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The Use of Augmented Reality-Supported Activities in Environmental Education for Early Childhood: A Quasi-Experimental Study

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Abstract: This study aimed to examine the comprehension performance difference between children who participated in an augmented reality-based environmental education activity and those who participated in an activity based on coloring pages. The study involved 94 participants, including 47 in the experimental group and 47 in the control group. The researcher-developed Life Cycle Test, consisting of 9 open-ended questions on the water cycle, plant life cycle, and food chain, was used for data collection. In the first phase, children in both groups were asked questions from the Life Cycle Test, and their responses were recorded. Both groups then participated in a coloring activity, with the control group receiving explanations from the teacher about their colored pages and being asked the test questions. In contrast, the experimental group received explanations about using augmented reality applications and 3D visuals before answering the test questions. The pre-test data showed no significant difference in Life Cycle Test scores between the two groups. However, post-test results revealed that the augmented reality intervention better supported children's understanding than the explanations based on coloring pages. The study's findings suggest that augmented reality applications can be a powerful tool for enhancing children's understanding of environmental concepts in early childhood education.

Keywords: early childhood education; environmental education; life cycle; technology; augmented reality

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1. Introduction

Environmental education involves developing and supporting attitudes, values, awareness, knowledge, and skills that prepare people to take conscious action for the environment [1,2]. It is known that the foundations of attitudes towards the environment and the world are formed during early childhood [3]. Therefore, it is essential to initiate environmental education activities in the early years [4]. In this process, careful attention should be paid to the methods, techniques, and materials used to ensure the effectiveness and sustainability of the education provided.

Educational materials have been enriched, and technological materials have started to be used alongside traditional materials. As digital technology has become an integral part of the education system and is more integrated into society, it has significantly transformed learning and teaching opportunities [5]. The innovations brought by integrating technology into education are felt at all levels of education [6,7]. The inclusion of technology in educational environments is essential for children in the preschool period. In cases where the teachers or educators cannot implement out-of-school learning environments or natural experiences, transporting the real environment into the classroom environment with technological tools can be an effective alternative for environmental education. In this context, augmented reality applications, which are among the current technologies, can play an essential role in the educational process, as they can present real-world experiences in a safe learning environment [8–11].

Current technologies have the potential to provide new and additional contributions to activities to be carried out in early childhood and can enrich children's learning experi-

ences [12,13]. During this period, children who have not yet developed abstract thinking can accelerate their learning processes with the contributions of augmented reality technology in concretizing [14]. It should also be noted that environmental education is a broad concept that includes many topics. Observing some topics in nature may take a very long time, and could be difficult and dangerous for children. For this reason, alternative teaching tools are needed. When the relevant literature is examined, it is seen that augmented reality applications are used as an alternative teaching tool that can be used in environmental education at different learning levels [15–18]. This tool can support environmental education both inside and outside the classroom. Mei and Yanga [16] utilized an augmented reality application in their research to help students reach their defined goals and complete tasks associated with those goals. Students followed the geographical location guidance displayed on their devices' screens to reach predetermined target destinations. Before proceeding to the next destination, students were instructed to read the provided directions, check the environment for correct answers, and record these answers on their worksheets. Thus, environmental education was conducted through an augmented reality application that defined specific tasks for the students. The results indicated that this application could enhance students' environmental awareness [16]. Similarly, using augmented reality applications during field trips can contribute to children's learning [15]. Furthermore, an augmented reality application used in the classroom can increase a child's interest in environmental education [18]. Indeed, it has been concluded that environmental education facilitated by augmented reality applications positively impacts students' knowledge, attitudes, behaviors, and environmental awareness [17]. The current study emphasized the applicability of augmented reality technology in early childhood settings and classroom environments. This research assessed the understanding of the performance of children participating in a 3D augmented reality-based environmental education activity. Due to the limited number of studies in the literature regarding environmental education during early childhood using augmented reality applications and the need for examples of how these applications can be utilized in classroom settings, the present research is considered significant. Additionally, this current research may provide important insights for educators about augmented reality and lay the groundwork for new research on the use of technology in early childhood environmental education.

1.1. Literature Review

Environmental Education and Technology in Early Childhood

Education is an essential tool for individuals to evaluate life's positive and negative aspects and turn them into lessons to build a better future [19]. Due to the inadequate and constantly changing nature of environmental awareness, progress in education is crucial [20]. Environmental education is becoming increasingly critical in this context, especially for developing attitudes and behaviors towards the environment [21]. Environmental education can be defined as an action that aims to increase or develop knowledge and understanding of natural, physical, and human environments through an interdisciplinary approach, focusing on increasing the public's understanding and appreciation of nature and the environment [22–24]. Furthermore, this educational process aims to transform children into environmentally and socially conscious leaders who can make informed choices towards a sustainable lifestyle [25,26]. One of the aims of environmental education is to "change the child's relationship with nature" [27], that is, to help the child develop and maintain a "deep connection" with nature [28]. Of course, this education aims not only to learn what children need to learn about the environment, but also to ensure that children develop the right attitudes and positive relationships with the environment [29]. Therefore, environmental education is considered a priority area in early childhood education [30].

Early childhood experiential environmental learning is a crucial investment in the future, helping children develop respect and care for their environment [31]. Researchers and practitioners emphasize that early childhood is critical for developing environmental literacy [32–35]. Children's knowledge of and love for nature play a significant role in

developing positive attitudes and behaviors towards the environment [36,37]. It is stated that environmental education aimed at increasing children's understanding of and interest in nature is essential for children to exhibit positive behaviors towards the environment [38]. This education provides children with information about the importance of the environment and helps them understand the impact of their behavior on the environment. The educational materials used in this process are an effective tool for instilling environmental awareness in children. In this context, developing and using educational materials that can attract children's curiosity and interest in nature, instill environmental awareness, and strengthen their love of nature is essential. These materials can support children's exploration of nature, development of environmentally conscious behaviors, and learning to live in harmony with nature, thereby laying an essential foundation for a more sustainable world in the future.

The selection of methods in environmental education is crucial to ensure an effective and lasting learning process. In recent years, the increasing application of technology in education has brought about significant innovations [39], and these innovations have been felt at all levels of education [6,7]. Early childhood education is no exception, and the use of technological tools has also been on the rise in this period [40]; numerous technological applications can capture children's attention, trigger their curiosity, and facilitate enjoyable, lasting learning [41,42]. These applications create numerous valuable learning opportunities for children. Integrating digital and analog tools is exemplified as a way to create multimodal learning opportunities [43,44]. In this context, digital tools are seen as complementary to other resources, not competing with traditional methods [44]. The multimodal features of digital and analog applications can be particularly appealing for promoting multidimensional early childhood education [12,13,45,46]. Smart mobile devices offer students different learning styles [47] and different skills to engage in the educational process [48]. The role of technology in environmental education is not just significant, but is also exciting, as it opens new possibilities for engaging and educating children about the environment.

Environmental education aims to increase awareness about their environments and their environments' evolution and teach them skills that will enable them to understand better the environmental challenges affecting society [49]. In this process, there are many complex topics that students need to explore and understand. Therefore, environmental education can often be further facilitated with organized field trips or through technologies such as mobile devices and/or augmented reality applications [49]. For example, in a study on environmental pollution, one group received an education based on verbal narration and question-and-answer techniques, while the other group received an education based on tools such as computers, internet tools, and projectors [50]. The study results showed that technology-supported education increased children's knowledge about environmental pollution more effectively than traditional education. Incorporating technological tools like smart mobile devices into natural sciences education enhances the visualization of key phenomena and simplifies the comprehension of the concepts [51]. When the literature on the use of technology in environmental education is examined, it is seen that the studies in the literature report various advantages of technology. In studies where different technologies are used, it has been determined that technology-supported applications increase knowledge about environmental education [52–54], interest in environmental education [18], participation in the environmental education process [55], contribute to the development of positive attitudes [56,57], increase environmental awareness [58–60], and increase environmental literacy levels [61]. The number of studies focusing on the early childhood period is quite limited among these studies, highlighting the need for more research in this area. The current study addressed this gap by focusing on both the early childhood period and the usability of augmented reality technology, which was tested as a current technology in environmental studies.

1.2. Augmented Reality Studies in Early Childhood Education

The use of technology in education is rapidly advancing, and the range of digital technologies routinely used by young children has expanded considerably [40,62]. One critical and emerging digital technology in education has recently been augmented reality [63]. As a result of the integration of information and communication technologies into early childhood education programs, the use of augmented reality applications has become more widespread [64]. Augmented reality is a technology that enriches the real physical world with computer-generated 3D virtual objects with which users can interact through cameras, smartphones, or tablets [65]. It is a powerful and motivating tool that activates various sensory organs of children through the appropriate combination of audio, visual, and tactile elements [66]. Furthermore, augmented reality is a technology application that actively engages children in the process and facilitates learning by doing and experiencing [11,67–71]. Applications developed using augmented reality technology can simultaneously use 3D objects, texts, images, videos, and animations [72] to represent different parts of the world and place digital images in natural environments, making virtual objects appear as part of the natural world [73,74]. In this context, it is emphasized that augmented reality applications are suitable for education and can enrich learning [75]. However, there is a need for further research in this area to fully understand the potential and limitations of augmented reality in early childhood education.

In recent years, augmented reality has emerged as a crucial educational tool [76]. It is widely reported that augmented reality is extensively used to enhance learning processes in various educational domains [77]. Augmented reality applications that provide engaging and enjoyable learning opportunities by stimulating multiple senses are essential learning environments, especially for preschool children [78]. Augmented reality applications capture children's attention and interest in this period [63], create a sense of reality, and concretize the content, reassuring educators and researchers about their effectiveness. They facilitate the development of peer relationships, transform information into colorful visual forms, and offer an entertaining learning environment [79]. With these characteristics, the use of augmented reality technology in education stimulates the senses of young children with sound and images, provides a sense of touch [78], arouses their curiosity, draws their attention, and directs them to explore [80]. Additionally, augmented reality applications can contribute to children's interactions, help them achieve the highest potential learning outcomes, and develop lifelong beneficial skills [81]. Furthermore, Huang et al. [82] report that augmented reality-supported applications facilitate children's cognitive development, provide advanced access to complex visualizations, and strengthen educational effects.

Augmented reality applications have been utilized in various domains during early childhood. The extant literature on augmented reality-based research in early childhood education reveals investigations on preschool children's attitudes towards augmented reality-enhanced picture books [83]; creating mathematical learning experiences with augmented reality applications in preschool settings [84–86], using augmented reality as an instructional tool for music education [87], word memorization, and pronunciation practices in language education [80], foreign language learning [88,89], interactive educational games [90], and the development of literacy skills [91]. Additionally, augmented reality technology has been employed in environmental education [92–97]. Furthermore, the literature suggests that augmented reality can enhance preschool children's interest and engagement [98–105], motivation [106–111], attention [112–114], knowledge, literacy, satisfaction [66], and recall levels [76,115]; enrich vocabulary and contribute to learning to read [113]; foster creativity [66,102,106,112,113]; and develop spatial abilities [110,116]. Additionally, studies have shown that augmented reality can improve learning outcomes during dramatic play [100], shared book reading [108], art activities [82], and alphabet learning [117].

The positive data in the literature on studies based on augmented reality applications have led to the idea that this technology can also be used in environmental education. However, while augmented reality offers new possibilities for different educational areas,

it has not yet been fully explored in educational settings [75]. Although there is research conducted in early childhood, these studies seem to have been examined in a limited manner compared to those conducted at other educational levels [118]. Aydoğdu and Kelpšiene [78] note that while researchers are interested in applying augmented reality technology in schools and preschool education, there is a lack of scientific evidence about implementing augmented reality tools in early childhood education. Furthermore, it is stated that the least amount of research on augmented reality has been conducted in early childhood education [119]. Therefore, investigating the effects of augmented reality applications on children in this age group has also become important. In the present study, the usability of augmented reality technology in environmental education was tested in early childhood, which was seen as a critical developmental stage for contact with nature [120,121].

1.3. Current Study

The present study explored the potential of augmented reality-based activities in environmental education. The research question addressed in this study is as follows:

What was the difference in Life Cycle Test performance between children who participated in an augmented reality-based environmental education activity and children who participated in an environmental education activity based on coloring pages?

2. Materials and Methods

2.1. Participants

This study, a collaborative effort involving 94 participants, aimed to investigate the effectiveness of augmented reality in environmental education for young children. The participants, 47 in the experimental group (25 girls, 22 boys) and 47 in the control group (23 girls, 24 boys), were crucial to the success of this research. The study included participants with a preference for children aged between 48 and 60 months to facilitate their comfort in using the augmented reality application. The average age of the children is 55.4 months, and they were enrolled in four different classrooms. Additional inclusion criteria include the children's willingness to participate in the study and providing written consent from their families. Demographic information regarding the children in the experimental and control groups is presented in Table 1.

Table 1. Demographic information.

Demographic Information		Experimental Group	Control Group
Gender	Girl	25	23
	Boy	22	24
Age	48–54 months	24	21
	55–60 months	23	26
Total		47	47

The participating classrooms' teachers also played a significant role in the study, ensuring the children felt comfortable and part of the process. The children in the study sample were randomly assigned to the experimental and control groups, making them an integral part of the study. During the assignment process, two classes were randomly designated as the control group and two classes as the experimental group.

2.2. Augmented Reality Content and Application

This research focused on the topic of life cycles in environmental education. Specifically, the study utilized 3D content on the water life cycle, plant life cycle, and food chain. The Quiver Vision application displayed the 3D augmented reality content. The application required downloading and printing the coloring pages from the website. These coloring pages contained black-and-white illustrations related to the water life cycle, plant life

cycle, and food chain topics. The users could color these illustrations in their preferred colors. Subsequently, the Quiver Vision app was opened and was scanned, upon which the content appeared in 3D with the colors applied by the user. These contents were based on the principle that the images on the coloring pages appear in 3D through a device and augmented reality application. The on-screen image changed as the device's position alters. For example, children observed evaporation on the water life cycle coloring page through a single illustration. However, with the augmented reality application, they had the opportunity to see the evaporation of water in a 3D and dynamic manner. In this respect, the augmented reality application had the potential to concretize information. The 3D content could sometimes be presented in a game-like format, providing a flow-based experience at other times. This study utilized the life cycle content package from Quiver Vision. The pages from the package were downloaded and printed, and the application was installed on the tablets to be used. Each water life cycle, plant life cycle, and food chain topic had a separate page and corresponding augmented reality content. Additionally, the videos recommended on the Quiver Vision website were used to prepare the content the teacher would present to the children.

2.3. Life Cycle Test

The "Life Cycle Test", a vital study component, was meticulously designed and evaluated. It consists of 9 open-ended questions based on the water life cycle, plant life cycle, and food chain topics. The researcher developed the questions, and a draft rubric was created to evaluate the open-ended questions reliably. The teachers were provided with texts and test questions to be presented through the coloring pages, and they were asked to evaluate the appropriateness of the questions. After the evaluation process, the teachers administered the test to eight children who were not part of the experimental or control groups to assess the comprehensibility of the questions. The draft rubric was submitted for review to the four teachers participating in the study, and a consensus was reached on the final rubric through their feedback. According to the finalized rubric, incorrect answers were scored as 0, partially correct answers as 1, and entirely correct answers as 2 points. Additionally, two teachers collaborated with the researcher during the evaluation process, and the inter-rater reliability was assessed, ensuring the thoroughness and reliability of the evaluation process, which aimed to instill confidence in the study's results. The questions included in the "Life Cycle Test" were developed based on the coloring pages and the content presented by the teachers to the children. This approach facilitated the creation of a standardized test for comparing the groups. The children's test performances demonstrated the effectiveness of the environmental education activity conducted. Sample questions from the "Life Cycle Test" included the following:

1. What factors assist in the pollination of a plant?
2. Which consumers make up the food chain?
3. What are the primary stages of the water life cycle?

2.4. Procedures

This study followed a quasi-experimental process with a pre-test/post-test control group design. First, ethical approval was obtained from Akdeniz University, the Provincial Directorate of National Education granted implementation permission in Antalya, and consent forms were collected from the parents. Subsequently, meetings were held with the administrators and teachers working in the schools where the application would take place, and information about the study was provided. The researcher then introduced the augmented reality application to the teachers using the tablets brought. The classroom environment was arranged to allow children to color comfortably. Additionally, care was taken to ensure that the space was well lit so that the augmented reality application could function effectively. The teachers conducted the applications to be carried out with the children in the classroom environment, and the researcher was present in the classroom environment to contribute to the implementation process. In the first phase of the

application, the questions in the prepared life cycle test were assigned to the experimental and control groups, and the responses were recorded. Later, the teacher provided both the experimental and control groups with colorless pages from the life cycle package of the Quiver Vision application. Then, the children colored the pages according to their preferences. After the coloring activity, the teachers talked about the life cycle of the coloring pages for each child in the control group. This explanation was carried out separately for each of the topics of the water life cycle, plant life cycle, and food chain, using the colored pages by the children. At the end of each topic's coloring and explanation process, questions related to that topic were asked. The teachers used the same prompts to support children who had difficulty understanding the questions. For example, for children struggling with the question, "Which consumers make up the food chain?" The teachers rephrased it for all affected children by asking, "Who is involved in a food chain? Starting with plants, which animals are present?" This approach allowed them to define the concepts in simple language without affecting the other questions, thereby facilitating the children's thinking. The exact process was carried out for the experimental group using the 3D augmented reality system. The experimental group first performed the coloring activity. Then, each child, accompanied by the teacher, scanned the coloring pages using the tablets and examined the resulting 3D image. After the children examined all the images created in the augmented reality application for a few minutes, the teachers performed the same explanation on the 3D image for the experimental group as they did for the control group (Figure 1). Therefore, the fundamental difference between the two groups was the contribution of the 3D augmented reality application to enrich and concretize the content. At the end of the activities, the questions in the life cycle test were asked of both groups, and the answers were recorded. To facilitate classroom management, all applications in the experimental and control groups were conducted by two teachers together. The same teachers administered the "Life Cycle Test" to both groups. During both the pre-test and post-test processes, the children were told that the questions asked were not an exam and that the questions did not have right or wrong answers so that they could think freely. After the post-test data were collected, the analysis phase was initiated.

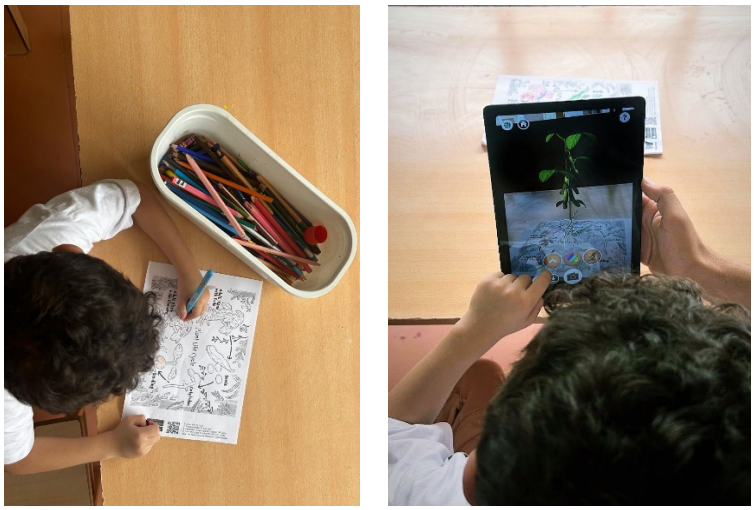

Figure 1. The study's implementation process.

2.5. Data Analysis

Normality tests were first conducted to test the intervention outcomes in this study. Since the pre-test and post-test results showed normal distribution, independent sample *t*-tests were used to determine potential differences between the groups. When the difference between the groups was statistically significant, the effect size was calculated using Cohen's d. Additionally, Kendall's W Coefficient of Concordance was calculated to determine the agreement between the two teachers and the researcher involved in the evaluation process.

The results were 0.956 for the pre-test and 0.961 for the post-test, indicating a high level of agreement among the evaluators.

3. Results

Before the data obtained from the research process were analyzed, a normality test was conducted, and it was determined that the data of the experimental and control groups were normally distributed. The data obtained from the pre-test showed no statistically significant difference at a 95% confidence interval between the scores of the children in the two groups on the Life Cycle Test. The means, standard deviations, and independent samples' *t*-test results for the experimental and control groups obtained during the pre-test process are presented in Table 2.

Table 2. Mean, standard deviation, and results of the independent samples' *t*-test for the p pre-test.

Group	N	Mean	SD	SE	t	*p*
Experimental group	47	4.297	1.852	0.270	−0.952	0.344
Control group	47	4.680	2.044	0.298		

An examination of the results presented in Table 2 reveals no statistically significant difference (t = −0.952, $p > 0.05$) between the experimental and control groups regarding the scores obtained from the life cycle test. Therefore, before any intervention, the children participating in the study had similar knowledge about the life cycle, including the water life cycle, plant life cycle, and food chain. The post-test results, however, indicated that the explanations using coloring pages and the augmented reality intervention increased the children's test performance. Specifically, the mean test score of the experimental group increased from 4.297 to 13.595 (t = −22.125, $p < 0.05$). In contrast, the mean score of the control group increased from 4.680 to 9.766 (t = −16.027, $p < 0.05$). Additionally, the means, standard deviations, and independent samples' *t*-test results for the post-test scores of the experimental and control groups are presented in Table 3.

Table 3. Mean, standard deviation, and results of the independent samples' *t*-test for the post-test.

Group	N	Mean	SD	SE	t	Cohen *d*
Experimental group	47	13.595	2.071	0.302	8.147 *	1.681
Control group	47	9.766	2.469	0.360		

* $p < 0.05$.

An examination of the results presented in Table 3 reveals a statistically significant difference (t = 8.147, $p < 0.05$) between the experimental and control groups regarding the scores obtained from the life cycle test. These results indicated that the augmented reality intervention was more effective in supporting the children's understanding level than the coloring page-based explanation. Furthermore, the analysis of effect size showed that the difference between the two groups was of a large effect size [122].

Based on the information provided above, the research question can be answered as follows:

Children who learned about the water life cycle, plant life cycle, and food chain using the 3D augmented reality application performed better on the Life Cycle Test than children who learned the same content through coloring page-based explanations (t = 8.147, $p < 0.05$, $d = 1.681$).

4. Discussion

This study examined the difference in performance between the control group, which learned about the water life cycle, plant life cycle, and food chain topics through coloring sheets and teacher explanations and the experimental group, which learned through a 3D augmented reality application and teacher explanations. The scores of the children on the

Life Cycle Test were the yardstick for this comparison. In the pre-test phase, there was no significant difference between the test performances of the two groups. However, in the post-test phase, the experimental group that learned the topics of the water life cycle, plant life cycle, and food chain through the augmented reality application outperformed the control group, marking a significant difference.

In this study, we underscore two key points. First, we highlight the immense potential of augmented reality applications to enhance understanding significantly. Second, we evaluate the practicality of these features in environmental education. Previous studies on augmented reality with early childhood children have consistently shown that this technology not only boosts children's interest and motivation [123,124], but also creates a stimulating learning environment [125] that they thoroughly enjoy [126]. In this context, the augmented reality application likely improved the children's performance by increasing their eagerness to participate in the activity. Numerous studies targeting different age groups have demonstrated that augmented reality-supported activities have a positive impact on the participants' understanding levels [127–129]. There is also evidence in the literature that augmented reality technology enhances the understanding performance of early childhood children [83]. These findings align with the results of our study. The fact that children engaged in environmental activities with coloring pages on the water life cycle, plant life cycle, and food chain and then experienced these visuals in 3D with the teacher's explanation seems to have positively affected their understanding. Therefore, it can be said that 3D and animated visuals concretized the subject better than 2D visuals. Concretizing abstract concepts is a key feature of augmented reality technology [14]. This function can significantly enhance students' understanding of performance [130]. For instance, in the current study, a child's concrete observation of each stage of the plant life cycle and experiencing this process in 3D produced more positive results than just a visual explanation. This teaching method has many advantages, such as being carried out quickly and in different environments [131].

The primary focus of this study is to assess the impact of augmented reality technology in environmental education for children. The results of the experimental process conducted in the study suggest that this technology can be effectively used in environmental education for children. A review of the literature reveals that there are studies where augmented reality technology is employed in environmental education [132,133]. The results of these studies indicate that augmented reality applications have a significant additional learning effect as a mobile-supported learning tool in environmental education [97]. These applications enhance the level of comprehension of the topics in the environmental education process and support children's learning by enabling them to construct knowledge more effectively [134,135]. The study's results by Huang et al. [53] show that using augmented reality technology improves users' learning outcomes. Moreover, the activities conducted with this technology increased the users' desire to acquire more information about the environment and helped them develop a more positive emotional attachment to the environment. Similarly, the results of the study by Wang et al. [54] show that a game developed using augmented reality significantly increased the participants' knowledge of sustainability and climate change issues. Indeed, using augmented reality in environmental education can contribute to users developing a more detailed understanding [15]. Therefore, the results of the relevant studies are consistent with the results of the current study. The fact that children interact with digital content and see the life cycle processes with 3D visuals may have enabled them to develop a more detailed understanding. For example, instead of learning the stages of the water cycle through coloring pages and narrations, seeing it in a 3D animated form, experiencing the stages separately through the application, and having the teacher's narration accompany this process has enriched the learning experiences. Therefore, in parallel with the results of the relevant studies in the literature, this study also provides positive evidence for the use of augmented reality technology in environmental education.

Augmented reality applications have the potential to significantly enhance children's learning in various areas, providing detailed and interactive content and concretizing abstract concepts through 3D-enriched environments. Studies on using augmented reality in environmental education have consistently reported numerous positive outcomes related to these applications. Results such as increased user interest in environmental education [136], encouraging a student-centered format [94], increasing participation [55], finding the topic interesting and valuable [82], providing a positive effect on environmental attitudes, behaviors, and awareness [17,135], and positively impacting the awareness of environmental issues [16,132] all demonstrate that this application can be used effectively in environmental education.

The present study will contribute to the literature in two important ways. Firstly, a substantial portion of the studies on using augmented reality in environmental education have utilized this technology as a supplementary tool in field trip activities [15,53]. In the current study, augmented reality technology, which has been found to have many benefits in these studies, has been used in the classroom context for environmental education. Indeed, creating an environment that will allow children to learn every stage of a topic, such as the food chain in nature, is difficult. Additionally, it is challenging for children to observe the evaporation and condensation that make up the water cycle in nature. In this regard, the current study's results are essential in creating an interactive and 3D environment where children can learn concepts and events related to the life cycle. Furthermore, the number of studies in the literature focusing on early childhood is quite limited. Studies focus on the primary school [17,97,136], middle school [15,53], high school [137], and university [16] levels. Considering that environmental education provided at an early age can ensure that children develop positive attitudes towards the environment in future periods [35], the current study's provision of data on environmental education in early childhood is highly significant.

5. Conclusions and Recommendations

In this study, the performance of early childhood children on the Life Cycle Test was compared after explanations using coloring pages and a 3D augmented reality application. Within this framework, the groups colored the pages related to the water life cycle, plant life cycle, and food chain according to their preferences. Subsequently, the control group was given an explanation using the coloring pages, while the experimental group was given an explanation using a 3D augmented reality application. According to the test results, children who participated in the 3D augmented reality application activity performed better than those who only participated in the activity with the coloring pages. Based on these results, the augmented reality application increases children's level of understanding and can be used as a tool in environmental education. The results will contribute to the literature, as studies on early childhood children are limited. Moreover, evidence has been provided that this technology can effectively teach children about natural events that they cannot observe or would be difficult for them to observe within a specific time frame in the classroom setting.

Several recommendations can be made based on the study's results. Future research could focus on children aged 48–60 months, as well as different age groups in early childhood. This would allow for the observation of differences arising from age-related cognitive development. Additionally, larger sample sizes could be utilized to examine variables such as gender, location, and socioeconomic differences. This would enable more generalized conclusions regarding the use of augmented reality in environmental education for children. Furthermore, future studies could test the applicability of augmented reality applications in various topics related to environmental education. Additionally, building on this classroom study, it is recommended that research be conducted on how augmented reality applications can be integrated into outdoor activities. Finally, for future studies, it may be beneficial to use the Analysis of Covariance (ANCOVA), a method that compares

data sets with two variables (treatment and effect, where the effect variable is called the 'variate') in the presence of a third variable (the 'covariate').

6. Limitations

This study has certain limitations. The data for this research are limited to 94 children who participated in the study. Although larger participant groups are typically not preferred in studies testing technological devices and applications, more research is needed to generalize the findings. Additionally, the age range of the children who participated in the study is between 48 and 60 months. Therefore, the results of this study are limited to this age range. Environmental education has a very broad scope; the current study is restricted to the topics of the water life cycle, plant life cycle, and food chain. Furthermore, many topics related to environmental education have utilized observation in nature as a method for instruction. The present study is confined to the classroom environment. Additionally, the current study employed 3D content as the augmented reality material.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical restrictions.

Conflicts of Interest: The author declares no conflicts of interest.

References

1. Monroe, M.C.; Plate, R.R.; Oxarart, A.; Bowers, A.; Chaves, W.A. Identifying effective climate change education strategies: A systematic review of the research. *Environ. Educ. Res.* **2019**, *25*, 791–812. [CrossRef]
2. UNESCO. *The Tbilisi Declaration: Final Report: Intergovernmental Conference on Environmental Education*; UNESCO: Paris, France, 1978.
3. Wilson, R. *Nature and Young Children: Encouraging Creative Play and Learning in Natural Environments*, 2nd ed.; Routledge: London, UK, 2012.
4. Güler Yıldız, T.; Öztürk, N.; İlhan İyi, T.; Aşkar, N.; Banko Bal, Ç.; Karabekmez, S.; Höl, Ş. Education for sustainability in early childhood education: A systematic review. *Environ. Educ. Res.* **2021**, *27*, 796–820. [CrossRef]
5. Otterborn, A.; Sundberg, B.; Schönborn, K. The impact of digital and analog approaches on a multidimensional preschool science education. *Res. Sci. Educ.* **2024**, *54*, 185–203. [CrossRef]
6. Borokhovski, E.; Bernard, R.M.; Tamim, R.M.; Schmid, R.F.; Sokolovskaya, A. Technology-supported student interaction in post-secondary education: A meta-analysis of designed versus contextual treatments. *Comput. Educ.* **2016**, *96*, 15–28. [CrossRef]
7. Tondeur, J.; Van Braak, J.; Valcke, M. Towards a typology of computer use in primary education. *J. Comput. Assist. Learn.* **2007**, *23*, 197–206. [CrossRef]
8. Abdoli-Sejzi, A. Augmented Reality and Virtual Learning Environment. *J. Appl. Sci. Res.* **2015**, *11*, 1–5.
9. Hwang, G.J.; Wu, P.H.; Chen, C.C.; Tu, N.T. Effects of an augmented reality-based educational game on students' learning achievements and attitudes in real-world observations. *Interact. Learn. Environ.* **2015**, *24*, 1895–1906. [CrossRef]
10. Küçük, S.; Kapakin, S.; Göktaş, Y. Tıp fakültesi öğrencilerinin mobil artırılmış gerçeklikle anatomi öğrenimine yönelik görüşleri. *Yükseköğretim Ve Bilim Derg.* **2015**, *5*, 316–323. [CrossRef]
11. Wojciechowski, R.; Cellary, W. Evaluation of learners' attitude toward learning in ARIES augmented reality environments. *Comput. Educ.* **2013**, *68*, 570–585. [CrossRef]
12. Kewalramani, S.; Veresov, N. Multimodal creative inquiry: Theorising a new approach for children's science meaning-making in early childhood education. *Res. Sci. Educ.* **2022**, *52*, 927–947. [CrossRef]
13. Rhoades, M. "Little pig, little pig, let me come in!" Animating the three little pigs with pre-schoolers. *Early Child. Educ. J.* **2016**, *44*, 595–603. [CrossRef]
14. Somyurek, S. Attracting Z generation's attention in learning process: Augmented reality. *Educ. Technol. Theory Implement.* **2014**, *4*, 63–80.
15. Kamarainen, A.M.; Thompson, M.; Metcalf, S.J.; Grotzer, T.A.; Tutwiler, M.S.; Dede, C. Prompting connections between content and context: Blending immersive virtual environments and augmented reality for environmental science learning. In *Immersive Learning Research Network: 4th International Conference, iLRN 2018, Missoula, MT, USA, June 24–29, 2018, Proceedings 4*; Springer International Publishing: Berlin/Heidelberg, Germany, 2018; pp. 36–54.

16. Mei, B.; Yang, S. Nurturing environmental education at the tertiary education level in China: Can mobile augmented reality and gamification help? *Sustainability* **2019**, *11*, 4292. [CrossRef]
17. Ozturk, E.; Akcay, G. Can environmental education supported by augmented reality (AR) applications improve the environmental awareness of primary school students? *Eurasia Proc. Educ. Soc. Sci.* **2023**, *31*, 216–229. [CrossRef]
18. Safitri, D.; Marini, A.; Auliya, A.F.; Wardhani, P.A. Development of augmented reality-based interactive learning media to increase interest in environmental education. *Eurasian J. Educ. Res.* **2023**, *106*, 101–117. [CrossRef]
19. Beier, M.; Rittmayer, A. Literature overview: Motivational factors in STEM: Interest and self-concept. *Assess. Women Men Eng.* **2008**, *10*, 1–10.
20. Gough, S. Co-evolution, knowledge and education: Adding value to learners' options. *Stud. Philos. Educ.* **2009**, *28*, 27–38. [CrossRef]
21. Emanuel, R.; Adams, J.N. College students' perceptions of campus sustainability. *Int. J. Sustain. High. Educ.* **2011**, *12*, 79–92. [CrossRef]
22. Masalimova, A.R.; Krokhina, J.A.; Sokolova, N.L.; Melnik, M.V.; Kutepova, O.S.; Duran, M. Trends in environmental education: A systematic review. *EURASIA J. Math. Sci. Technol. Educ.* **2023**, *19*, em2228. [CrossRef]
23. Smolyaninova, O.G.; Gruzdeva, E.A.; Smolyaninov, A.A. Online mediation in the socialization of children with disabilities: Environmental conditions in the Arctic and the north of the Krasnoyarsk territory. *Educ. Self Dev.* **2021**, *16*, 346–361. [CrossRef]
24. Sorakin, Y.; Akarturk, H.; Oznacar, B.; Prokopyev, A.I.; Burkhanova, I.Y.; Musin, O.A.; Shaleeva, E.F.; Krivonozhkina, E.G. Educational reflections on the coronavirus pandemic in three different countries. *Eurasia J. Math. Sci. Technol. Educ.* **2022**, *18*, em2180. [CrossRef]
25. Oschepkov, A.A.; Kidinov, A.V.; Babieva, N.S.; Vrublevskiy, A.S.; Egorova, E.V.; Zhdanov, S.P. STEM technology-based model helps create an educational environment for developing students' technical and creative thinking. *EURASIA J. Math. Sci. Technol. Educ.* **2022**, *18*, em2110. [CrossRef] [PubMed]
26. Qarkaxhja, Y.; Kryukova, N.I.; Cherezova, Y.A.; Rozhnov, S.N.; Khairullina, E.R.; Bayanova, A.R. Digital transformation in education: Teacher candidate views on mobile learning. *Int. J. Emerg. Technol. Learn.* **2021**, *16*, 81–93. [CrossRef]
27. Cheng, Y.; Lou, S.; Kuo, S.; Shih, R. Investigating elementary school students' technology acceptance by applying digital game-based learning to environmental education. *Australas. J. Educ. Technol.* **2013**, *29*, 96–110. [CrossRef]
28. Zapf, M. Social Work and the Environment: Understanding People and Place. *Crit. Soc. Work* **2010**, *11*, 3.
29. Surjanti, J.; Nugrohoseno, D.; Musfidah, H. The implementation of interest-based entrepreneurship curriculum in the theory of economics course. *Consort. Asia-Pac. Educ. Univ.* **2018**, *296*, 012012. [CrossRef]
30. Abe, O. Naze Kankyou Kyouiku Wo Manabunoka. In *Kankyou Kyouiku*; Shuppan, K., Ed.; The Japanese Society for Environmental Education: Tokyo, Japan, 2012; pp. 1–10.
31. Phenice, L.A.; Griffore, R.J. Young children and the natural world. *Contemp. Issues Early Child.* **2003**, *4*, 167–171. [CrossRef]
32. Copple, C.; Bredekamp, S. *Developmentally Appropriate Practice in Early Childhood Programs Serving Children from Birth Through Age 8*, 3rd ed.; National Association for the Education of Young Children: Washington, DC, USA, 2009.
33. North American Association for Environmental Education. *Early Childhood Environmental Education Programs: Guidelines for Excellence*; North American Association for Environmental Education: Washington, DC, USA, 2016.
34. Samuelsson, I.; Kaga, Y. The Contribution of Early Childhood Education to a Sustainable Society. *UNESCO*. 2008. Available online: https://unesdoc.unesco.org/ark:/48223/pf0000159355 (accessed on 16 June 2024).
35. Wilson, R.A. Environmental education programs for preschool children. *J. Environ. Educ.* **1996**, *27*, 28–33. [CrossRef]
36. Myers, O.E.; Saunders, C.D.; Garrett, E. What do children think animals need? Developmental trends. *Environ. Educ. Res.* **2004**, *10*, 545–562. [CrossRef]
37. Özkan, K.E. Sürdürülebilir kalkınma bağlamında çevre sorunlarının önemi: Türkiye ve AB karşılaştırması. Master's Thesis, Bilecik Şeyh Edebali Üniversitesi, Bilecik, Türkiye, 2017.
38. Hedefalk, M.; Almqvist, J.; Östman, L. Education for sustainable development in early childhood education: A review of the research literature. *Environ. Educ. Res.* **2015**, *21*, 975–990. [CrossRef]
39. Gözüm, A.İ.C.; Kandır, A. Digital games pre-schoolers play: Parental mediation and examination of educational content. *Educ. Inf. Technol.* **2021**, *26*, 3293–3326. [CrossRef]
40. Edwards, S.; Straker, L.; Oakey, H. Statement on Young Children and Digital Technology. Available online: https://www.earlychildhoodaustralia.org.au/wp-content/uploads/2018/10/Digital-policy-statement.pdf (accessed on 14 June 2024).
41. Gözüm, A.İ.C. Digital games for STEM in early childhood education: Active co-playing parental mediation and educational content examination. In *STEM, Robotics, Mobile Apps in Early Childhood and Primary Education: Technology to Promote Teaching and Learning*; Springer Nature: Singapore, 2022; pp. 489–523. [CrossRef]
42. Gözüm, A.İ.C.; Kandır, A. Developing a parental mediation scale of digital games for children. *Int. J. Curric. Instr.* **2020**, *12*, 336–358. Available online: https://ijci.globets.org/index.php/IJCI/article/view/420 (accessed on 16 June 2024).
43. Kress, G.R. *Literacy in the New Media Age*; Psychology Press: London, UK, 2003.
44. Yelland, N.J. A pedagogy of multiliteracies: Young children and multimodal learning with tablets. *Br. J. Educ. Technol.* **2018**, *49*, 847–858. [CrossRef]
45. Areljung, S.; Sundberg, B. Potential for multi-dimensional teaching for 'emergent scientific literacy' in pre-school practice. *J. Emergent Sci.* **2018**, *15*, 20–27.

46. Siry, C. Towards multidimensional approaches to early childhood science education. *Cult. Stud. Sci. Educ.* **2014**, *9*, 297–304. [CrossRef]
47. Kalogiannakis, M.; Ampartzaki, M.; Papadakis, S.; Skaraki, E. Teaching natural science concepts to young children with mobile devices and hands-on activities. A case study. *Int. J. Teach. Case Stud.* **2018**, *9*, 171–183. [CrossRef]
48. Sezgin, S.; Bozkurt, A.; Yılmaz, E.A.; Van der Linden, N. Gamification, education and theoretical approaches: Motivation, engagement and sustainability in learning processes. *Mehmet Akif Ersoy Univ. Educ. Fac. J.* **2020**, *45*, 169–189. [CrossRef]
49. Ducasse, J. Augmented reality for outdoor environmental education. In *Augmented Reality in Education*; Geroimenko, V., Ed.; Springer: Cham, Switzerland, 2020; pp. 329–352.
50. Kabadayı, A.; Altınsoy, F. Traditional and technological methods for raising pre-school children's awareness of environmental pollution for sustainability. *Discourse Commun. Sustain. Educ.* **2018**, *9*, 134–144. [CrossRef]
51. Fokides, E.; Zachristou, D. Teaching natural sciences to kindergarten students using tablets: Results from a pilot project. In *Mobile Learning Applications in Early Childhood Education*; IGI Global: Hershey, PA, USA, 2020; pp. 40–60. [CrossRef]
52. Fauville, G.; Hodin, J.; Dupont, S.; Miller, P.; Haws, J.; Thorndyke, M.; Epel, D. *Virtual Ocean Acidification Laboratory as an Efficient Educational Tool to Address Climate Change Issues*; Springer: Berlin/Heidelberg, Germany, 2011.
53. Huang, T.C.; Chen, C.C.; Chou, Y.W. Animating eco-education: To see, feel, and discover in an augmented reality-based experiential learning environment. *Comput. Educ.* **2016**, *96*, 72–82. [CrossRef]
54. Wang, K.; Tekler, Z.D.; Cheah, L.; Herremans, D.; Blessing, L. Evaluating the effectiveness of an augmented reality game promoting environmental action. *Sustainability* **2021**, *13*, 13912. [CrossRef]
55. Huh, J.R.; Park, I.J.; Sunwoo, Y.; Choi, H.J.; Bhang, K.J. Augmented reality (AR)-based intervention to enhance awareness of fine dust in sustainable environments. *Sustainability* **2020**, *12*, 9874. [CrossRef]
56. Pearson, E.; Dorrian, J.; Litchfield, C. Harnessing visual media in environmental education: Increasing knowledge of orang-utan conservation issues and facilitating sustainable behaviour through video presentations. In *The Media, Animal Conservation and Environmental Education*; Routledge: London, UK, 2013; pp. 61–77.
57. Yang, B.; Wu, N.; Tong, Z.; Sun, Y. Narrative-based environmental education improves environmental awareness and environmental attitudes in children aged 6–8. *Int. J. Environ. Res. Public Health* **2022**, *19*, 6483. [CrossRef] [PubMed]
58. Sahabuddin, E.S.; Dirawan, G.D. Green school-based animation video media in increasing student's awareness of the environment. *Int. J. Elem. Educ.* **2022**, *6*, 386–392. [CrossRef]
59. Putri, H.E.; Maraputra, A.N.; Efna, M.J.; Permana, Y.; Martiningtyas, M.P.; Listiyanti, P.A.; Wulandari, H. Improvement of student awareness on cleanliness and environmental health through stop motion video technology. *J. Phys. Conf. Ser.* **2020**, *1521*, 042042. [CrossRef]
60. Uzunboylu, H.; Cavus, N.; Ercag, E. Using mobile learning to increase environmental awareness. *Comput. Educ.* **2009**, *52*, 381–389. [CrossRef]
61. Shakirova, N.; Berechikidze, I.; Gafiyatullina, E. The effects of immersive AR technology on the environmental literacy, intrinsic motivation, and cognitive load of high school students. *Educ. Inf. Technol.* **2023**, *29*, 9121–9138. [CrossRef]
62. Yuen, S.; Yaoyuneyong, G.; Johnson, E. Augmented reality: An overview and five directions for AR in education. *J. Educ. Technol. Dev. Exch.* **2011**, *4*, 119–140. [CrossRef]
63. Hassan, S.A.; Rahim, T.; Shin, S.Y. ChildAR: An augmented reality-based interactive game for assisting children in their education. *Univ. Access Inf. Soc.* **2021**, *21*, 545–556. [CrossRef]
64. Martínez, A.A.; Benito, J.R.L.; González, E.A.; Ajuria, E.B. An experience of the application of augmented reality to learn English in infant education. In Proceedings of the 2017 International Symposium on Computers in Education, Lisbon, Portugal, 6–8 November 2017.
65. Lee, L.K.; Chau, C.H.; Chau, C.H.; Ng, C.T. Using augmented reality to teach kindergarten students English vocabulary. In Proceedings of the 2017 International Symposium on Educational Technology (ISET), Hong Kong, China, 26–28 June 2017; pp. 53–57.
66. Cascales, A.; Laguna, I.; Pérez-López, D.; Perona, P.; Contero, M. An experience on natural sciences augmented reality contents for preschoolers. In *International Conference on Virtual, Augmented and Mixed Reality*; Springer: Berlin/Heidelberg, Germany, 2013; pp. 103–112.
67. Chen, Y.C.; Chi, H.L.; Hung, W.H.; Kang, S.C. Use of tangible and augmented reality models in engineering graphics courses. *J. Prof. Issues Eng. Educ. Pract.* **2011**, *137*, 267–276. [CrossRef]
68. Dunleavy, M.; Dede, C.; Mitchell, R. Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *J. Sci. Educ. Technol.* **2009**, *18*, 7–22. [CrossRef]
69. Talan, T.; Yilmaz, Z.A.; Batdi, V. The effects of augmented reality applications on secondary students' academic achievement in science course. *J. Educ. Sci. Environ. Health* **2022**, *8*, 333–347. [CrossRef]
70. Wu, H.K.; Lee, S.W.Y.; Chang, H.Y.; Liang, J.C. Current status, opportunities and challenges of augmented reality in education. *Comput. Educ.* **2013**, *62*, 41–49. [CrossRef]
71. Yılmaz, Z.A.; Batdı, V. Artırılmış gerçeklik uygulamalarının eğitimle bütünleştirilmesinin meta-analiz ve tematik karşılaştırmalı analizi. *Eğitim Bilim Derg.* **2016**, *41*, 273–289. [CrossRef]
72. Wang, X.; Kim, M.J.; Love, P.E.; Kang, S.C. Augmented Reality in built environment: Classification and implications for future research. *Autom. Constr.* **2013**, *32*, 1–13. [CrossRef]

73. Alyousify, A.L.; Mstafa, R.J. AR-Assisted Children Book for Smart Teaching and Learning of Turkish Alphabets. *Virtual Real. Intell. Hardw.* **2022**, *4*, 263–277. [CrossRef]
74. Furht, B. *Handbook of Augmented Reality*; Springer: New York, NY, USA, 2011.
75. Dobrovská, D.; Vaněček, D. Implementation of augmented reality into student practical skills training. In Proceedings of the International Conference on Intelligent Human Systems Integration, Modena, Italy, 19–21 February 2021; pp. 212–217.
76. Ibáñez, M.B.; Delgado-Kloos, C. Augmented reality for STEM learning: A systematic review. *Comput. Educ.* **2018**, *123*, 109–123. [CrossRef]
77. Hossain, M.J.; Ahmed, T. Augmented reality-based elementary level education for Bengali character familiarization. *SN Comput. Sci.* **2021**, *2*, 31. [CrossRef]
78. Aydoğdu, F.; Kelpšiene, M. Uses of augmented reality in preschool education. *Int. Technol. Educ. J.* **2021**, *5*, 11–20.
79. Kuzgun, H. Artırılmış gerçeklik teknolojisinin okul öncesi dönemde kullanımı: Durum çalışması. Master's Thesis, Afyon Kocatepe University, Afyon, Türkiye, 2019.
80. Chen, Y.; Zhou, D.; Wang, Y.; Yu, J. Application of augmented reality for early childhood English teaching. In Proceedings of the 2017 International Symposium on Educational Technology (ISET), Hong Kong, China, 27–29 June 2017; pp. 111–115. [CrossRef]
81. Rapti, S.; Sapounidis, T.; Tselegkaridis, S. Enriching a traditional learning activity in preschool through augmented reality: Children's and teachers' views. *Information* **2023**, *14*, 530. [CrossRef]
82. Huang, Y.; Li, H.; Fong, R. Using augmented reality in early art education: A case study in Hong Kong kindergarten. *Early Child Dev. Care* **2016**, *186*, 879–894. [CrossRef]
83. Yılmaz, R.M.; Küçük, S.; Göktaş, Y. Are augmented reality picture books magic or real for preschool children aged five to six? *Br. J. Educ. Technol.* **2017**, *48*, 824–841. [CrossRef]
84. Lee, H.S.; Lee, J.W. Mathematical education game based on augmented reality. In *Technologies for E-Learning and Digital Entertainment*; Pan, Z., Zhang, X., El Rhalibi, A., Woo, W., Li, Y., Eds.; Springer: Berlin/Heidelberg, Germany, 2008; pp. 442–450.
85. Stotz, M.; Columba, L. Using augmented reality to teach subitizing with preschool students. *J. Interact. Learn. Res.* **2018**, *29*, 545–577. Available online: https://www.learntechlib.org/primary/p/173651/ (accessed on 14 June 2024).
86. Zhu, Y.; Wang, S.J. A Tangible augmented reality toy kit: Interactive solution for early childhood education. In *Interactivity, Game Creation, Design, Learning, and Innovation*; Brooks, A.L., Brooks, E., Eds.; Springer: Berlin/Heidelberg, Germany, 2017; pp. 12–19. [CrossRef]
87. Preka, G.; Rangoussi, M. Augmented reality and QR codes for teaching music to preschoolers and kindergarteners: Educational intervention and evaluation. In Proceedings of the CSEDU 2019, Heraklion, Greece, 2–4 May 2019; pp. 113–123.
88. Hsieh, M.C.; Lee, J.S. AR marker capacity increasing for kindergarten English learning. In Proceedings of the International Multi Conference of Engineers and Computer Scientists, Hong Kong, China, 19–21 March 2008.
89. Yılmaz, R.M. Educational magic toys developed with augmented reality technology for early childhood education. *Comput. Hum. Behav.* **2016**, *54*, 240–248. [CrossRef]
90. Zhu, Y.J.; Yang, X.Y.; Wang, S.J. Augmented reality meets tangibility: A new approach for early childhood education. *EAI Endorsed Trans. Creat. Technol.* **2017**, *4*, 153059. [CrossRef]
91. Pan, Z.; López, M.; Li, C.; Liu, M. Introducing augmented reality in early childhood literacy learning. *Res. Learn. Technol.* **2021**, *29*, 1–21. [CrossRef]
92. Çakırlar Altuntaş, E. Belgesel temelli artırılmış gerçeklik uygulamalı çevre eğitiminin etkililiği üzerine bir çalışma. Ph.D. Thesis, Hacettepe University, Ankara, Türkiye, 2021.
93. Fajarianto, O.; Setiawan, M.I.; Mursidi, A.; Sundiman, D.; Sari, D.A.P. The development of learning materials for the introduction of animals in early childhood using augmented reality. In Proceedings of the International Conference on Knowledge Management in Organizations, Zamora, Spain, 25–28 August 2018; pp. 722–727.
94. Kamarainen, A.M.; Metcalf, S.; Grotzer, T.; Browne, A.; Mazzuca, D.; Tutwiler, M.S.; Dede, C. EcoMOBILE: Integrating augmented reality and probeware with environmental education field trips. *Comput. Educ.* **2013**, *68*, 545–556. [CrossRef]
95. Koutromanos, G.; Tzortzoglou, F.; Sofos, A. Evaluation of an augmented reality game for environmental education: "Save Elli, Save the Environment". In *Research on e-Learning and ICT in Education: Technological, Pedagogical and Instructional Perspectives*; Mikropoulos, T.A., Ed.; Springer: Berlin/Heidelberg, Germany, 2018; pp. 231–241. [CrossRef]
96. Rasalingam, R.R.; Muniandy, B.; Rass, R. Exploring the application of augmented reality technology in early childhood classroom in Malaysia. *J. Res. Method Educ.* **2014**, *4*, 33–40. [CrossRef]
97. Theodorou, P.; Kydonakis, P.; Botzori, M.; Skanavis, C. Augmented reality proves to be a breakthrough in Environmental Education. *Prot. Restor. Environ.* **2018**, *7*, 219–228.
98. Antonia, D.; Evgenia, R. Artful Thinking and Augmented Reality in Kindergarten: Technology Contributions to the Inclusion of Socially Underprivileged Children in Creative Activities. In Proceedings of the 8th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-Exclusion, Thessaloniki, Greece, 20–22 June 2018; pp. 187–194.
99. Cai, S.; Chiang, F.K.; Sun, Y.; Lin, C.; Lee, J.J. Applications of augmented reality-based natural interactive learning in magnetic field instruction. *Interact. Learn. Environ.* **2017**, *25*, 778–791. [CrossRef]
100. Han, J.; Jo, M.; Hyun, E.; So, H.J. Examining young children's perception toward augmented reality-infused dramatic play. *Educ. Technol. Res. Dev.* **2015**, *63*, 455–474. [CrossRef]

101. Hanid, M.F.A.; Said, M.N.H.M.; Yahaya, N. Learning strategies using augmented reality technology in education: Meta-analysis. *Univ. J. Educ. Res.* **2020**, *8*, 51–56. [CrossRef]
102. Li, J.; Van Der Spek, E.D.; Hu, J.; Feijs, L. Turning your book into a game: Improving motivation through tangible interaction and diegetic feedback in an AR mathematics game for children. In Proceedings of the CHILD PLAY 2019 Annual Symposium on Computer-Human Interaction in Play, Barcelona, Spain, 22–25 October 2019.
103. Lorusso, M.L.; Giorgetti, M.; Travellini, S.; Greci, L.; Zangiacomi, A.; Mondellini, M.; Reni, G. Giok the alien: An AR-based integrated system for the empowerment of problem-solving, pragmatic, and social skills in pre-school children. *Sensors* **2018**, *18*, 2368. [CrossRef]
104. Sofianidis, A. Why do students prefer augmented reality: A mixed-method study on preschool teacher students' perceptions on self-assessment AR quizzes in science education. *Educ. Sci.* **2022**, *12*, 329. [CrossRef]
105. Utami, F.; Andika, W.D.; Sumarni, S. Introduction to Sea Animals with Augmented Reality Based Flashcard for Early Childhood. In Proceedings of the 4th Sriwijaya University Learning and Education International Conference (SULE-IC 2020), Palembang, Indonesia, 24–26 October 2020; Atlantis Press: Amsterdam, The Netherlands, 2021; pp. 215–220.
106. Yousef, A.M.F. Augmented reality assisted learning achievement, motivation, and creativity for children of low-grade in primary school. *J. Comput. Assist. Learn.* **2021**, *37*, 966–977. [CrossRef]
107. Zafeiropoulou, M.; Volioti, C.; Keramopoulos, E.; Sapounidis, T. Developing physics experiments using augmented reality game-based learning approach: A pilot study in primary school. *Computers* **2021**, *10*, 126. [CrossRef]
108. Cheng, K.H.; Tsai, C.C. The interaction of child–parent shared reading with an augmented reality (AR) picture book and parents' conceptions of AR learning. *Br. J. Educ. Technol.* **2016**, *47*, 203–222. [CrossRef]
109. Chiang, T.H.C.; Yang, S.J.H.; Hwang, G.J. An augmented reality-based mobile learning system to improve students' learning achievements and motivations in natural science inquiry activities. *Educ. Technol. Soc.* **2014**, *17*, 352–365.
110. Lin, H.C.K.; Chen, M.C.; Chang, C.K. Assessing the effectiveness of learning solid geometry by using an augmented reality-assisted learning system. *Interact. Learn. Environ.* **2013**, *23*, 799–810. [CrossRef]
111. Zulfikri, A.Z.; Masnan, A.H. The Use of Interactive Games in Children's Teaching and Learning Processes: An Innovation. *Southeast Asia Early Child. J.* **2023**, *12*, 128–134. [CrossRef]
112. Kotzageorgiou, M.; Kellidou, P.M.; Voulgari, I.; Nteropoulou, E. Augmented reality and the symbolic play of pre-school children with autism. In Proceedings of the 17th European Conference on e-Learning, Athens, Greece, 1–2 November 2018; Ntalianis, K., Andreatos, A., Sgouropoulou, C., Eds.; ACPIL: London, UK, 2018; pp. 273–280.
113. Kelpšienė, M. The usage of books containing augmented reality technology in preschool education. *Pedagogika* **2020**, *138*, 150–174. [CrossRef]
114. Kahriman Pamuk, D.; Elmas, R.; Pamuk, S. Augmented reality and science activities: The views of preschool pre- and in-service teachers. *YYU J. Educ. Fac.* **2020**, *17*, 671–699.
115. Santos, M.E.C.; Lübke, A.I.W.; Taketomi, T.; Yamamoto, G.; Rodrigo, M.M.T.; Sandor, C.; Kato, H. Augmented reality as multimedia: The case for situated vocabulary learning. *Res. Pract. Technol. Enhanc. Learn.* **2016**, *11*, 4. [CrossRef] [PubMed]
116. Higgins, J. Cognising with others in the we-mode: A defence of 'first-person plural' social cognition. *Rev. Philos. Psychol.* **2020**, *12*, 803–824. [CrossRef]
117. Safar, A.H.; Al-Jafar, A.A. The effectiveness of using augmented reality apps in teaching the English alphabet to kindergarten children: A case study in the State of Kuwait. *Eurasia J. Math. Sci. Technol. Educ.* **2017**, *13*, 417–440. [CrossRef]
118. Madanipour, P.; Cohrssen, C. Augmented reality as a form of digital technology in early childhood education. *Australas. J. Early Child.* **2020**, *45*, 5–13. [CrossRef]
119. Masmuzidin, M.Z.; Aziz, N.A.A. The current trends of augmented reality in early childhood education. *Int. J. Multimed. Its Appl. (IJMA)* **2018**, *10*, 47–58. [CrossRef]
120. Arnold, H.E.; Cohen, F.G.; Warner, A. Youth and Environmental Action: Perspectives of Young Environmental Leaders on Their Formative Influences. *J. Environ. Educ.* **2009**, *40*, 27–36. [CrossRef]
121. Cutter-Mackenzie, A.; Edwards, S.; Moore, D.; Boyd, W. *Young Children's Play and Environmental Education in Early Childhood Education*; Springer: Cham, Switzerland, 2014.
122. Cohen, J. *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed.; Routledge: New York, NY, USA, 1988.
123. Aydoğdu, F. Augmented Reality for Preschool Children: An Experience with Educational Contents. *Br. J. Educ. Technol.* **2022**, *53*, 326–348. [CrossRef]
124. Bülbül, H.; Özdinç, F. How real is augmented reality in preschool? Examination of young children's AR experiences. *J. Theor. Educ. Sci.* **2022**, *15*, 884–906. [CrossRef]
125. Albayrak, S.; Yılmaz, R.M. An Investigation of Pre-School Children's Interactions with Augmented Reality Applications. *Int. J. Hum.-Comput. Interact.* **2022**, *38*, 165–184. [CrossRef]
126. Rambli, D.R.A.; Matcha, W.; Sulaiman, S. Fun learning with AR alphabet book for preschool children. *Procedia Comput. Sci.* **2013**, *25*, 211–219. [CrossRef]
127. Bursalı, H.; Yılmaz, R.M. Effect of augmented reality applications on secondary school students' reading comprehension and learning permanency. *Comput. Hum. Behav.* **2019**, *95*, 126–135. [CrossRef]
128. Danaei, D.; Jamali, H.R.; Mansourian, Y.; Rastegarpour, H. Comparing reading comprehension between children reading augmented reality and print storybooks. *Comput. Educ.* **2020**, *153*, 103900. [CrossRef]

129. Şimşek, B.; Direkci, B. The effects of augmented reality storybooks on student's reading comprehension. *Br. J. Educ. Technol.* **2023**, *54*, 754–772. [CrossRef]
130. Chen, C.M.; Tsai, Y.N. Interactive augmented reality system for enhancing library instruction in elementary schools. *Comput. Educ.* **2012**, *59*, 638–652. [CrossRef]
131. Law, C.; So, S. QR Codes in Education. *J. Educ. Technol. Dev. Exch.* **2010**, *3*, 85–100. [CrossRef]
132. Castillo-Gonzalez, W.; Lepez, C.O.; Bonardi, M.C. Augmented reality and environmental education: Strategy for greater awareness. *Gamification Augment. Real.* **2023**, *1*, 10. [CrossRef]
133. Negi, S.K. Exploring the impact of virtual reality and augmented reality technologies in sustainability education on green energy and sustainability behavioral change: A qualitative analysis. *Procedia Comput. Sci.* **2024**, *236*, 550–557. [CrossRef]
134. Chien, Y.C.; Su, Y.N.; Wu, T.T.; Huang, Y.M. Enhancing students' botanical learning by using augmented reality. *Univ. Access Inf. Soc.* **2019**, *18*, 231–241. [CrossRef]
135. Karagozlu, D. Creating a sustainable education environment with augmented reality technology. *Sustainability* **2021**, *13*, 5851. [CrossRef]
136. Safitri, D.; Lestari, I.; Maksum, A.; Ibrahim, N.; Marini, A.; Sudrajat, A.; Iskandar, R. Ecolabel with augmented reality on the website to enhance student environmental awareness. *Int. J. Ecol.* **2022**, *2022*, 8169849. [CrossRef]
137. Aliabadi, K.; Joneidi Jafari, F.; Pourroostaei Ardakani, S. The Effect of Augmented Reality-Based Environmental Literacy Education Program on the Environmental Knowledge, Attitude and Behavior of Highschool Students. *Environ. Educ. Sustain. Dev.* **2021**, *9*, 9–22. [CrossRef]