether dVR has a quantifiable impact on the learning of very young students, particularly in relation to concepts tied to the study of the natural environment. The inquiry also extended to whether the results generated through dVR use are superior or inferior compared to those obtained through conventional teaching tools/materials.

Moreover, it was considered essential to scrutinize students' learning satisfaction levels in their interactions with a dVR application. This aspect is noteworthy as learner satisfaction is an important predictor of learning outcomes (Li & Tsai, 2020). From the numerous factors that influence learning satisfaction, ease of use, enjoyment, and motivation were selected. Additionally, the element of immersion was also considered, given its significance in VR. Thus, with these considerations in mind, the following hypotheses were examined:

- H1. The use of a dVR application results in a better understanding of concepts related to the study of the natural environment, compared to conventional teaching materials. Students′ prior knowledge and gender affect the results.
- H2a-e. Students believe that dVR application compared to conventional teaching materials: (a) offer a more enjoyable learning experience, (b) are more immersive, (c) are easier to use, and (d) are more motivating. Students′ gender has an effect on the above factors.
- H3a-e. Enjoyment (a), immersion (b), ease of use (c), and motivation (d) will have an effect on the learning outcomes of both tools.

A within-subjects research design incorporating two treatments/conditions was employed. This strategy involved the same participants been taught using two distinct tools, namely dVR and traditional instructional materials. The rationale for adopting this research design included: (i) the ability to employ smaller sample sizes without undermining the results′ reliability, (ii) the circumvention of potential confounding effects arising from individual differences, given that the treatments involved the same participants, and (iii) the participants serving as their own controls, renders the variance among groups irrelevant (Keren, 2014).

However, to mitigate potential downsides of the within-subjects design, several precautions were implemented. To counter the fatigue effect, which might manifest as students losing interest due to exposure to previous lessons during their school day, all sessions were consistently scheduled on the same weekdays and during the same teaching periods. To offset the carryover and context effects, the use of the tools was randomized, and students were kept uninformed about which tool they would be using in each session. The most significant limitation of this design is the practice effect. This implies that if the content remains constant across the treatments, the exposure during the initial treatment would inevitably influence the learning outcomes of the subsequent session, as the students would have already acquired some knowledge. To navigate this challenge, the content used in the two conditions was not identical, but it was comparable/equivalent. This issue will receive further attention in section ″3.2 Materials and apparatus.″ Furthermore, to boost the reliability of the data, it was opted to conduct four sessions for each condition.

3.1. Sample and duration

An a priori power analysis was conducted with the aim of estimating the required sample size for the study. In this process, G*Power was utilized, a statistical power analysis program, to ensure that the sample size allowed for more than sufficient power to detect medium-sized effects in the data. The analysis was grounded on the guidelines proposed by Cohen (2013), for within-subjects designs featuring two conditions. Given an fCohen of 0.25, a power of 0.90, and a probability error of 0.05, the required sample size should fall somewhere between 28 and 61 participants, contingent upon the correlation among the repeated measures. A correlation range of 0.3 to 0.7 for this calculation was applied, noting that the sample size for the default correlation value of 0.5 would stand at 44 participants. With these calculations in mind, a total of 52 students were successfully recruited from kindergartens in the city (name omitted for review). However, due to unforeseen absences during one or more sessions, the final sample size was reduced to 45 students. It should be noted that all participants were proficient in computer use, knowledgeable in both keyboard and mouse operations (skills that were required minimally for controlling the dVR application. Moreover, they were not taught subjects related to the study's theme, as presented in a coming section.

The duration of the project encompassed a total of eight sessions, four for each treatment, with each session lasting for an hour and a half. It has to be noted that the project's objectives, procedures, and instruments underwent a rigorous review by the Department's ethical committee and its approval was granted. Additionally, considering the involvement of minor participants in the study, the written consent from the students' parents or legal guardians was obtained, thereby securing the research's ethical integrity.

3.2. Materials

The initial step in developing the materials for the two treatments involved the selection of the learning content. As the general theme was the study of the natural environment, it was decided to focus on the year's seasons. Indeed, the study of seasons is an integral component of a kindergarten's curriculum. It assists children in comprehending concepts related to time and sequence. It also heightens their awareness of natural events and the order in which they occur (Bracken & Crawford, 2010). It is also evident that very young students often grapple with understanding how seasons occur. In addition to this, they harbor a number of misconceptions pertaining to seasons, which include the belief that seasons exist primarily for the production of fruits and vegetables, that the sun orbits the Earth, and that the Earth-side facing the sun experiences summer while the other side endures winter. They also inaccurately believe that the seasons are caused by clouds blocking the sun and that the Earth's proximity to the sun changes with the seasons, being closer during the summer and farther during the winter (Küçüközer & Bostan, 2010).

For all seasons, it was decided to present facts and information pertaining to the natural environment during a given season, including weather patterns, plants, fruits and vegetables, animal and human behaviors, as well as major holidays and events associated with each season. In the case of the conventional materials treatment, winter and spring were chosen. Conversely, for the dVR treatment, summer and autumn were selected. Regardless of the treatment, the presentation of a season lasted for two sessions.

The materials for the conventional treatment, included videos, paintings, images, reference cards, and songs related to the selected seasons. These were carefully selected to ensure relevance to the topics under discussion for each season. The selected paintings and images were displayed on the classroom walls to serve as constant visual reminders, while the students were engaged with the videos and music using tablets that were provided to them. It has to be noted that the same images, paintings, videos, and songs were used in the dVR application.

For the development of the dVR application OpenSimulator was used. It is a multi-platform, multi-user 3D application server, with the capacity to construct a virtual environment that can be accessed through various clients on multiple protocols. Two islands were created, representing the "kingdoms" of summer and autumn (Figure 1). Upon arrival, the user was greeted by a fairy, a non-player character (NPC), meaning that it was a computer-controlled character programmed to follow certain paths, present information, and respond to users' input. This fairy served as a guide, providing the users with their location, directions, and the recommended route to follow. During their exploration of these islands, users encountered an additional eight NPCs including the King of Autumn and the Queen of Summer along with six princes and princesses. Each of these NPCs represented a specific month within a season and delivered facts and information related to that season. In order to assess the user's comprehension, some NPCs posed questions about the information they have learned thus far. Furthermore, the user's journey around the island was enriched with videos, images, paintings, fairy tales, and songs. It is important to note that the development of the dVR application incorporated several of Mayer's multimedia design principles (Mayer & Fiorella, 2014). For instance, in line with the multimedia, modality, and redundancy principles, text usage was minimized in favor of delivering information through spoken words and images/videos. Adhering to the segmenting principle, the seasonal information was divided into several pieces and disseminated by various NPCs, giving students control over the pace at which they received each piece of information. Finally, in order to satisfy the coherence principle, irrelevant information was discarded and emphasis was placed on maintaining simplicity in the presentation of relevant information.

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Figure 1. Screenshots from the dVR application

3.3. Instruments

For the purpose of data collection, eight evaluation tests (two for each season), one pre-test, as well as structured interviews were employed. The pre-test was administered prion to the project's beginning in order to check what students already knew about seasons. The rest of the tests were administered at the end of the teaching of a session. All tests, with exception of the pre-test which comprised of 20 questions, comprised of ten questions, arranged in an ascending order of difficulty and were designed to assess if the students had successfully acquired declarative knowledge. The format of the questions was a matter of consideration, keeping in mind (i) the tender age of the respondents and their inability to read and (ii) the need not to compromise the validity of the data. Consequently, all questions were presented using concise text and an array of explanatory images. This is because when it comes to kindergarten students, the comprehensibility of a question and the accuracy of an answer are significantly enhanced when visual aids are used (Semel et al., 2004). The question types covered image matching, selection of appropriate images, true-false and yes-no questions, given that comprehension in this age group is primarily limited to brief words and phrases (MacGinitie et al., 2000). In order to eschew oversimplification, the tests were designed such that most questions featured more than one correct answer, and, in some instances, no correct answer

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at all. The tests were conducted on an individual basis, with teachers providing necessary assistance by reading out the questions and elucidating the pictures if needed. No predefined time limit was imposed for the completion of the tests, given the age of the participants and the consequent impracticality of strict time constraints. However, it was observed that no test extended beyond a ten-minute duration.

In lieu of questionnaires, structured interviews were utilized to capture students' perspectives on the two instructional tools. The questions were derived from the Learning Experience Questionnaire, a validated modular scale designed for investigating user viewpoints on educational software (Fokides et al., 2019). Although the scale normally examines 12 factors, for the purpose of this study, four were chosen: motivation (three items), enjoyment (six items), ease of use (six items), and immersion (four items). Responses were solicited using a five-point Likert-like scale, ranging from 1 (signifying total disagreement or very little) to 5 (representing total agreement or very much). To cater to the age of the children, instead of numbers, emoticons were utilized (a sad face for very little, less sad for little, and so forth). Along with this, the content of the questions was modified using the same principles as the evaluation tests in order to enhance students' comprehension. This involved using short texts that were directly aligned with the inquiries. The process of completion took approximately ten minutes and was conducted in a similar manner to the evaluation tests, individually in an interview format. The content of the questions had to be read out to the young students to ensure they understood both the questions and the emoticon meanings. Each student was given the opportunity to respond to the questionnaire twice, once for each tool.

3.4. Procedure

The teaching method to be pursued underwent careful consideration. Fowler (2015) put forth a compelling framework for learning within 3D virtual environments that could be tailored to meet the requirements of kindergarten instruction. This framework harnessed the notion of pedagogical immersion to map learning stages onto distinct types of learning environments. It effectively reduces the complexity of learning in VR to three fundamental stages: conceptualization, construction, and dialogue. In the conceptualization stage, learners are introduced to new facts, concepts, and theories. They navigate through a virtual space specifically designed to embody these concepts, interact with others, and exchange viewpoints. The construction stage explains the facts and concepts and permits the testing and application of the newly introduced theories and concepts. It also facilitates problem-solving and skill acquisition. Here, students delve deeper into the concepts that have just been introduced. They explore, ask questions, and perform actions related to the new concepts while receiving feedback. This stage necessitates a high degree of realism, with experiential learning being a cornerstone. During the dialogue stage, students engage in discourse and critically reflect on their acquired knowledge. They can assess their evolving understanding through interactions or discussions with their peers, thereby recognizing the broader social context of their learning. Students can self-evaluate, reflect, discuss, and exchange ideas. This dynamic process culminates in the consolidation of the new concept or knowledge and its integration with existing experiences and the real environment. For the purposes of this study, the decision was made to adhere to the aforementioned framework in both the dVR and the conventional materials conditions (with some adaptations). The procedure that was followed is articulated in the subsequent paragraphs.

During a preparatory teaching session (before the project's commencement), the participating students were given detailed instructions on the use of the dVR application. For that matter, another application was developed, bearing no relation to the learning topic, to serve as a familiarization tool. The students were given the liberty to freely navigate this application in order to understand its control mechanism. It is important to underscore that no significant issues were encountered, as the control of the application was largely dependent on the use of the arrow keys and the mouse (a feature similar to the main application). Furthermore, the students were already proficient in the use of tablets and mobile phones, thereby facilitating a smooth transition.

Students were divided into groups of three and each group was provided with a computer (Figure 2). Every student in the group was given a 20-minute session to control the avatar and make decisions about their navigation path. The other two students in the group, under the guidance of the teacher, interacted with the student controlling the application. They provided directions on where to go and what to search. It was observed that in most groups, students enthusiastically discussed their observations and exchanged opinions. This setup ensured that each student had a chance to control the application.

In the first stage, that of conceptualization, students were granted the freedom to navigate the virtual environment, guided by the NPC that symbolized the specific season under investigation. This allowed them to familiarize themselves with the various facets of the season at hand. Progressing to the construction phase, students are led to the NPC's residence, metaphorically referred to as the "palace." Here, they were exposed to a variety of multimedia content, including videos, images, and songs, which aimed to consolidate the understanding they gained during the conceptualization phase. These resources covered a broad range of season-related themes such as the nature, weather, fruits, and vegetables, as well as peoples' habits during this period. Concurrently, the NPC provideed details about the season, offering explanations and expanding upon the content that the students were engaged with. The objective of this stage was to convey a thorough understanding of the facts and underlying concepts associated with the season under study. The final phase (dialogue stage), promoted peer collaboration within student groups. Students were encouraged to engage in discussions and address questions put forth by the NPCs to assess the knowledge they have acquired. The primary goal here is to reinforce newly acquired knowledge and facilitate its integration with their pre-existing understanding.

As for the conventional materials treatment, during the conceptualization stage, students listened to songs, watched videos (both using the tablets that were provided to them), and reviewed images and paintings related to the season of study (Figure 2). Following this, during the construction stage, teachers elucidate the content that the students have viewed and listened to, made use of reference cards, and guided students in creating paintings that depicted themes associated with the relevant season. The concluding dialogue stage brought students together in a classroom assembly, promoted discussion, exchange of ideas, and interpretation of their artwork. They further expounded on their understanding by responding to queries from the teachers.

Figure 2. Photos from the project's implementation

4. Results

Out of the 45 participating students, 23 were girls. Students' tests were graded on a ten-point scale. Two new variables were calculated representing the average of students' scores in the tests of each tool. In addition, as emoticons were used for students' responses in the questionnaires, numerical values were assigned to them, depending on the emoticon's image (e.g., 1 for the very sad emoticon and 5 for the very happy one). The resulting data were inserted into SPSS 29 for conducting all the analyses presented below. Cronbach's α was used for assessing the internal consistency of the questionnaires. Given that the α values (either in the factors or in the questionnaires as a whole) were above the.70 threshold which is generally used as a rule of thumb (Taber, 2018), it was concluded that their internal consistency was satisfactory. Following that, ten variables were calculated (five for each tool) representing the average score per factor, per student. Table 1 presents descriptive statistics for the study's variables.

Variable	**Boys** (*n* = 22)		**Girls** (*n* = 23)					
	M	*SD*	*M*	*SD*				
Pre-test	6.27	1.52	6.04	2.42				
	Conventional materials				**dVR**			
Variable	**Boys** (*n* = 22)		**Girls** (*n* = 23)		**Boys** (*n* = 22)		**Girls** (*n* = 23)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Evaluation tests	7.05	0.89	7.02	1.34	8.91	1.01	8.83	1.01
Enjoyment	3.19	0.91	3.18	0.84	3.90	0.53	3.69	0.68
Immersion	2.99	0.98	2.91	0.80	3.85	0.79	3.15	0.87
Ease of use	2.98	0.68	2.78	0.78	3.77	0.76	2.91	1.05
Motivation	3.21	1.08	2.86	1.02	4.11	0.59	3.70	0.97

Table 1. Descriptive statistics for the study's variables

For analyzing the results in the evaluation tests and for examining H1, a within-subjects Analysis of Covariance (ANCOVA) was conducted, as the goal was to examine whether there were differences in the learning outcomes of the two tools, after controlling for students' prior knowledge. The results in the pre-tests served as a covariate. In addition, gender was used as a between-subjects factor, because it was considered interesting to examine whether there were differences in the results between boys and girls. The data were fairly normally distributed as indicated by their skewness values. Moreover, no issues were noted regarding the assumption of the variables' homogeneity of variance (assessed by conducting Levene's Tests of Equality of Error Variances) and the equality of the covariance matrices of the groups (assessed by conducting Box's Tests of Equality of Covariance Matrices). Please note that Mauchly's Test of Sphericity could not be conducted, as there were only two treatments/tools.

Table 2 presents the results of the ANCOVA. The effect of the pre-tests on the averaged scores of the evaluation tests was significant [$F(1, 42) = 26.75$, $p < .001$], meaning that students who achieved high scores in the pre-test also achieved high scores in the evaluation tests of both tools. On the other hand, gender did not have an effect [$F(1, 42) = 0.001$, $p = .974$]. There were significant differences in the learning outcomes produced by the two tools and the effect size was large [$F(1, 42) = 9.95$, $p = .003$, $\eta 2p = 0.192$]. Then again, there was no interaction effect between the evaluation tests and the pre-tests [$F(1, 42) = 0.10$, $p = .757$], as well as between the evaluation tests and gender [$F(1, 42) = 0.02$, $p = .867$]. This suggests that students' prior knowledge and their gender did not have a differential/moderating effect on the within-subjects variable (performance in the evaluation tests) across its different levels (conventional materials and dVR application).

Source	*SS*	*df*	*MS*	*F*	*p*	η_p^2
Between-Subjects						
Pre-test	24.35	1	24.35	26.75	<.001	.389 (very large)
Gender	0.001	1	0.001	0.001	.974	.000 (small)
Error	38.24	42	0.91			
Within-subjects						
Evaluation tests	8.68	1	8.68	9.95	.003	.192 (large)
Pre-test*Evaluation tests	0.09	1	0.09	0.10	.757	.002 (small)
Gender*Evaluation tests	0.03	1	0.03	0.02	.867	.001 (small)
Error	36.65	42	0.87			

Table 2. The results of the repeated measures ANCOVA test for the evaluation tests

Notes. SS = sum of squares; MS = mean square; ηp2 = partial eta squared effect size; for the interpretation of the effect sizes (in parentheses), the following cutoff values were used:.010-small effect size,.059-medium effect size,.138 or higher-large effect size (Cohen, 2013)

For examining the results in the questionnaires (H2a-d), four ANOVA tests were conducted (equal to the number of factors), using gender as a between-subjects factor, because it was considered interesting to examine gender's role. As with the ANCOVA test, there were no issues regarding the assumptions for conducting these tests. As far as enjoyment is concerned, the effect of gender on the averaged scores of enjoyment was not significant [$F(1, 43) = 0.61$, $p = .441$], indicating that, in both tools, boys and girls rated

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enjoyment similarly (Table 3). There were significant differences between the two tools regarding enjoyment and the effect size was very large [F(1, 43) = 12.21, p =.001, η2p = 0.221]. There was no interaction effect between gender and enjoyment [F(1, 43) = 0.35, p =.558], suggesting that students' gender did not have a differential effect on enjoyment across its different levels (conventional materials and dVR application) (Table 3).

Source	*SS*	*df*	*MS*	*F*	*p*	η_p^2
Between-Subjects						
Gender	0.28	1	0.28	0.61	.441	.014 (small)
Error	19.57	43	0.46			
Within-subjects						
Enjoyment	8.278	1	8.28	12.21	.001	.221 (very large)
Gender*Enjoyment	0.236	1	0.24	0.35	.558	.008 (small)
Error	29.144	43	0.68			

Table 3. The results of the repeated measures ANOVA test for Enjoyment

Gender had a significant effect on the averaged scores of immersion [F(1, 43) = 5.26, p =.027, η2p = 0.109]; boys rated immersion differently than girls (boys gave higher scores for this factor in both tools, see Table 4). There were significant differences between the two tools regarding immersion and the effect size was large [F(1, 43) = 8.05, p =.007, η2p = 0.158]. There was no interaction effect between gender and immersion [F(1, 43) = 2.58, p =.115], suggesting that gender did not have a differential effect on immersion across its different levels (Table 4).

Source	*SS*	*df*	*MS*	*F*	*p*	η_p^2
Between-Subjects						
Gender	3.38	1	3.38	5.26	.027	.109 (medium to large)
Error	27.67	43	0.64			
Within-subjects						
Immersion	6.84	1	6.84	8.05	.007	.158 (large)
Gender*Immersion	2.19	1	2.19	2.58	.115	.057 (medium)
Error	36.51	43	0.85			

Table 4. The results of the repeated measures ANOVA test for Immersion

The effect of gender on the averaged scores of ease of use was significant [F(1, 43) = 10.81, p =.002, $\eta 2p$ = 0.201], meaning that, in both tools, boys rated ease of use differently than girls (boys gave higher scores for this factor in both tools, see Table 5). There were significant differences between the two tools regarding ease of use and the effect size was medium to large [F(1, 43) = 5.96, p =.019, $\eta 2p$ = 0.122]. There was no interaction effect between gender and ease of use [F(1, 43) = 3.06, p =.089], suggesting that gender did not have a differential effect on ease of use across its different levels (Table 5).

Source	*SS*	*df*	*MS*	*F*	*p*	η_p^2
Between-Subjects						
Gender	6.30	1	6.30	10.81	.002	.201 (very large)
Error	25.07	43	0.58			
Within-subjects						
Ease of use	4.77	1	4.77	5.96	.019	.122 (medium to large)
Gender*Ease of use	2.45	1	2.45	3.06	.087	.066 (medium)
Error	34.44	43	0.80			

Table 5. The results of the repeated measures ANOVA test for Ease of use

The effect of gender on the averaged scores of motivation was not significant [F(1, 43) = 3.59, p =.065], meaning that, in both tools, both boys and girls rated motivation similarly (Table 6). There were significant differences between the two tools regarding ease of use and the effect size was very large [F(1, 43) = 20.31, p <.001, $\eta 2p$ = 0.321]. There was no interaction effect between gender and motivation [F(1, 43) = 0.02, p =.890], suggesting that gender did not have a differential effect on motivation across its different levels (Table 6).

Source	*SS*	*df*	*MS*	*F*	*p*	η_p^2
Between-Subjects						
Gender	3.31	1	3.31	3.59	.065	.077 (medium)
Error	39.68	43	0.92			
Within-subjects						
Motivation	16.92	1	16.92	20.31	<.001	.321 (very large)
Gender*Motivation	0.02	1	0.02	0.02	.890	.000 (small)
Error	35.81	43	0.83			

Table 6. The results of the repeated measures ANOVA test for Motivation

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Finally, two multiple linear regression analyses were run (using the Enter method), for examining which factors had an impact on the learning outcomes the two tools produced (H3a-d). As presented in Table 7, none of them played a statistically significant role in the conventional materials treatment. On the other hand, immersion (t = 2.51, p =.016) and enjoyment (t = 2.94, p =.006), had a positive impact on students' learning outcomes when they used the the dVR application.

Conventional materials	Model summary	$F(5, 39) = 0.61$, $p = .692$, $R = .270$, $R^2 = .073$				
	Factors	***B***	***SE B***	***β***	***t***	***p***
	Enjoyment	-.55	.40	-.43	-1.37	.179
	Effectiveness	.28	.39	.21	0.71	.480
	Immersion	.27	.27	.21	0.98	.333
	Ease of use	-.12	.35	-.08	-0.35	.732
	Motivation	.27	.25	.25	1.08	.288
dVR	Model summary	$F(5, 39) = 7.08$, $p < .001$, $R = .690$, $R^2 = .476$				
	Factors	***B***	***SE B***	***β***	***t***	***p***
	Enjoyment	.66	.23	.41	2.94	.006
	Effectiveness	.03	.21	.02	0.16	.873
	Immersion	.39	.15	.35	2.51	.016
	Ease of use	.10	.14	.11	0.75	.457
	Motivation	-.08	.16	-.07	-0.51	.613

Table 7. The results of the regression analyses

Notes. B = unstandardized beta coefficient, SE B = standard errors for B, β = standardized error coefficient

Summarizing the results presented above and for confirming or rejecting the research hypotheses that were set, the following can be noted.

- H1. This hypothesis was confirmed regarding learning outcomes; the results from the use of a dVR application were better compared to conventional materials. On the other hand, students' prior knowledge and gender did not affect the differences between the two tools.
- H2a-d. These hypotheses were confirmed. Students considered that the dVR application (a) offered a more enjoyable learning experience, (b) were more immersive, (c) were easier to use, and (d) motivated them to learn more compared to conventional materials. Yet, in all the above factors, students' gender did not play a role in the differences between the two tools.
- H3a-d. As far as the conventional materials treatment is concerned, these hypotheses were rejected, because none of the factors affected the learning outcomes. As far as the dVR application treatment is

concerned, two out of the four hypotheses were confirmed. That is because only students' enjoyment and immersion affected learning outcomes.

5. Discussion

5.1. Comments on the learning outcomes

As previously discussed, the central objective of this research was to explore the pedagogical application of VR within kindergarten settings, particularly within the domain of the study of the natural environment. The underlying assumption was that VR utilization would elicit more substantive learning outcomes compared to conventional educational resources. The analysis of the data from the evaluation tests substantiated this hypothesis, aligning with a substantial body of scholarly work examining the nexus between VR's instructional utility and the realm of early childhood education (Bakr et al., 2018; Kusuma et al., 2018; Lorusso et al., 2018; Passig & Schwartz, 2014; Schmitz et al., 2020; Smit et al., 2021). Therefore, it is crucial to consider the reasons leading to this outcome.

The research by Siu-Yung Jong et al. (2020) attributed the enhancement of learning outcomes to specific attributes inherent in VR applications, namely interaction, the capacity for exploration, and the affordances for explanation and reflection. These integral components were adeptly incorporated within the deployed dVR application in this study. Furthermore, the heightened perception and understanding of educational content facilitated by VR's immersive qualities far exceed what could be achieved through static mediums such as textbooks, reference cards, or other conventional pedagogical tools (Blascovich et al., 2002).

Concerning the learning context, the impact of VR on the educational process appears to be subject-dependent. Several studies (e.g., Checa & Bustillo, 2020; Jensen & Konradsen, 2018) have emphasized this technology's overarching transformative potential in the educational landscape. However, the efficacy of VR is more pronounced in fields like mathematics and the sciences (Kim & Ke, 2017), particularly in areas that prioritize declarative knowledge and procedural learning (Radianti et al., 2020). These insights coherently elucidate the observed learning advancements in the student cohort under investigation, given that the instructional content was geared towards the examination of the natural environment.

The structure and scenario of the dVR application, alongside its presentation methodology, harbored numerous game-like characteristics that bore a resemblance to video games. This observation is pivotal, as Kafai (1996) has elucidated within the realm of video games, such attributes furnish a conduit through which children, particularly those of tender age, can embark on exploratory learning journeys. The video-game-like nature of the application not only facilitated immersive experiences that can stir emotions but also bolstered the significance of the experience itself. This, in turn, enhanced the likelihood of recollection of the experience and, more critically, the assimilation of knowledge therein.

Further emphasizing the pedagogical potency of game-based learning, Shute et al. (2015) posited that engagement with educational games can heighten children's learning achievements, catalyzing a transformative effect on their cognitive processes, attitudes, socio-emotional comportment, and skill sets. Young learners are known to internalize information conveyed through play. The ensuing iterative practice within the game framework serves to fortify their grasp of declarative knowledge, thereby augmenting their educational performance (Hsiao & Chen, 2016).

Moreover, the dVR's game-like elements provided a foundation to apply several pedagogical principles delineated by Gee (2003), principles that are instrumental in the scaffolding of knowledge. For instance, the dVR environment fostered active and critical learning, in line with the active critical learning principle. It empowered students with the agency to make decisions and offered a multitude of pathways to navigate and engage with the learning materials (multiple routes principle). Furthermore, the virtual environment afforded learners the capacity to synthesize meaning and knowledge utilizing diverse modalities, such as images, auditory cues, music, video, and interactive elements, resonating with the multimodal principle.

As a result of the above, the learning outcomes achieved when using the dVR application were superior, a testament to its efficacy in enabling children to cultivate intuitive knowledge.

5.2. Comments on the factors examined in the questionnaires and their influence on the learning outcomes

On the basis of the study's findings, immersion had a direct impact on learning outcomes in the dVR treatment. As presented in a previous section, immersion refers to a system's capacity to deliver a virtual environment that bestows upon users a profound sense of realism, as noted by Atsikpasi and Fokides (2022). An aspect intimately tied to immersion is the concept of presence, which is the compelling sensation of existing within the virtual milieu. Both immersion and presence catalyze cognitive and affective engagement in the virtual domain, which invariably enhances the comprehension of educational content (Lindgren et al., 2016; Fokides & Atsikpasi, 2022; Maas & Hughes, 2020). A consensus arises from various scholarly inquiries, suggesting that the depth of immersion in VR systems is directly proportional to the amplification of educational outcomes (Alhalabi, 2016; Passig et al., 2016; Villena-Taranilla et al., 2022; Webster, 2016). Yet, the data analysis revealed that immersion exerts a significant influence on learning, which denotes that even systems with lower levels of immersion have the potential to affect learning. This

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observation lends partial corroboration to the findings of Makransky et al. (2019), wherein students experiencing a high-immersion science lab simulation reported an elevated sense of presence but demonstrated suboptimal learning compared to their engagement with a lower-immersion variant of the same simulation. In fact, what the authors suggested that a heightened sense of presence can be inherently engaging, it may also introduce cognitive overload and distraction. This could inadvertently diminish the learner's capacity to assimilate and retain new information, thereby impeding the formation of desired learning outcomes.

Enjoyment was the second factor that impacted learning outcomes when students used the dVR application. moreover, students enjoyed more the dVR application than the conventional material. Numerous scholars have underscored the pivotal role that enjoyment plays in the successful integration of VR into educational settings (Abichandani et al., 2019; Butt et al., 2018; Caro et al., 2018). Shernoff et al. (2003) posited that a lack of enjoyment is a principal factor that inhibits young learners from realizing their full academic potential. Additionally, they have linked a sense of boredom during the learning process to the emergence of conflicts amongst learners. Building upon these findings, a recent study by Lorusso et al. (2020) has further elucidated the relationship between enjoyment and educational outcomes. The research also indicated a positive correlation between fun and student participation, suggesting that the engaging nature of an activity can significantly enhance a child's involvement, as well as foster interaction and cooperation. In the study at hand, children shared the dVR application (as they worked in groups of three), developing an environment conducive to interaction, collaboration, and mutual assistance. This cooperative dynamic it is probable to amplified the childrens' enjoyment derived from the educational activity. Moreover, the Lorusso et al. (2020) study suggested that the association between increased enjoyment and enhanced learning may be particularly strong at this developmental stage. There is a compelling implication that young children's learning experiences are heightened when elements of fun are integrated, as their age may render them more receptive to enjoyment-facilitated educational approaches. In summary, the extant literature robustly supports the notion that enjoyment is a critical component in educational VR applications, with significant implications for participation, engagement, and social dynamics among young learners. The potential of VR to transform educational experiences through enjoyment merits further exploration, particularly as it relates to optimizing learning outcomes in early childhood education.

Based on the findings of this study, dVR successfully motivated students to engage with the content more than conventional teaching materials. This observation is consistent with a body of prior research suggesting that interactive and experiential activities offered by VR significantly enhance learner motivation (e.g., Ewert et al., 2013; Yeh & Lan, 2018; Zavalani & Spahiu, 2012). Furthermore, the literature provides evidence that 3D applications have a stronger motivational impact on learners compared to 2D applications, as demonstrated by Limniou et al. (2008). The engaging, game-like characteristics inherent to VR technology are also known contributors to increased motivation, according to research by Cooke-Plagwitz (2008), and Sharma et al. (2013). These dynamic elements of VR may significantly captivate students, leading to greater investment in the learning process. Yildirim et al. (2018) have proposed that virtual learning environments amplify student motivation by affording opportunities for self-directed learning, a key component of modern educational paradigms. Additionally, the aspect of enjoyment within VR settings has been highlighted as a motivating factor, a point made by Chandra et al. (2009) in their work. Nevertheless, it is noteworthy that the link between motivation and actual learning outcomes, which has been well-established in prior studies (e.g., Atsikpasi & Fokides, 2022; Fokides & Zampouli, 2017), was not corroborated in the context of this investigation. This absence of a clear connection may either be a situational anomaly or suggest that the dVR application in question did not sufficiently motivate students to effect a measurable impact on their learning outcomes. In this respect, further research is warranted to explore this discrepancy and to ascertain whether specific attributes of the dVR application could be refined to enhance its educational efficacy.

In their work, Lee et al. (2010) posited that the efficacy of VR as a tool for enhancing learning outcomes is heavily predicated on its user-friendliness. This assertion was echoed by Asad et al. (2022), who argued that the ease of use of VR is paramount for its effective implementation and subsequent augmentation of experiential learning processes. Contrary to these studies, the present research did not establish a direct correlation between the ease of use of and the enhancement of learning. Furthermore, the findings from this investigation indicate that the dVR application was perceived as easier to use than conventional materials. This observation could ostensibly lend credence to the integration of VR into early childhood education. However, one must approach this conclusion with a degree of caution. It appears counterintuitive that children between the ages of four and six would find a VR application simpler to navigate than conventional learning tools with which they have daily interaction, despite their existing familiarity with digital devices such as tablets and smartphones. The Hawthorne effect, as detailed by Zantua (2017), may offer a viable explanation for this phenomenon. This effect elucidates a scenario where individuals alter their behavior in response to their cognizance of being under observation. Nevertheless, it is equally plausible that the students genuinely found the dVR application to be easy to use, as was similarly reported in other studies. For instance, Yang et al. (2010) documented that students, although slightly older

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than those in the current study, perceived VR-based assignments as straightforward tasks akin to playing a game.

5.3. Implications for research and practice

This research makes a contribution to the field of early childhood education by exploring the application of dVR in kindergarten settings. The contribution centers on three key areas: (i) evaluating the effectiveness of dVR applications in teaching young learners about the natural environment, a subject often overlooked for this age group, (ii) quantifying and contrasting the educational outcomes attained through dVR with those achieved using conventional learning materials, and (iii) assessing the influence of specific factors on learning outcomes. In this respect, the research has discernible implications for the ones involved in research, the software industry, and education. Notably, findings demonstrate that immersion and enjoyment in learning activities are substantial contributors to educational outcomes. These insights empower software developers to craft more engaging and immersive applications. Moreover, the collaboration between software developers and educators is encouraged to generate captivating and enjoyable activities that amplify these two critical factors. Contrarily, the anticipated correlation between motivation and learning was not observed in this study, challenging the widely recognized link between these elements. This unexpected result suggests the necessity for further research to elucidate the conditions under which motivation significantly influences learning outcomes.

Drawing from the evidence gathered, the integration of dVR applications into day-to-day kindergarten instruction emerges as a compelling proposition. However, successful implementation hinges on addressing two principal concerns. Firstly, the establishment of robust instructional frameworks is essential. This study proposed one such framework, but further investigation is warranted to identify potentially superior alternatives. Secondly, the duration of the sessions (running ninety minutes each) proved exhaustive and comprehensive, yet poses practical challenges in ordinary teaching environments by disrupting established routines and activity flows. To accommodate such innovative educational technology, it is imperative that education policymakers recognize and adapt the curricular structures and time allocations to better suit these teaching methods. This adaptation will ensure the seamless integration of dVR into kindergarten curricula, enabling educators to fully harness its potential without compromising the existing educational ecosystem.

5.4. Limitations and future work

This research encompasses certain constraints that warrant consideration. The primary limitation pertains to the sample size which, despite being statistically sufficient, might have benefited from enlargement to bolster the reliability of the findings. Similarly, the scope of the study could be expanded beyond the current number of sessions to achieve a more robust set of data. The curriculum content covered in the study was confined to a select number of concepts associated with the seasons of the year. This limitation raises questions about the potential performance of students on a broader range of subjects. Furthermore, the tender age of the kindergarten participants may cast doubt on the validity of both their performance on assessment tests and their responses to questionnaires, given their developmental stage.

These considerations should serve as a roadmap for subsequent investigations. Incorporating a broader spectrum of learning topics, augmenting sample sizes, and increasing the number of sessions are likely to yield more definitive proof regarding the pedagogical efficacy of dVR applications in early childhood education settings. Moreover, it would be prudent to delve into the perceptions held by students and educators towards this technology. Such an inquiry could extend to alternative pedagogical models that may prove superior in effectiveness. Comparative analyses that juxtapose the outcomes from dVR with those from other technological interventions would contribute valuable insights to the field. Lastly, the necessity for longitudinal studies cannot be overstated. Technological devices and applications are susceptible to the phenomenon known as the "wow effect," characterized by an initial surge of enthusiasm among students encountering a new technology for the first time, as noted by Kamstrup (2016). This effect can significantly influence study outcomes, though its impact typically wanes with time. Therefore, long-term research is imperative to discern the enduring educational impact of technologies like dVR, beyond the initial novelty phase.

6. Conclusion

The study at hand employed a dVR application with the aim of investigating its impact on the learning process of kindergarten students, particularly in topics centered around the seasons of the year. Upon comparison, the dVR application outperformed conventional teaching materials, yielding superior results in terms of student learning outcomes. Notably, the students not only enjoyed the learning process offered by the dVR application but were also found to be more engaged and motivated to learn. In addition to this, the application was deemed user-friendly, with students affirming its contribution to their learning process. In sum, despite its constraints, this study contributes to the relatively limited research pool examining the influence of dVR on kindergarten education. It recognizes the intriguing educational potential of this tool, although further research is certainly warranted. The future of this technology in education lies in its uncharted possibilities and in discerning effective strategies for its integration into regular teaching practices.

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