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Predictors of Deep Learning and Competence Development in Children Aged 5–7 Using Augmented Reality Technology

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Abstract: While a number of studies have shown the potential and benefits of augmented reality (AR) technology for preschool education, less attention has been paid to the problem of children's deep learning and development of the competencies applying AR and to the pedagogy of AR. The aim of the study presented in this paper is to uncover the educational predictors of deep learning and competence development of 5–7-year-old children using AR technology. The research adopted a quantitative research approach and a survey design. The participants were 319 preschool teachers using AR technology for children's education. The study revealed that a statistically significant predictor of promoting deep learning in preschool children is teachers' roles, based on a constructivist and socio-cultural approach, when using AR. The research highlights the roles of the teacher as a creator of learning contexts and situations that engage children; the teacher as a proactive facilitator of children's learning; and the teacher as an educator who acts, thinks and reflects with children, among others. Statistically significant educational predictors of children's competence development were found to be: teachers' perceptions of AR technology, the roles assumed by teachers, and the areas of children's education in which AR technology is used.

Keywords: augmented reality technology; preschool education; deep learning; children's competences; the roles of teachers

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1. Introduction

Augmented reality (AR) is a technology that overlays real-world elements with digital content through computer-generated information in real time and adds 3D sight, sound, or other effects to the observer's reality [1–5]. Augmented reality has a direct connection to the real environment, as 3D digital objects are layered on top of real-time images of directly visible objects in the physical world [6,7]. Thus, synchronous interaction between the real world and the virtual environment is ensured. Maas and Hughes [8] and Ablyaev et al. [5] point out that a trigger, e.g., a QR code, a marker, a certain image, or a location, is required for augmented reality objects to appear. However, according to research [9,10], the concept and application of AR technology still pose a problem for preschool-aged children's teachers, even though teachers are motivated to integrate AR technology into preschool education.

In the last decade, AR technology has been widely used in the education of preschool children for experiencing wonder, fun, playfulness, increased motivation [10–13], the possibility of combining perception and action (receiving, reorganizing, and applying information in different modalities) [11], and the possibility of receiving instant feedback [12]. According to researchers, AR increases the diversity of children's learning styles, expands their sensory perception of the real world, and personalizes their learning [7].

According to Kayaduman and Sağlam [13], research conducted in the field of preschool education is usually dedicated to the problem of how AR technology should be applied at this age, what difficulties are faced, and how they are solved. Moreover, a considerable amount of research is dedicated to determining which preschool-aged children competencies are developed through the application of AR technology [5,6,11,12,14–18]. There is a lack of research that reveals the impact of AR technology application on preschool-aged children's competency development, with the exception of digital competency, which is actively explored [18–20]. There is no research dedicated to identifying the educational predictors of preschool-aged children's competency development applying AR technology. Our study aims to discover these predictors.

Research begun in the recent years shows how the application of AR technology creates conditions conducive to children's deep learning [7,21–23]. Our study contributes to the development of this emerging field by aiming to reveal the educational predictors of children's deep learning through the application of AR technology, as this aspect has not yet been explored.

Thus, in the present study, the aim was to answer the following questions: what are the characteristics of the practices of preschool teachers who use AR technology in education of 5–7-year-old children? What are the predictors of deep learning for 5–7-year-olds using AR technology? What are the predictors of 5–7-year-olds' competence development using AR technology?

2. Review of the Literature

2.1. Children's Deep Learning and AR

Marton and Saljo [24] defined deep learning by combining aspects of deep and surface learning. Surface learning is understood as passive and reproductive, based on memorization of facts, not related to real-world phenomena; deeper learning is associated with learner activity—engaging in learning, changing ways of thinking, and questioning. Deep learning is associated with the interaction between the learner and the learning context—learning in the real world, the search for meaning, and the holistic view [24,25]. Entwistle [26] also emphasizes the learner's activity and autonomy—the drive to explore and understand ideas for oneself, which leads to a deep level of understanding (what do I know and how did I learn it). Other researchers associate deep learning with activities based on high-level cognitive processing and metacognition (thinking about one's thinking) [27]. Ferenc [27] and Choi [21] reveal the effectiveness of deep learning as collaborative learning. Thus, the deep learning construct encompasses the higher cognitive abilities of Bloom's taxonomy (comprehension, application, analysis, synthesis/creation, and evaluation) [28], but also includes the learner's autonomy and self-regulatory capacity in learning, and hence co-learning abilities. The third dimension of the deep learning construct is the ability to learn in a real-world context, interacting with natural phenomena. The focus of our study was not on the children's acquired deep learning skills (as a result of their learning, those are a part of the structure of competences acquired by the children), but on the characteristics of the deep learning process, which show the preconditions for deep learning that have been created, and the children's reliance on deep learning skills.

The deep learning approach in preschool is inseparable from children's learning through play. Building on the components of deep learning identified by Leavers [29] (child well-being as freedom to act spontaneously, with confidence; engagement as activity, motivation, openness to stimuli, and cognitive processing), Sando et al. [30] explored the relationship between deep learning in childhood and play. A statistically significant relationship was found between all types of play studied and deep learning.

Over recent years, a new direction has emerged in the field of deep learning research—analyzing if and how the usage of AR contributes to the enhancement of children's deep learning. It was revealed that the use of AR technology enriches children's learning with the multimodality characteristic of deep learning. With AR technology, learning content contains elements of text, graphics, 3D video, or audio and allows information to be accessed through different perceptual channels [23]. Through AR technology for learning, children directly experience and learn through the process of self-learning, critically evaluate, and solve problems [21,23]. By combining real-world and virtual objects, and immersing children in a safe and engaging learning process, AR ensures creativity, leads to the development of higher-order thinking skills, creates the opportunity to see the objects being explored from different perspectives, and fosters a better understanding of complex and abstract concepts [12,22].

With the development of digital technologies and their integration into preschool education, games based on deep learning skills are being developed, focusing on the development of higher-order thinking skills, independent exploration, creativity and problem-solving abilities, and freedom of action [31]. According to Varma et al. [22], to achieve deep learning in children, AR technology, which allows the experience of an object through multiple senses, and deep learning technology as a field of machine learning need to be integrated.

The reviewed sources enable us to presume that the use of AR technology in preschool promotes children's deep learning, which is active, self-regulated, experiential, creative, problem-solving-based, meaningful, multimodal, and collaborative. However, further research is needed on the promotion of deep learning in preschool children through the use of AR technology in natural preschool settings.

2.2. The Impact of AR Technology on Children's Competence Development

Competency is defined as an integral part of a person's knowledge, skills, and attitudes, which collectively precondition behavior required for work or daily practical life [32]. The competencies of preschool-aged children are defined as practical, referring to their ability to act in accordance with the knowledge, skills, and attitudes they have acquired [32]. Children apply practical behavior, based on one's acquired entirety of knowledge, skills, and attitudes, by learning (some authors distinguish academical competencies) [33], exploring their surrounding world [34,35], connecting and maintaining interactions with others [33,36], overcoming challenges, uncertainties, or solving problems [32,34], expressing themselves through the means of art [37], according to their capabilities, taking care of their own and others' well-being and health, and using digital technology for safe learning and experiential activities [18].

Components of preschool-aged children's competencies are based on research. Socio-emotional competence consists of self-awareness skills, self-management skills, social awareness skills, relationship skills, and responsible decision-making skills [36,38]; cognitive competence includes scientific thinking and scientific knowledge [34], as well basic mathematical literacy [39]; communication competence encompasses speaking, listening, reading, and writing skills [33]. The most important components of art competencies include sensitivity for art visuals, artistic creativity, and visual, musical, or other artistic skills [37,40]; digital competence comprises digital information management, digital communication and cooperation, production of digital content, responsible usage, and problem solving [18,20].

Based on established competence constructs, formed preschool education direction based on competencies, are created programs oriented to the development of competencies [19,41–43].

No publications were found that focus on the impact of AR technology on the competence development of preschool children, except for digital competence. However, the literature on other topics is rich in information on the impact of AR on children's skills, knowledge, and values. We have organized this information according to competence areas.

Research reveals which features of AR technology create added educational value for the development of cognitive competencies in preschool children. It has been established that, with the help of AR technology, rich, visual, and multi-perspective context has a statistically significant impact on the attention skills of children in the experimental group [44], and on the retention of information visualized in a 3D format [45], understanding of concepts and complex subjects that are embodied by AR technology [11,12], understanding of spatial relationships [12], thinking skills and imagination when children's physical experiences, virtual images, and fantasies are integrated [14,45,46].

AR books contribute to the development of children's communicative competence, as they allow children to experience the content of books in an engaging, interactive, and multimodal way when AR is utilized as a medium to enhance immersiveness [47]. Additionally, AR books have been shown to increase the understanding and retelling of stories in a statistically significant way [47]. The use of AR technologies helps children learn the alphabet, sound analysis and word structure, as touching a letter or its marker allows children to hear the sound it represents, and to recognize and form words [6,17]. Exposure to AR applications or tools encourages children to communicate with each other and create stories together [14].

With AR, children's social competence can be developed through the AR content and by encouraging children to act together by communicating and collaborating. AR technology allows to superimpose animated facial expressions on children's faces to facilitate the perception of emotions and to associate facial expressions with appropriate emotional adjectives. Studies have shown that AR-mediated interventions with children on the autism spectrum have been successful in improving facial expression recognition, joint attention skills, and social communication skills [5]. A study by Albayrak and Yilmaz [3] shows that flexibility in pedagogy is essential for AR application usage. A child using them flexibly enables interactions between child–material, child–teacher, and child–child. When a child acts according to the specific teacher's instructions, such interactions are reduced. These studies are supported by Leinonen et al. [14] in their research with AR sandboxes—when children have the opportunity to act and explore freely, such activities with AR tools encourage active communication, supporting each other's ideas, sharing experiences, and learning from each other.

When applying AR technologies in the area of health competencies development, the aspects of ensuring children's safety and motivation of active learning are prioritized. Research shows that AR technology is useful for learning safe behavior, allowing children to demonstrate objects (poisonous snake) and situations (volcanic eruption) that are dangerous to observe directly [45]. In order to promote children's agile learning, AR tools integrate the possibility to perform interactive actions such as touching, scrolling, twisting, zoom-in–zoom-out movements, and clicking, which contribute to the promotion of fine motor skills [3]. Agile learning is supported by GPS-based apps to assist with travel, QR code-based information about outdoor objects, and their internal structure [16].

In the development of artistic competence, the application of AR technology creates new opportunities for artistic expression. Some AR applications are designed to combine colors [48]; others are for learning about the properties of sound [49]; for learning notes and listening to music, a virtual keyboard is used; for learning to play instruments, AR visual guides and virtual hands projected on the instrument are used [50–52] as one benefit of an AR application is a highlighted individual learning environment with virtual notes and the possibility to use real instruments supplementing them with virtual information [53].

In order for AR technology to be successfully integrated into preschool education, children need to develop basic digital literacy. Tuli and Mantri [54] revealed the difficulties experienced by children due to the lack of understanding of the content, the principle of operation, problems in controlling the devices, distractions, inaccurate movements, etc. On the other hand, most studies show that children gradually develop digital competence. Preschool children learn to use AR navigation systems integrated into games [25], begin to understand the ways in which technology works and its capabilities through interaction with the technology, and learn to perform actions using basic commands [55].

2.3. AR and Teaching Process

Research shows that AR is compatible with constructivist theory by providing preschool children with comfortable, innovative, dynamic, inclusive, and experiential learning environments [44]. To awaken children's authentic learning, educators model learning contexts that are content-rich, relevant to children's needs and capacities, enriched with commonly used AR technology tools, in both group and outdoor settings [12,56]. AR technology enables each child to create personalized learning experiences and to directly explore the educational content presented at their own pace [11].

The use of AR is also grounded in socio-cultural theory [57], as it is important for children's deep learning to enable their social interactions, to learn from each other, and to provide the scaffolding and social support [14]. Traditional approaches to learning, where the teacher is at the center of the learning process and children remain passive listeners, focus on the content of the learning but not on the learning process itself [58]. The use of AR technologies can lead to the transformation of preschool education from a traditional to a constructivist approach [45]. On the other hand, sometimes the reverse phenomenon is observed and may be noticed where teachers, in order to integrate AR technologies into children's education, academicize the educational process by taking on the role of a guide and instructor and by making the child only a passive participant [12].

The roles of the teacher using AR technology often depend on the open- or closed-ended nature of the apps. Papadakis and Kalogiannakis [59] distinguish Manipulable apps, where the teacher can take on the role of an observer or a minimal information provider (providing children with minimal explanations on how to turn the app on, off, and control it) [56,60]. Another group of apps that can be distinguished is Constructive or "productivity" apps, where the teacher takes on the role of a creator of learning contexts or a modeler of engaging situations [56]. Another group of apps that can be identified is the closed-ended group of Instructional apps, where the teacher takes on the role of an instructor, explaining and demonstrating to the children not only how to operate the app but also how to complete the task step by step. In addition to the above-mentioned groups of apps, Papadakis and Kalogiannakis [59] identify another specificity: the apps encourage collaboration. In this case, the teacher can take on the role of acting, thinking, and reflecting with the children. When apps are complex and difficult to manage, the teacher has to take on the role of a mediator between the AR technology and the children (to help, explain, and support) and a proactive facilitator (to raise questions, encourage, overcome challenges, solve problems, etc.) [56].

Masmuzidin et al. [46], in a review of research on the use of AR in preschool, identified the content of education as one of the themes to be analyzed, stressing that the content of AR applications and tools should be in line with the content of the preschool curriculum and the children's age-related capabilities. Research reveals the domains in which AR technology is used in preschool education: science, language learning, mathematics, arts, engineering technology, physical education, and social education [44–46,60,61].

On the other hand, there are fewer studies on what roles teachers take on when using AR technology than there are studies on what areas of education teachers integrate AR technology into.

2.4. Teachers' Perceptions and Attitudes towards AR

In studies examining preschool teachers' perceptions and acceptance of AR technology, there is an overwhelmingly positive attitude towards the use of AR in children's education. Teachers are positive about aspects of children's engagement in the educational process, as well as about the results of AR education and the possibilities of personalizing education. According to teachers, the use of AR technology creates a more enjoyable, child-centered, playful learning process and increases children's chances of achieving their learning goals [62,63]. It motivates and engages children in learning; it develops children's abilities, such as to find information, to use data, to work collaboratively, to concentrate, to understand the meaning of a word, and so on [10]; promotes children's autonomous and active learning [63]; turns science education into a creative process [45]; and creates the conditions to ensure the integrity of the tools used, where AR technologies are used in conjunction with the real world, thus increasing children's interest and enthusiasm to learn [54]. The use of AR technologies, according to teachers, makes children's learning process more flexible and responsive to each child's individual needs and interests, thus facilitating learning [63].

Teachers also report that AR technology is suitable as a teaching aid tool in preschool classrooms [10], which is easy to use and assists with classroom management [62]. The results of a study conducted by Wei et al. [64] confirm that teachers are willing to use AR as a teaching tool, as they believe that the use of AR technology promotes a learning process that is fun, playful, and engaging for children.

Teachers also point to the systematic use of AR technology. The importance of integrating AR technology into daily teaching practices is supported by Ozdamli and Karagozlu's [45] study, in which teachers express the view that AR apps should be used with the learning materials throughout the school year rather than in a fragmented way, because the use of AR technology enhances children's willingness to actively participate in learning activities, helps them to maintain their focus for longer periods of time, and contributes to children's eagerness to learn and to their learning success.

Teachers who are motivated to show the benefits and challenges of using AR technology in preschool children's education reveal the difficulties of organizing the children's educational process. They highlight that the greatest difficulty for preschool children is learning to operate tools with AR technology, which motivates teachers to learn how to select the appropriate tools for children's use (based on age, ways of interacting with the tool, and use in games and other activities) [45,54]. Another challenge is to properly integrate AR activities into children's learning; otherwise, they become distracting. Some teachers argue that inappropriate use of tools with AR technology results in a less intimate child–teacher interaction [63].

Teachers who do not have experience using AR technology have many preconceptions. [65] found that as many as four-fifths of the Turkish preschool teachers in the study had not developed activities for children using AR technology because they did not have the right tools and did not know how to integrate AR technology tools or apps into the children's educational process. About half of these teachers thought that AR technology could not be used in children's art education. Two-thirds of the teachers said that using AR can create dependency in children; about half of the teachers said that using AR can lead to social, communication, and language problems; and some of the teachers mentioned health and concentration problems.

Thus, the research on teachers' attitudes towards the use of AR technology in the education of preschool children shows that the majority of teachers have positive attitudes towards AR technology, highlights some of the teachers' perceived challenges in using it in their children's education, and reveals the perceived benefits of AR technology for children's educational quality and achievement. On the other hand, studies on teachers' attitudes do not provide much analysis of the roles that teachers take on in the application of AR technology and the impact of these roles on children's educational outcomes and learning characteristics.

3. Research Aims and Hypotheses

The aim of the study presented in this paper was to identify educational predictors of deep learning and competence development in children aged 5–7 using AR technology.

A total of two hypotheses were examined:

H1. *Teachers' cognition of AR technology, children's education areas, where AR technology is applied, and teachers' roles applying AR technology are statistically significant educational predictors for children's deep learning using AR technology.*

H2. *Teachers' cognition of AR technology, children's education areas, where AR technology is applied, and teachers' roles applying AR technology are statistically significant educational predictors for the development of children's competencies using AR technology.*

The first hypothesis was developed based on the theoretical assumption that children's deep learning is a process and that qualitative characteristics could be influenced by the use of AR technology. It also draws on research that shows preschool-aged children's deep learning using AR technologies has the following characteristics: active, autonomous/self-regulated, experiential, creative, problem-based, meaningful, multimodal, collaborative [11,12,21–23,31]. The questionnaire for teachers included the question "What are the characteristic significant features of children's learning when you use AR technology in children's education?" and included statements for each characteristic feature of the deep learning process, e.g., "The use of AR technology promotes children's active learning (engaging engagement, interested, active activity, searching and discovering)".

The aim was to check which educational factors associated with the use of AR technology can be predictors of children's deep learning, i.e., encourage the learning process of children with the above characteristics.

One factor that was highlighted was teachers' perception of AR technology. Teachers were asked, "Which statement do you think best fits the definition of AR technology?" and teachers were given four definitions, one of which was a precise definition of AR technology [3], the next is the definition of mixed reality [4], the third is the definition of AI [18], and the fourth is the definition of robotics [66]. This sought to determine whether teachers differentiate AR technology from other digital technologies or whether their perception of AR technology is a predictor of children's deep learning.

Another highlighted educational factor was child preschool education areas (covering educational content, children's activities, and environments intended for its implementation), where AR technology is used. Based on the analysis of the already conducted research, it is revealed that AR technology is applied in the following areas of children's preschool education: social education, natural science, language learning, mathematics learning, artistic education, engineering technological education, and physical education [44,46,60,61]. Teachers were asked, "In which areas of early and preschool education do you use AR technology?" and statements were given for each area of education linked to AR tools, such as "I use AR technology in the area of language learning ('smart marker' for independent letter recognition, word reading, etc.)".

The aim was to determine if the teachers participating in the research apply AR technology in these areas or whether AR technology use in them is the predictor of children's deep learning.

Another important educational factor was teachers' role in applying AR technology. Based on the analysis of research on the application of AR technology to the education of 5–7-year-old children, the following roles performed by teachers are distinguished: (a) practicing using Manipulable and Constructive apps—an observer of children's interaction with AR tools; the creator of situations involving children in activities; the creator of educational contexts with many opportunities for learning in different ways; the provider of minimally necessary information about AR measures; (b) practicing using instruction-based apps (Instructive apps)—the instructor showing children how to perform activities with AR tools step by step; (c) practicing using complex, challenging apps—an intermediary between the content of the AR tool, ways of working with it, and the child; a proactive moderator of children's learning; acting, thinking, and reflecting together with children [11,12,14,59]. The questionnaire included the question "What is your role as an educator in the application of AR technology in children's education?" and included the statements corresponding to each possible role of a teacher, e.g., "I provide children with the minimum necessary technical information to enable them to use and interact with AR tools on their own". The aim was to determine the roles the teachers participating in the study assume when applying AR technology in children's education and whether these roles they assume are predictors of children's deep learning.

The second hypothesis was formed with reference to the research and preschool education curriculum, which depicts the results of children's learning: children acquire social, civil, cultural, science, communication, artistic, health protection, and digital competence basics. Preschool education in our country is oriented toward the development of these competencies, which are presented in the Priešmokyklinio ugdymo bendroji programa

2023 [43] as children's achievements. Teachers were asked, "What is the impact of your use of the used AR technologies on the development of the competences listed below?" and the statements were made, elaborating on the construct of competences, e.g., "It has an impact on social, civic, cultural competence (covering the following achievement domains: perception and expression of emotions, self-regulation and self-control, self-awareness and self-esteem, relationships with adults, relationships with peers, personal and civic identity)". Additionally, the aim was to examine which of the aforementioned educational factors associated with the use of AR technology can serve as predictors of the development of children's competences.

4. Materials and Methods

In order to achieve the research aim, a quantitative research approach [67] and a survey design [68] were adopted, using a questionnaire for teacher-reported measures on the use of AR technologies in education of 5–7-year-old children and their impact on children's deep learning and competence development. The questionnaire for preschool teachers was developed on the basis of a theoretical approach, i.e., by analyzing research articles on the topic of the study and operationalizing the object of the study.

The quantitative study is suitable for determining teachers' attitudes towards children's education using AR technology and for revealing the predictors of deep learning and competence development.

The research instrument consisted of 37 statements designed to reveal the following aspects of the use of AR technology in education of children aged 5–7 years: what the characteristics of children's learning are when teachers use AR technology in their education; which children's competence development is affected by teachers' use of AR technology; which definition of AR technology teachers agree with; in which children's activities teachers use AR technology; what roles in children's education teachers play when using AR technology. The questionnaire also included 4 demographic questions: the age of the teacher completing the questionnaire; gender; the years of teaching experience; and the level of digital literacy the teacher has achieved. The statements were not divided into subscales, as an exploratory factor analysis (EFA) was planned to identify latent factors. In the questionnaire instructions, the participants were invited to voluntarily participate in the survey and were informed about the guarantee of anonymity and confidentiality. A 7-point Likert scale was used to rate the statements, where teachers rated their agreement with the statement on a scale from 1 to 7, with 1 being "strongly disagree" and 7 being "strongly agree". The internal consistency of the questionnaire statements was found to be high, with a Cronbach Alpha of 0.931.

4.1. Sample

Participants were Lithuanian preschool teachers who use AR technology in the educational process. Only those teachers who use AR technology in their children's education were invited to participate in the study. A non-probability sample was formed for the questionnaire survey. The Raosoft sample size calculator was used to calculate the sample size with a margin of error of 5%, a 95% confidence interval, and a 50% response rate. The minimum sample size meeting these conditions was 319 teachers. The number of teachers who completed the questionnaire was 336, but 17 forms were rejected as incomplete. Table 1 shows the distribution of participants by socio-demographic characteristics.

The data show that teachers with different ages and lengths of teaching experience took part in the survey, with a fairly proportional distribution by age and length of service. Among the participants of the research, only 0.6% were male, which corresponds to the reality of preschool education in the country. When assessing their level of digital literacy, the majority of teachers classified themselves as intermediate users based on the digital literacy level descriptions provided to them, while only 10.3% classified themselves as advanced users.

Table 1. Data on the participants in the study (n = 319).

Characteristics of the Participants in the Study		*n*	%
Age	20–30	30	9.4
	31–40	95	29.8
	41–50	96	30.1
	51–60	76	23.8
	61 and more	22	6.9
Gender	Female	317	99.4
	Male	2	0.6
Years of experience in teaching	Less than 2	17	5.3
	From 2 to 5	56	17,6
	From 5 to 10	43	13.5
	From 10 to 15	49	15.4
	From 15 to 20	53	16.6
	From 20 to 25	27	8.5
	25 and more	74	23.2
Degree of digital literacy	Beginner	76	23.8
	Intermediate	210	65.8
	Advanced	33	10.3

4.2. Procedure

All teachers took part in the questionnaire on a voluntary basis. The questionnaire was administered in paper and electronic formats. The questionnaire was uploaded to the electronic portal https://www.manoapklausa.lt/, accessed on 30 January 2024. The invitation to respond to the questionnaire, together with an email giving a broad overview of the purpose of the questionnaire and the procedure for completing it, was sent to all preschool establishments in the country, as well as to schools with pre-primary education groups. The researcher provided a paper form of the questionnaire to those teachers who preferred not to fill out the electronic form. Teachers were asked to consider their practices of applying AR while working with groups of preschool-aged children and to answer the given questions. The aim was to ensure that the survey sample should cover the widest possible population of teachers using AR technology. The data were collected between March and November 2023.

4.3. Data Analysis

Figure 1 shows the design of the data analysis. In the first stage, an exploratory factor analysis (EFA) was carried out, which led to the identification of 5 latent factors: F1: Children's deep learning with AR technology; F2: Children's competence development with AR technology; F3: Teachers' perceptions of AR technology. F4: Children's educational domains in which AR technology is applied; F5: Teachers' role in the application of AR technology. In the second stage, descriptive statistical analyses were carried out for each factor, and percentages were calculated. In the third stage, a multivariate linear regression analysis was carried out to determine the effect of 3 independent variables (F3: teachers' perception of AR technology; F4: children's educational areas using AR technology; F5: teachers' roles in AR technology) on the effect of 2 dependent variables (F1: children's deep learning with AR technology; F2: children's development of competencies using AR technology).

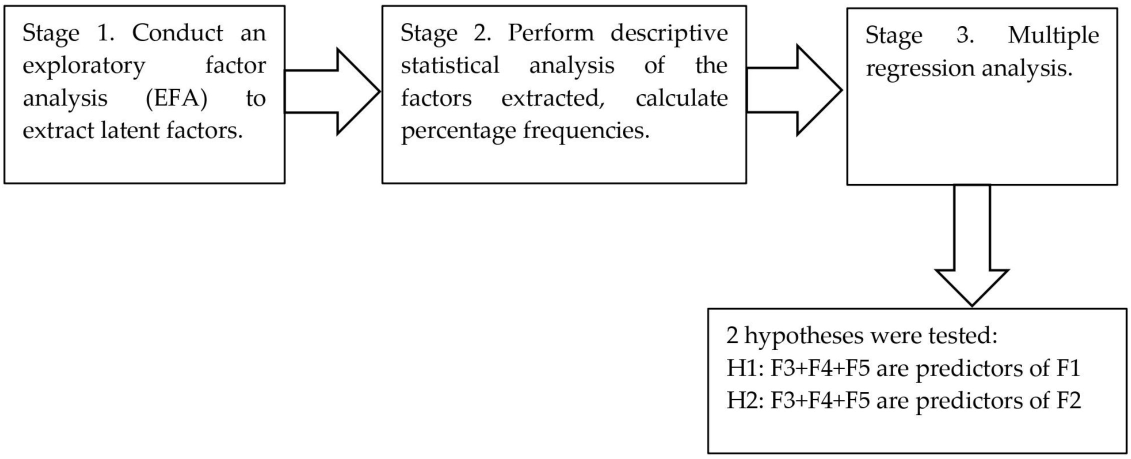

Figure 1. Data analysis design.

The survey data were analyzed using the IBM SPSS Statistics 27 package. The skewness and kurtosis coefficients were calculated to assess whether the data fit the normal distribution. For a sample larger than 300 participants, an asymmetry coefficient value of $-2 < As < 2$ and an excess coefficient value of $-4 < Ex < 4$ indicate that the distribution of the data is close to a normal distribution [69]. Exploratory factor analysis (EFA) was used to reduce the number of questionnaire variables to reveal latent factors [70]. The maximum likelihood (ML) approach of the common factor model (CFM) was used. Factors are interrelated in the developmental process, and therefore a Promax non-orthogonal oblique rotation was applied [71–73]. The Kaiser–Meyer–Olkin (KMO) test was used to test the suitability of the data for exploratory factor analysis. The Cronbach Alpha test was used to determine the internal consistency of the extracted factor statements, with sufficient internal consistency of the factor statements indicated by a Cronbach Alpha value > 0.7 [74].

Descriptive statistics were used to calculate means and standard deviations and percentages for the extracted factor data. Multivariate regression analysis was performed to determine whether the independent variables (F3; F4; F5) were statistically significant predictors of the dependent variables (F1; F2). According to Bekšienė [75], a regression model is appropriate when the coefficient of determination R square > 0.25, i.e., explains more than 25% of the variance of the dependent variable, when the relationship between the variables is statistically significant (F-value, Sig < 0.05), and when the variance inflation index (VIF) is VIF < 4. The standardized coefficient beta (SCB) of a regression model indicates the extent to which the independent variables explain the variance of the dependent variable. The factor is a statistically significant predictor if Unstandardized B > 0,20; Sig < 0.05.

4.4. Ethics

As the questionnaire was published on the electronic portal https://www.manoapklausa.lt/ or distributed in paper version to teachers, they were free to choose whether or not to complete the questionnaire. Teachers who completed the questionnaire expressed their consent to participate in the study. The questionnaire was anonymous and did not reveal personal information about the participants. This ensured complete confidentiality. During the process of filling up the questionnaire, the participants could discontinue filling it up at any time and no longer participate in the study. The data were handled in accordance with all ethical requirements. The questionnaire and methodology for this study were approved by the Ethics Committee of Vytautas Magnus University (31 January 2023, No. SA-EK-23-23).

5. Results

In the first stage of data analysis, exploratory factor analysis was applied to reduce the number of questionnaire variables and to reveal latent dependent and independent factors. Before the factor analysis, the data were checked for a normal distribution. The coefficient of asymmetry for each variable showed that the values satisfy the condition that the coefficient of asymmetry falls within the range (−1.5; 1.5); the coefficient of excess showed that all questions satisfy the condition that the coefficient of excess falls within the range (−2.5; 2.5). The data show that the distribution is close to a normal distribution [47].

The data were tested for goodness of fit for factor analysis using Bartlett's criteria (x^2; df, p) and the KMO criterion (>0.600). The values obtained indicate the suitability of the data for exploratory factor analysis: KMO = 0.912; x^2 = 1039.171; df = 429; $p < 0.0001$. Exploratory factor analysis revealed 5 latent factors (Table 2).

Table 2. Exploratory factor analysis results.

Order No.	Factors	Weights of the Variables	Cronbach's Alpha
F1	Children's deep learning with AR technology	0.874–0.630	0.919
F2	Developing children's competences using AR technology	0.956–0.405	0.901
F3	Teachers' perceptions of AR technology	0.839–0.589	0.835
F4	Areas of children's education using AR technology	0.856–0.680	0.915
F5	Teachers' roles in the application of AR technology	0.876–0.571	0.915

Two dependent factors have been identified as predictors of children's educational outcomes: children's deep learning using AR technology (F1) and children's competence development using AR technology (F2). Three independent factors were also found that predict the factors of AR technology use in children's education that influence children's educational outcomes: teachers' perceptions of AR technology (F3); children's educational domains in which AR technology is used (F4); and teachers' roles in AR technology use (F5). The factors extracted explain 65.62% of the total variance explained.

In the second stage of data analysis, in order to reveal the teachers' attitudes towards the impact of AR technology on children's deep learning, the development of children's competences, the teachers' perception of AR, and the specifics of AR in their groups, descriptive statistical analysis of the extracted factors was carried out, and the frequencies were computed (Figures 2–6).

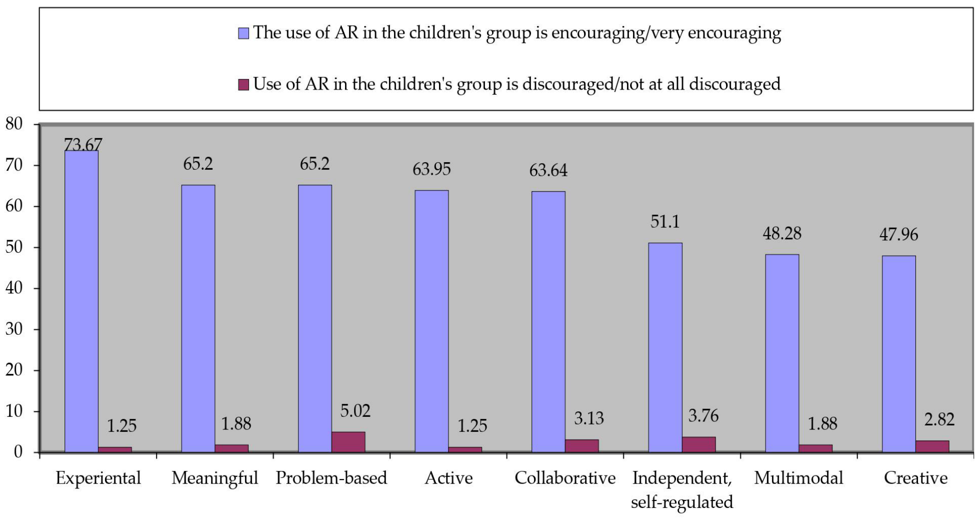

Figure 2. Teachers' perceptions of whether the use of AR technology promotes children's deep learning (%).

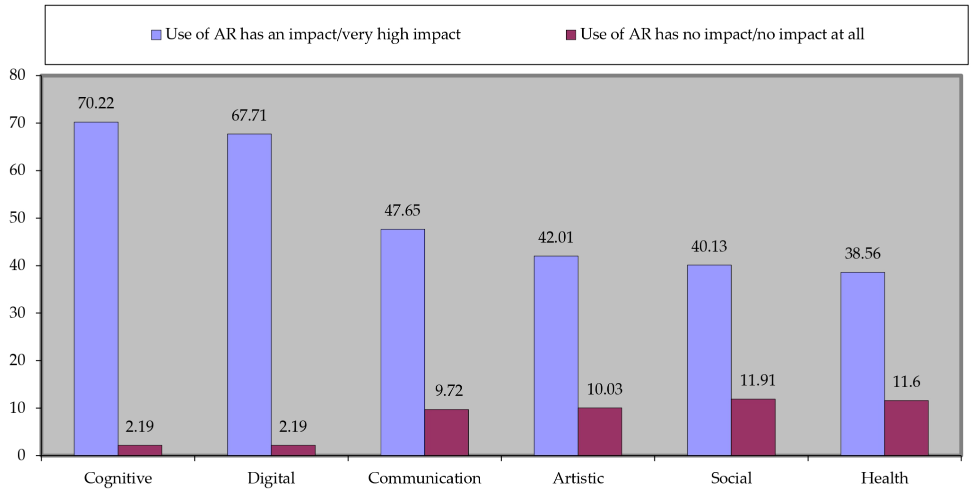

Figure 3. Teachers' attitudes towards the impact of using AR technology on children's competence development (%).

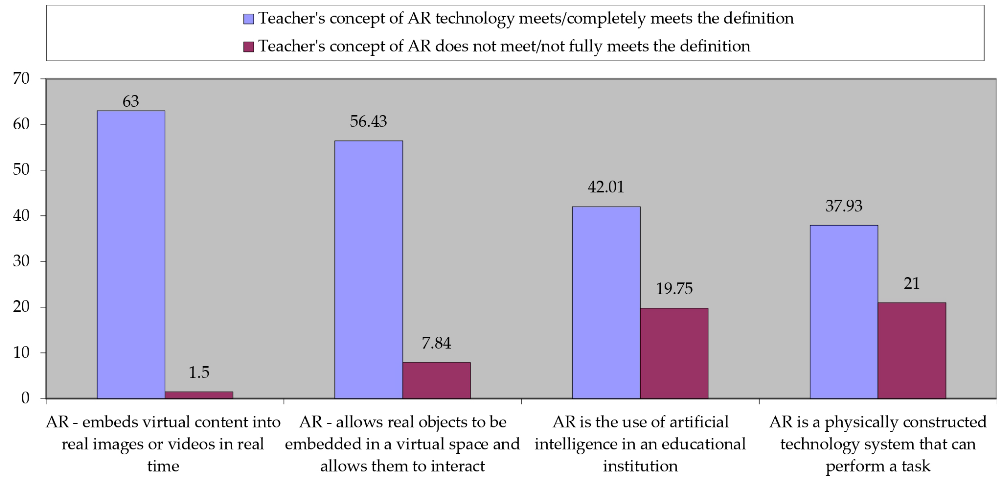

Figure 4. Teachers' opinion on which definition of AR technology corresponds to their conception (%).

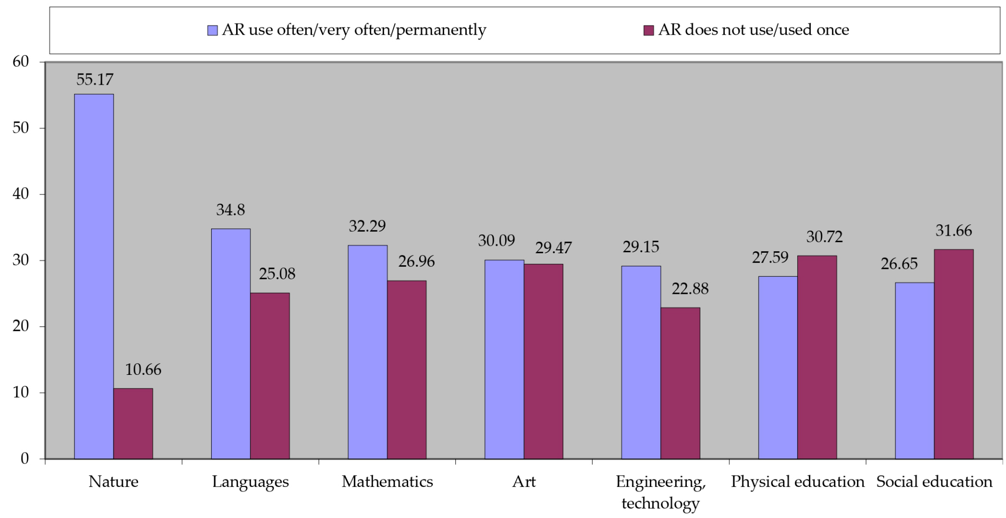

Figure 5. Teachers' information on which areas of children's education they use AR technology (%).

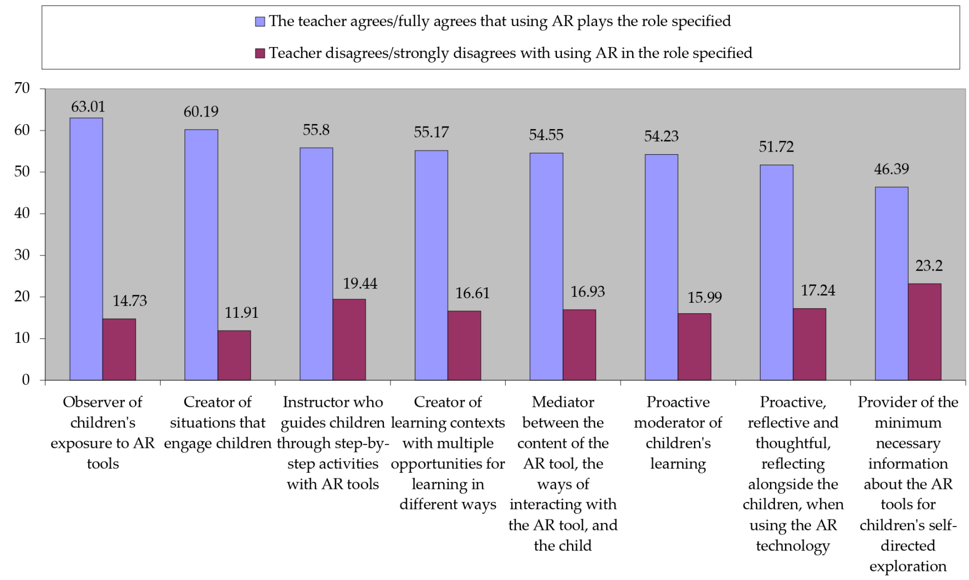

Figure 6. Teachers' perception of their roles in children's education using AR technology (%).

The graphs show the percentage of teachers with the highest and lowest scores expressing their attitude towards the variable.

Teachers' attitudes towards promoting children's deep learning using AR technology (Figure 2). The data show that the highest percentage of teachers (73.67%) perceive that the use of AR technology in children's education encourages/very much encourages children's experiential learning through exploration, explanation, and discovery. 63.64–65.20% of teachers reported that AR technology encourages/very much encourages deep learning, including other characteristics—meaningful, problem-based, active, collaborative. Teachers observe children's active involvement in activities with AR tools, their challenge and problem solving, meaning-making processes, working together towards a common goal, clarifying together, and sharing experiences. A little less than half of the teachers (47.96–51.10%) indicate that the use of AR technology promotes/very much promotes independent, multimodal, creative learning. The estimate for independent learning is lower because teachers observe that children often need support or scaffolding in order to be able to manage AR tools on their own; the estimate for creativity is lower because some AR tools require step-by-step instruction for children, and it is difficult for teachers to model a creative educational process. On the other hand, the percentage of teachers who expressed the view that the use of AR technology does not/does not encourage deep learning in children was only a few percent.

Teachers' perceptions of the competences of children promoted by the use of AR in education (Figure 3). The data show that teachers perceive the greatest impact of AR on the development of children's cognitive (reported by 70.22% of teachers) and digital (reported by 67.71% of teachers) competences. The impact of AR on all other competences assessed—communication, artistic, social, and health—was observed and reported by less than half of the teachers (38.56–47.65%). A tenth of all teachers indicated that the use of AR technologies in their groups has no/completely no impact on the development of these competences in children.

Teachers' perceptions of AR technology (Figure 4). Teachers were offered 4 definitions of AR technology and asked to indicate whether they agreed with the definition of AR given. Teachers were asked to rate each of the definitions given. One of the definitions was accurate: "AR embeds virtual content into real images or videos in real time". The other definitions did not reflect the true meaning of AR. The data show that 63.00% of the teachers identified their concept with the exact definition of AR technology. At the same time, 56.43% of the teachers agreed with the mixed reality definition: "AR allows real objects to be embedded in a virtual space and allows them to interact". Some teachers

(42.01%) identify the concept of AR with the concept of AI: "AR is the use of artificial intelligence in educational institutions", while some (37.93%) identify it with the features of robotics. Thus, teachers' conception of AR technologies is not precise.

Teachers' information on the areas of children's education where they use AR technology (Figure 5). The data show that the highest proportion (55.17%) of teachers use AR technology often/very often/regularly for learning about nature. Only one-tenth of the teachers indicated that they do not use AR technology for nature education or have used it once. In all other areas of education (languages, mathematics, art, engineering technology, physical education, social education), AR technology is used frequently/very frequently/constantly by between 26.65% and 34.80% of teachers. One-third of the teachers in these areas have never used AR technology or have used it only once. Teachers were able to comment on the reasons for the use/non-use of AR in different areas of education, the most important of which is the lack of age-appropriate AR tools for children.

Here we discuss teachers' perceptions of their roles in the educational process using AR technology (Figure 6). The data show that the highest percentage of teachers (63.01% and 60.19%) use AR technology to observe children's interactions with AR tools and to create situations that engage children in the activity. Only a slightly lower proportion of teachers (55.17%) play the roles of creators of learning contexts with multiple opportunities for learning in different ways. The smallest number of teachers, but still almost half (46.39%), take on the role of provider of the minimum necessary information on AR tools to encourage children to act in a self-regulating way. These roles are encouraged by Manipulable and Constructive apps, which allow children to act independently, exploring and discovering on their own. More than half (55.80%) of the teachers have a trainer who guides the children in step-by-step activities with AR tools. Instructive apps are closed-ended and based on instructions. Children are usually not able to work independently with these apps, especially if they are more complex, so teachers take the lead. They usually also play the roles of a mediator between the content of the AR tool, the way it works, and the child (54.55%); a proactive facilitator of the children's learning (54.23%); active thinking reflecting with the children (51.72%); making AR tools accessible to children and making children's learning effective. The data show that teachers have a good identification of their roles in relation to the use of AR in children's education.

In the third stage of data analysis, multiple regression analysis was applied to determine whether the independent factors (F3, F4, and F5) are predictors of the dependent factors (F1 and F2). First, we analyzed teachers' perceptions of AR technology (F3) in children's educational domains where AR technology was used (F4). Then, we analyzed teachers' roles in applying the AR technology (F5 includes predictors of children's deep learning with AR technology (F1)) (Table 3).

Table 3. Results of multiple regression analysis: Model 1. Dependent variable: children's deep learning with AR technology.

Model 1	**Unstandardized B**	**Std. Error**	**Standardized Coefficients Beta (β)**	**t**	**Sig. *p***
(Constant)	2.179	0.289		7.538	0.001
F3. Teachers' conception of AR technology	0.026	0.030	0.041	0.854	0.394
F4. Areas of children's education where AR technology is used	0.063	0.031	0.097	2.029	0.043
F5. Teachers' roles in the application of AR technology	0.560	0.047	0.556	12.022	0.001

Regression analysis revealed that F3, F4, and F5 explain 33.3% of the variance in children's deep learning with AR technology (F1). The coefficient of determination R2 = 0.333, and the obtained regression model is statistically significant (F = 52.305, $p < 0.001$; VIF < 1.093/1.086/1.010).

Only one statically significant predictor—the roles of teachers applying AR technology (β = 0.556, $p < 0.001$)—was found to have an effect on children's deep learning with AR technology. The other two factors (F3 and F4) were not statistically significant predictors: teachers' perception of AR technology (β = 0.041, $p > 0.05$) and children's educational domains in which AR technology is applied (β = 0.097, $p < 0.05$). In the case of both factors, unstandardized B < 0.20 (should be >0.20), and for the F3 factor, $p > 0.05$.

The model is written by the following regression equation: children's deep learning with AR technology = 2.179 + 0.560 F5.

It was also analyzed whether teachers' conception of AR technology (F3), children's educational domains in which AR technology is applied (F4), and teachers' roles in AR technology (F5) are predictors of children's development of competence in using AR technology (F2) (Table 4).

Table 4. Results of multiple regression analysis: Model 2. Dependent variable: children's competence development using AR technology.

Model 2	Unstandardized B	Std. Error	Standardized Coefficients Beta (β)	t	Sig. *p*
(Constant)	0.217	0.406		0.534	0.594
F3. Teachers' conception of AR technology	0.411	0.042	0.444	9.730	0.001
F4. Areas of children's education where AR technology is used	0.253	0.044	0.262	5.765	0.001
F5. Teachers' roles in the application of AR technology	0.317	0.065	0.212	4.834	0.001

Regression analysis revealed that F3, F4, and F5 explain 40.0% of the variance in children's competence development using AR technology. The coefficient of determination R2 = 0.400, and the obtained regression model is statistically significant (F = 69.919, $p < 0.001$; VIF < 1.093/1.086/1.010).

Three statistically significant predictors were identified: teachers' perceptions of AR technology (β = 0.444, $p < 0.001$); children's educational domains in which AR technology is used (β = 0.262, $p < 0.001$); and teachers' role in the application of AR technology (β = 0.212, $p < 0.001$).

The model is written by the following regression equation: Children's competence development using AR technology = 0.217 + 0.411 F3 + 0.253 F4 + 0.317 F5.

6. Discussion

The study revealed that a key, statistically significant predictor of children's deep learning with AR technology is the roles teachers assume when using AR tools. The roles of the teacher, based on a constructivist and socio-cultural approach: creator of educational contexts and situations that engage children; proactive facilitator of children's learning; and active, reflective, thoughtful, and collaborative educator, create the preconditions for children's deep (active, self-directed, experiential, multi-modal, problem-based, creative, meaningful) learning. The role of the teacher, who specifies how to work with AR applications step by step, is contradictory to the preschool education methodology and is unfavorable for self-regulated, creative, and collaborative learning.

Our quantitative study has not provided insights into the reasons why some teachers choose to use AR technology in the children's education as a trainer who guides children through step-by-step activities with AR tools. The assumptions about possible reasons were implied in the article by Papadakis and Kalogiannakis [59], published before our study, which discusses the impact of open- and closed-ended apps on teacher pedagogy. Open-ended apps—"Constructive or 'productivity' apps, which are characterized by an open-ended design that allows users to create their own content or digital artifact using the app" and "Manipulable apps allow for guided discovery and experimentation within a predetermined context or framework" [59] (p. 261)—are in line with the capabilities and pedagogy of preschool children and create the conditions for deep learning. Closed-ended apps or Instructional apps, which have a predetermined "task" that requires specific actions to be performed in a certain sequence, encourage the use of academic approaches. Teachers show children how to complete tasks step by step, but these activities do not provoke deep motivational and cognitive engagement. The nature of the apps used by teachers could be the reason that leads them to opt for a constructivist educational approach or against it.

The results of our study imply the necessity of giving careful scrutiny to the selection and need to pay close attention to the choice of AR technology tools and the role assumed by the teacher in their use.

Other researchers have also raised these issues in their investigations of how teachers should act to avoid the academization of preschool children's education when using AR technology. Land and Zimmerman [56] highlighted the importance of creating contexts for learning, using multiple pedagogical strategies, and using live and technical podsolization to help children become active, deep learners—able to independently observe, understand, and explain phenomena and concepts. Tural [58] emphasizes that the use of AR will be active, in line with learner-centered pedagogy, if the activities are hands-on, inquiry-oriented, problem-solving, and the teacher poses thought-provoking questions to children. Masmuzidin et al. [46] also raise the issue that AR applications should be compatible with preschool pedagogy.

Our study also revealed that several educational factors are statistically significant predictors of children's successful competence development: not only teachers' roles in using AR applications and tools, as already discussed, but also teachers' perceptions of AR technology and the areas of children's education in which teachers integrate AR technology.

A statistically significant predictor of children's competence development, that was unexpected by the researchers, was teachers' perceptions of AR technology. When modelling the study, it seemed that teachers' chosen definitions of AR technology, whether accurate or not, would not be as important a predictor as the practical aspects of using AR technology to develop children's competences. However, according to the results of the study, the teachers' understanding of the concept of AR technology is a good indicator of their professionalism in this area. The identified predictor raises the issue of teachers' competence development in the field of AR technology in relation to the pedagogy of early childhood education.

Another predictor of children's competence development, the areas of children's education in which AR technology is used, highlighted the limited breadth of the use of AR technology.

From the teachers' point of view, the use of AR technology has the greatest impact on children's cognitive and digital competence development. Teachers also acknowledge that AR technology is mostly used for learning about nature. This suggests that AR technology is limited in its application, that it is restricted to one area of science education, and that it supports the development of children's deep learning skills only in the cognitive area. Based on the results of our study, the risk of a weak link between AR and creativity and imagination in preschool education persists.

This highlights the need to expand the targeted, creative use of AR in different areas of children's education, such as social, physical, and artistic education. It is important not to extend the duration of AR technology in children's groups or to use as many applications as possible—children's education should not be overloaded with AR technology. It is relevant to select AR tools or apps that foster deep learning in children, enrich it with opportunities that children do not have in the real world (e.g., to see the invisible inner workings of a structure), provide integral experiences (e.g., agile learning, hands-on science experiences), and are easy to incorporate into the everyday learning contexts that are being created.

The results of our study partially correspond to the review of the research, which, like our study, indicates that the main focus in the application of AR technology is dedicated to the children's science and mathematics education [44,61]. The use of social and health content AR technologies in preschool education is limited [5,15,45]. A progressive trend is to develop AR applications and tools for diverse content that promote collaborative and agile learning through their operating principle [14,15]. Masmuzidin et al. [46] in their research review also raise the issue that AR applications should be more aligned with the preschool curriculum, i.e., they should cover a wider range of content and a broader range of skills.

7. Limitations

Our study reveals the attitudes of teachers who use AR technology in the educational process, but we did not conduct observations of the educational process, nor did we assess the children's deep learning expression and their competences. Further research on the predictors of children's deep learning and competence development would be useful in order to monitor the natural educational process. Another limitation of the study is the use of the newly designed questionnaire, which was approved only for performing EFA. It was not approved for performing CFA. However, high Cronbach's alpha values of the entire questionnaire (0.931) and its individual sections (0.919; 0.901; 0.835; 0.915; and 0.915) demonstrate the suitability for quantitative data analysis. One more study limitation was influenced by the context of the research. In Lithuanian preschool education, the teaching staff is almost exclusively female; consequently, only two males participated. For these reasons, it was not possible to evaluate whether the gender of the teachers is the predictor of the children's deep learning and development of competence in using AR technology.

It was also analyzed if the age of the teachers, years of experience in teaching, or degree of digital literacy are predictors of children's deep learning and development of competence in using AR technology. The finding revealed that none of them are statistically significant predictors for children's deep learning and development of the competencies applying AR technology. Due to the limited scope of the publication, it was impossible to present this data in the article.

8. Conclusions

The study revealed that statistically significant predictors of promoting deep learning in preschool children are teachers' roles based on constructivist and socio-cultural approaches to AR technology: creator of learning contexts and situations that engage children; proactive facilitator of children's learning; and active, reflective, and thoughtful educator together with children. The processes of developing children's competencies are complex, and statistically significant educational predictors in this area are teachers' perceptions of AR technology, the roles assumed by teachers, and the domains of children's education in which AR technology is used.

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Data Availability Statement: Data are available from the authors and can be provided upon request.

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