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Extended Reality as an Educational Resource in the Primary School Classroom: An Interview of Drawbacks and Opportunities

José María Fernández-Batanero [1], Marta Montenegro-Rueda [1], José Fernández-Cerero [1] and Eloy López-Meneses [2,*]

[1] Department of Teaching and Educational Organization, University of Sevilla, 41013 Sevilla, Spain; batanero@us.es (J.M.F.-B.); mmontenegro1@us.es (M.M.-R.); jfcerero@us.es (J.F.-C.)
[2] Department of Education and Social Psychology, Pablo de Olavide University, 41013 Sevilla, Spain
* Correspondence: elopmen@upo.es

Abstract: The use of Extended Reality in Primary Education classrooms has emerged as a transformative element that enhances the teaching and learning process of students. In this context, examining the various effects that this tool can generate is essential to identify both the opportunities and limitations that teachers face when incorporating this technology into their practices. The aim of this research is to analyse the impact of the use of Extended Reality as an educational resource in Primary Education, focusing on teachers' perceptions. The information was collected through semi-structured interviews with 36 active teachers in Primary Education. The analysis of the data obtained identifies the benefits and functionalities offered by the implementation of Extended Reality in Primary Education classrooms, as well as the uncertainties and concerns that teachers have with the implementation of Extended Reality. The results highlight the significant opportunities that Extended Reality offers in the teaching–learning process, provided that teachers are adequately trained. Furthermore, this study offers valuable recommendations to guide future teachers and researchers in the successful integration of this technology into the educational process.

Keywords: ICTs; teachers; immersive learning; benefits; constraints

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1. Introduction

Today, the educational field is immersed in an era of constant transformation, driven by the need to incorporate innovative digital tools that enrich the learning experience of students. Previous studies show that the influence of ICT integration in educational practices is manifested through small educational innovations adapted to the individual methodology of teachers, which are intrinsically linked to their training and attitudes towards teaching and learning [1]. On the other hand, in the last decade, the expansion of online learning has reached the educational domain, which has led research to focus on exploring the potential of emerging technologies in virtual environments [2].

Recent developments, especially in mobile technology, have made innovative tools such as virtual reality (VR), mixed reality (MR) and augmented reality (AR) more accessible as learning resources in classrooms. This technological progress has introduced new terms and concepts, with Extended Reality (hereafter, XR) being a recent expression that encompasses the various forms of interaction with virtual systems [3]. In this context, XR has emerged as a promising technology with the potential to transform primary school classrooms, offering new perspectives and educational possibilities. As its cost has decreased and its ease of use has increased, its impact on education is growing [4]. This perspective plunges us into an exciting technological evolution that promises not only to enrich but also to revolutionise the educational experience at the earliest stages of schooling. The increasing accessibility and sophistication of XR technologies not only offer innovative educational resources but also open up an unprecedented range of opportunities for teaching and

learning in primary classrooms. The ability of XR to create immersive virtual environments where students can actively interact with educational content transcends the traditional boundaries of the classroom, encouraging participation, creativity and critical thinking.

From a theoretical perspective, it is crucial to understand the contributions that extended reality can offer, whether as a beneficial resource that facilitates the dissemination of information or as a disruptive element that could potentially replace teachers [5]. Furthermore, it is crucial to critically reflect on the contributions of extended reality in the educational domain, especially in the context of the development of the metaverse, which poses a challenge that educational theory must seriously address.

Although several studies have reported positive aspects of the integration of XR in schools, the widespread integration of XR as an educational resource for the improvement of the teaching–learning process is hampered by various barriers that limit its effective implementation [6]. This research has transformative potential in education, allowing students to have access to sensory experiences that improve the retention of the knowledge imparted. Therefore, the aim is to understand how XR in the primary classroom can stimulate interest, adapt to individual student needs, and improve the quality of education. Thus, this research aims to investigate the perception of Primary Education teachers in relation to the implementation of XR as an educational resource in the classroom. To achieve this objective, two key research questions are formulated to guide our study:

RQ1: What are the perceptions of Primary Education teachers when implementing Extended Reality as an educational resource in the classroom?

RQ2: What are the future recommendations for using Extended Reality in the Primary School classroom?

This study not only seeks to understand the current state of the implementation of XR in Primary Education classrooms but also to provide different perspectives and recommendations that can guide future teachers, researchers and/or educational leaders in the successful integration of this emerging technology in the educational process.

2. Theoretical Framework

The influence of digital technology in education has radically transformed the participation and development of the teaching–learning process. As technology has advanced, teachers are looking for new ways to integrate it into the educational environment. The term XR encompasses all environments that combine both real and virtual elements, where the human–machine interaction takes place through interactions generated by computer technologies and hardware [7].

XR, which encompasses Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality, has seen significant advances in the last decade, becoming an accessible and increasingly integral tool for Primary Education [8]. XR encompasses a wide range of technologies, ranging from simple enhancement of the real world through digital devices to fully immersive virtual experiences. In this continuum, both Virtual Reality (VR) and Augmented Reality (AR) are simply reference points, as is the 'real world' itself. In this scheme, the real world occupies one end, VR is at or near the opposite end, while AR spans a wide range in between [9,10].

The concept of XR is presented as an all-encompassing term for various technologies, unifying them under the premise of extending reality beyond physical boundaries [8]. The immersion characteristic of XR provides the ability to capture the user's attention, either by superimposing the digital on the physical environment (AR), fully immersing the user in a digital environment (VR) or combining these approaches somewhere in between (MR). It is precisely this immersion that reveals great potential for this tool in the educational domain [11].

Increasingly, the implementation of XR has become a strategy for delivering immersive educational experiences, generating significant benefits for students [12]. The adoption of XR has traditionally been limited by economic factors associated with the cost of the tools or the lack of availability of these tools in schools [13]. However, the development of

innovative technologies, including low-cost mobile XR, has created new opportunities for educational institutions to integrate more accessible immersive virtual environments [14].

XR has the potential to enable students to control their learning strategies during their teaching and learning process, leading to a greater connection between teacher and learner by enhancing both interaction and connectivity. In this regard, several studies distinguish XR according to its use: observational learning, operational learning, academic research and social learning [15,16].

Despite the potential of XR technology to provide a more enriching learning experience for students, it is necessary to consider the training and preparation of teachers for the effective integration of these technologies in the classroom [17]. The critical role of teachers in the teaching–learning process highlights the importance of addressing not only the availability of tools in the educational environment but also the skills and knowledge of teachers to use these technologies effectively. Adequate digital preparation and training of teachers ensures that the implementation of XR technology in the classroom provides a more meaningful educational experience and enhances its positive impact on student development [18,19].

Most parallel studies point to the impact that XR technology offers to primary school students, such as increased motivation, engagement or improved learning outcomes [20,21]. Other studies highlight the key aspects of making XR technology more accessible, such as the pedagogical integration of XR into subject content, the development of teachers' digital skills, the digital infrastructure for integrating XR into education systems and finally, the funding of XR projects in schools [22]. However, despite the great interest that XR is generating in recent years, studies that have considered various factors, such as the uses, advantages, limitations and effectiveness of XR from the perspective of teachers, are limited [12], as mainly studies are found that analyse its impact in the context of secondary or university education (tertiary studies [23]) or that focus exclusively on augmented reality [24].

In this sense, this study seeks to shed light on the implementation of XR in Primary Education, highlighting both the possibilities it offers and the obstacles that need to be overcome. By better understanding these factors, we can lay the foundation for more effective design and implementation of XR in the educational environment, ensuring quality education for all students, as well as understanding the concerns of primary school teachers regarding the application of XR technologies. As emerging technologies are transforming the society in which we live, the implementation of XR in the educational environment becomes evident due to its social and educational importance. The need to explore its specific application in Primary Education classrooms is evidenced by the fact that most studies focus on other educational levels. Therefore, adaptation and its pedagogical impact justify the need to address this gap and provide valuable knowledge for the design of effective educational strategies. The present research makes a significant contribution to the field of research by focusing on Primary Education because, although several studies have been conducted on this technology, few focus on this level of education where the learning dynamics and needs of students are different.

3. Method

3.1. Design

In order to address the proposed objective, a qualitative approach methodology was applied based on an interpretative paradigmatic perspective. The qualitative approach that characterises the interpretative paradigm is appropriate for studying phenomena of a social nature, as it attempts to understand the surrounding reality in its specific sense [25], such as the use of XR in educational centres. The diagram presented in Figure 1 describes the research methodology.

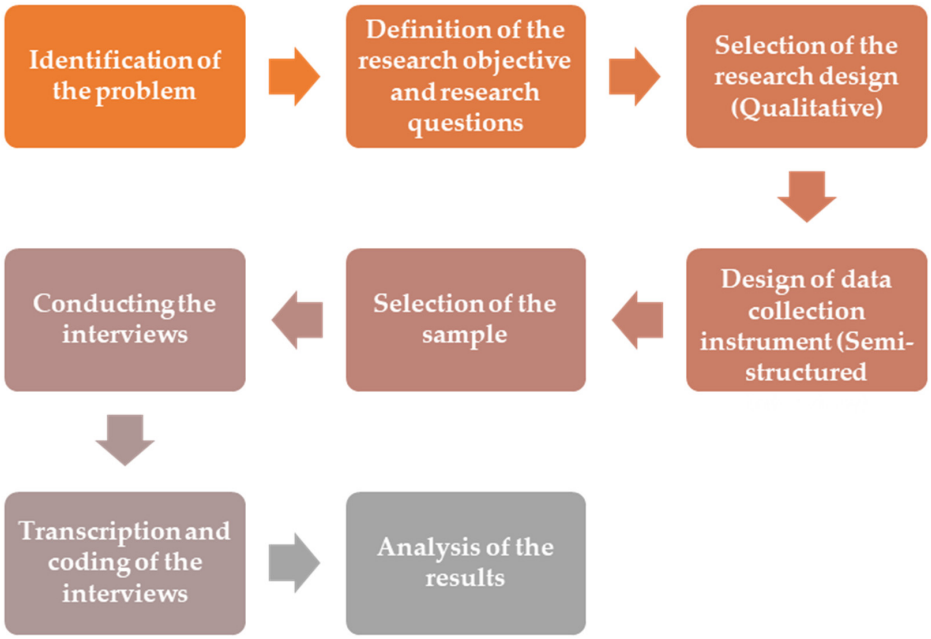


Figure 1. Research methodology.

3.2. Sample

In the present research, the sample consisted of a total of 36 active teachers who teach in different primary schools in the province of Seville (Spain). The distribution of participants according to gender was very balanced, with 55.5% of participants identified as male and 44.5% as female, who were mainly between 30 and 40 years old (50%). The majority of teachers had 5–15 years of teaching experience (61.11%). However, in terms of school ownership, 41.6% of the sample came from state-subsidised schools. Table 1 shows in detail the percentage of participants in the research according to their gender and the ownership of the schools in which they carry out their teaching practice. The access to the field was carried out in a natural way, by means of convenience sampling, more specifically through snowball sampling, allowing for the identification of potential subjects in the selected population, interviewing teachers who were accessed by telephone, as they agreed to participate in the study, during the months of September to October 2023. During these calls, their informed consent to participate in the research was obtained.

Table 1. Demographic data of participants.

Number of Participants			
Gender	Men	N	20
		%	55.5
	Women	N	16
		%	44.5
Age	Less than 30 years	N	5
		%	13.89
	Between 30 and 40 years	N	18
		%	50
	Between 40 and 50 years	N	8
		%	22.22
	More than 50 years	N	5
		%	13.89

Table 1. *Cont.*

Number of Participants			
Ownership of the centre	Public	N	12
		%	33.3
	Concerted	N	15
		%	41.6
	Private	N	9
		%	25
Teaching experience	Between 0 and 5 years	N	10
		%	27.78
	Between 5 and 15 years	N	22
		%	61.11
	More than 10 years	N	4
		%	11.11

3.3. Data Collection Instrument

The instrument used to collect information was the semi-structured interview. The interview script, apart from the preliminary questions (socio-demographic data of the participants), consisted of six questions on the assessment and perception of the use of XR in their teaching practice. Table 2 presents the planned questions for each interviewee.

Table 2. Interview questions.

Q	**Questions**
1	Demographic questions: gender, age, school ownership
2	How would you describe your initial experience of introducing Extended Reality in the Primary School classroom?
3	What have been the main challenges you have faced when introducing Extended Reality into the classroom?
4	What, in your experience, are the most significant opportunities that Extended Reality provides in the teaching–learning process in Primary Education?
5	From your teaching perspective, what changes or developments do you expect to see in the use of Extended Reality in the coming years?
6	How could the preparation of teachers to effectively integrate this technology in the classroom be improved?
7	Finally, is there anything else you would like to add?

The expert judgement strategy was chosen to validate the interview script using the Delphi method. This process was carried out through a document annexed to the interview containing a series of open questions. This document was distributed among a group of 14 specialists in the field of Educational Technology from different universities in Andalusia (Spain). For the selection of the experts, two mechanisms were established. Firstly, experts who met two or more of the following criteria were identified:

- Have taught subjects such as "Educational Technology", "New Technologies applied to Education" or "Information and Communication Technologies applied to Education" in academic institutions.
- Have training in the use of Information and Communication Technologies (ICT) and applied Emerging Technologies.
- Have published relevant research in academic journals or specialised conferences in the field of Emerging Technologies and Extended Reality in education.
- Have actively participated in research projects related to the use of Emerging Technologies or Extended Reality in the educational context.

These criteria were applied to ensure the participation of experts with solid knowledge and relevant experience in the specific areas of Emerging Technologies, such as Extended

Reality, in the educational context. This can be seen in Appendix A. On the other hand, for the selection of the experts, the method known as the "Expert Competence Coefficient" or "K-Coefficient" was used. This coefficient was obtained using the following formula: K = 1/2(Kc + Ka), where Kc represents the "Experience Coefficient" or the information that the expert possesses on the subject, and Ka is the "Argumentation Coefficient" or the basis of the experts' judgement [26].

In our case, the K coefficient was higher than 0.8 in 13 of the 14 selected experts, indicating a very acceptable level of competence [27]. The expert evaluations were carried out in successive rounds and anonymously, using the Delphi method, with the aim of reaching a consensus but allowing the maximum possible autonomy of the participants. The questions formulated to obtain the coefficient of expert competence are detailed in Appendix B.

3.4. Data Collection Procedure

The interviews were conducted remotely via telephone calls, ensuring the privacy and confidentiality of the participants by maintaining anonymity throughout the process. This methodological approach was selected with the intention of creating a comfortable and conducive environment for interviewees to share their experiences in an open and frank manner. The use of telephone interviews made it possible to overcome geographical barriers, facilitating the participation of teachers from different schools located in the province of Seville (Spain). Each interview lasted between twenty and thirty minutes and was conducted in Spanish. All subjects gave verbal and written (email) informed consent for inclusion before participating in the study. The study was conducted in accordance with the Declaration of Helsinki [28], and the fundamental principles of research integrity were respected in accordance with the Research Ethics Committee of the University of Seville.

3.5. Data Analysis Procedure

All telephone interviews were recorded with the consent of the participants and then manually transcribed and coded. In this way, the following stages were carried out: recording of the interviews, transcription of the recordings, pre-reading of the transcripts, coding of categories and deductive subcategories (construction of the categorical system) and the elaboration of a semantic network for the macrocategory. To carry out the content analysis, the Atlas.Ti (2022) software was used.

The categorical system used in the research is detailed below. The category "Opportunities" (OP) focuses on identifying and exploring the possible advantages and benefits that Extended Reality can offer in the Primary Education classroom. This category includes four subcategories: "motivation" (M), "academic performance" (AP), "personalisation of learning" (PL) and "co-operative work" (CW). The category "Obstacles" (OB) examines the challenges and limitations associated with the implementation of Extended Reality in Primary Education. It seeks to understand the possible technical, pedagogical or logistical barriers that could arise and affect the effective use of this technology. This category includes four subcategories: "teacher training" (TT), "availability of resources" (AR), "economic costs" (FC) and "infrastructures" (I). Finally, the category 'Future perspectives' (FP) focuses on the long-term expectations and visions of primary school teachers regarding the role of Extended Reality. It explores possible future directions, anticipated technological developments and how this tool could evolve to further enhance the educational process. This category includes three subcategories: "educational policies" (PP), "lifelong learning" (LL) and "funding" (F). Table 3 presents a detailed analysis of the categories, subcategories and the empirical evidence obtained through the research participants' responses.

Table 3. Codes, categories, subcategories and empirical evidence.

Categories	Subcategories	Evidence
Opportunity (OP)	Motivation (M)	"Whenever technology is used, students are motivated, and this has a positive impact on their learning" (INTERVIEW.06)
	Academic Performance (AP)	"The use of ICTs improves academic performance, because it is innovative, and students like it and are enthusiastic about it" (INTERVIEW.29)
	Personalisation of Learning (PL)	"The existence of enhanced personalisation of learning according to the characteristics of the learner makes Extended Reality incredible" (INTERVIEW.02)
	Co-operative Work (CW)	"To a greater extent, group work helps the teaching and learning process of students" (INTERVIEW.23)
Obstacles (OB)	Teachers Training (TT)	"The teacher has the opportunity to do some training on the technology, but it is not usually specific to Extended Reality" (INTERVIEW.20)
	Availability of Resources (AR)	"There is a shortage of resources to use for all pupils in the school at the same time" (INTERVIEW.01)
	Financial Cost (FC)	"Many centres do not have the money to use these tools unfortunately" (INTERVIEW.15)
	Infrastructure (I)	"The internet connection has been one of the worst problems we have had during the academic year" (INTERVIEW.32)
Future Prospects (FP)	Education policy (EP)	"A restructuring of education policies would be necessary to improve both their use and student learning" (INTERVIEW.17)
	Lifelong Learning (LL)	"Continuous training, there should be more facilities" (INTERVIEW.29)
	Funding (F)	"That schools allocate more funding to the acquisition of such resources" (INTERVIEW.10)

4. Results

In order to present the findings, the most relevant information gathered during the interviews with the participants has been examined in detail, in line with the objectives of the study and the previously established categorisation (Figure 2). The research results reveal three key themes (opportunities, obstacles, and proposals for the future) that will be analysed in the following sections.

4.1. Opportunities

Regarding the category "Opportunities" (OP), teachers have pointed out that the use of XR as an educational tool in the Primary Education classroom provides numerous benefits that significantly affect the teaching and learning process of students, such as motivation, as a positive impact is perceived after its use, and the improvement of academic performance, as a notable increase in the level of participation and interest of students has been observed. In addition, XR has proven to be effective in facilitating a deeper understanding of concepts by providing immersive experiences that stimulate critical thinking and information retention.

> *"A clear change is perceived after the use of Virtual Reality in school subjects, mainly because they are enthusiastic about using the technologies because they find them innovative. It motivates them and they like to use it"* (INTERVIEW.22)

> *"I observed that after applying this technology in my subject, the students understood and acquired the concepts and content much better, and it was reflected in the exams. I think it is quite significant in the process of teaching students"* (INTERVIEW.08)

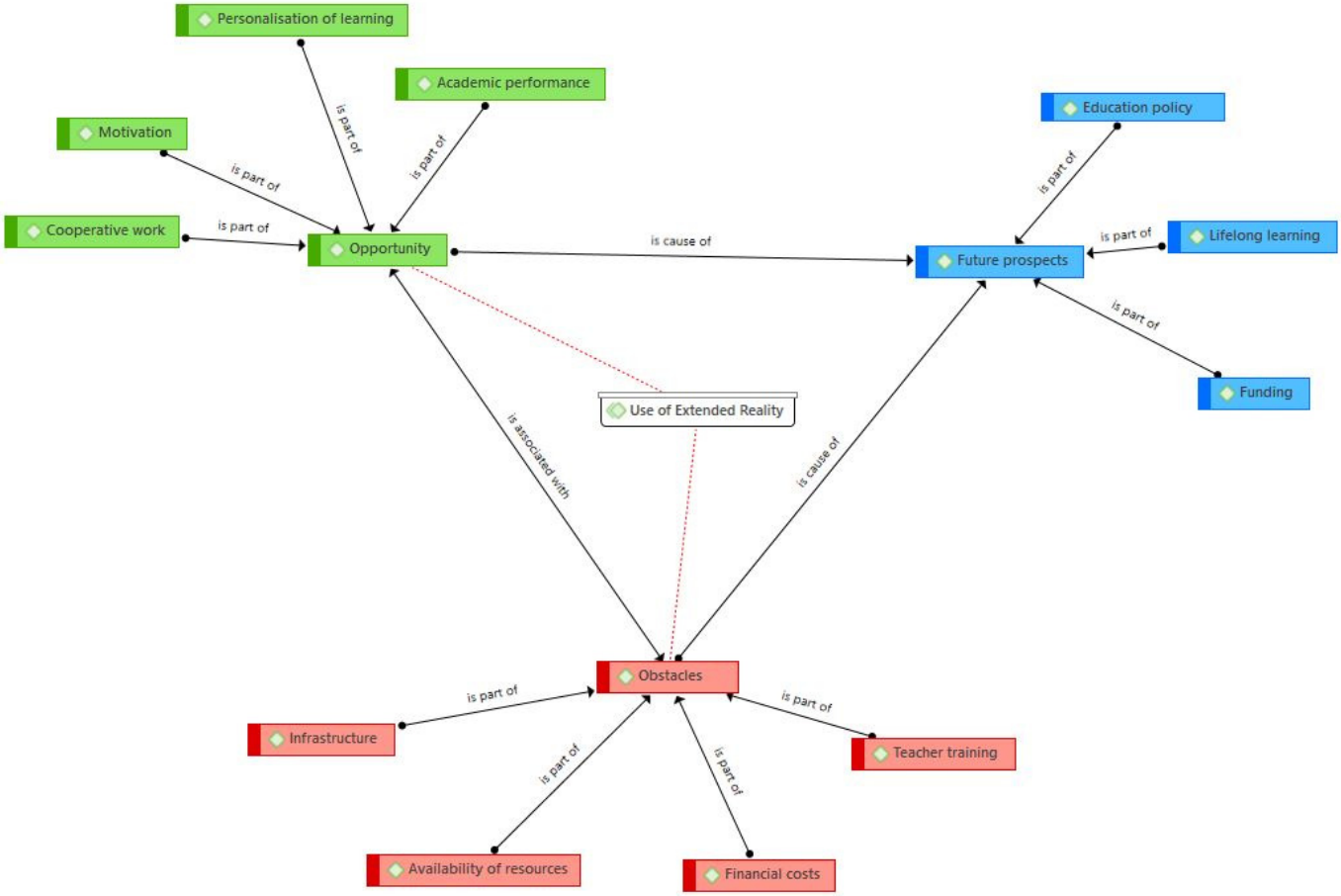


Figure 2. Graphical representation of macrocategories and subcategories in a semantic network.

However, a large percentage of the Primary School teachers who were interviewed reflected in the interviews about other opportunities that XR can provide for the improvement of the teaching and learning process of students. These include the use of co-operative methodology when working with this technology and the personalisation of learning depending on the individual needs of the pupil.

> *"The use of XR in school subjects has generated a clear change in the dynamics of collaborative work among students. It has been shown that the use of these technologies encourages greater interaction between students, creating an environment conducive to collaboration and mutual learning"* (INTERVIEW.19)

> *"The adaptability of these technologies allows content to be tailored to the individual needs of learners, facilitating a more focused approach to their learning preferences and styles"* (INTERVIEW.31)

4.2. Obstacles

Regarding the category "Obstacles" (OB) associated with the use of XR in Primary Education classrooms, teachers from the province of Seville agree that a significant obstacle is the lack of technological knowledge that teachers have to apply this technology in teaching. Implementing XR in the context of Information Technology (IT) requires the training and professional development of teachers in the extended use of these tools so that they can integrate IT into the curriculum of Primary School students.

"In my experience, many of us have not received adequate training on how to integrate Extended Reality into our classrooms. We don't know how to use the tools, and this creates a barrier to implementing the technology effectively." (INTERVIEW.12)

"Not understanding how to use Extended Reality is a barrier to designing meaningful educational activities. And therefore, we cannot take advantage of the full potential that this technology could offer our students". (INTERVIEW.33)

Another group of teachers pointed out that the lack of availability of these resources in schools, mainly due to economic restrictions or infrastructural limitations, is a problem for their implementation. The absence of these resources and an obsolete educational infrastructure limits students' opportunities for quality education. Embedding XR in the IT context requires an adequate technological infrastructure to ensure seamless and effective learning experiences. This requires centres to have a wide range of IT tools, such as high-capacity computers or headsets to deliver immersive experiences, a high-speed network, efficient resource management such as maintenance and upgrading of devices, technical support and network security.

"In our school, we have had difficulties in accessing the necessary technological resources to incorporate Extended Reality. The main barrier has been economic constraints, which prevent us from investing in specialised devices and equipment. In addition, the infrastructure of our classrooms is not prepared to handle these technologies either, which makes it difficult to use them". (INTERVIEW.31)

"Mainly there are not enough resources in the classroom to apply these technologies. That is why we try to use low-cost tools like Merge Cube, which does not need many resources to be applied in classrooms" (INTERVIEW.04)

"I have a lot of difficulties in using the XR due to technical problems or outdated devices". (INTERVIEW.38)

4.3. Future Prospects

Finally, in relation to the category "Future prospects" (FP), it has allowed us to analyse the long-term visions presented by Primary Education teachers regarding the impact and development of XR in the educational field, with the aim of understanding teachers' expectations about how its implementation could evolve and contribute to an improvement in the educational process. Among the main recommendations of the teachers interviewed were the development or adaptation of educational policies to facilitate the adoption of XR in the classroom, as well as understanding how teachers can be effectively trained to integrate XR into their teaching practices through training programmes. Other teachers consider it necessary to propose viable solutions to ensure the availability of resources through possible funding sources, curriculum planning and pedagogical strategies to maximise the educational potential of XR. A crucial recommendation also emerges regarding the need to address the financial issue. Several teachers emphasise the importance of proposing viable solutions to ensure the availability of resources necessary for the successful implementation of XR in the classroom. This includes exploring possible sources of funding, whether through government investment, collaborations with the technology industry or seeking funding at the local or regional level. Ongoing training and financial support are intertwined as key components to ensure an effective transition to the widespread use of XR in educational settings.

"I believe that changes are needed at the political and educational level to overcome these obstacles. For example, it would be necessary to adapt the existing curricular contents and incorporate Extended Reality experiences in a coherent way and aligned with the pedagogical objectives". (INTERVIEW.26)

"We currently have a big problem with the funding available to the school, as it limits us a lot when it comes to applying new methodologies that require electronic devices. Therefore, more funding would be a key element in solving this problem" (INTERVIEW.22)

"Raising teachers' awareness of continuous training for future educational practices with the use of technology is the key element to bring about a significant change in this process. Also, a greater development and accessibility of such training". (INTERVIEW.05)

5. Discussion

The analysis of the interviews has made it possible to address the research questions posed in the study. With regard to the first research question, more specifically the perception of Primary Education teachers when implementing Extended Reality as an educational resource in the classroom, two subcategories can be distinguished: the opportunities offered by XR as an educational tool and the obstacles that may hinder its effective implementation.

In relation to the opportunities, teachers highlight the capacity of XR to transform the educational experience in a significant way. Among the opportunities identified, student motivation, improved academic performance, personalisation of learning and co-operative work stand out. Multiple studies reflect that the learning process is initiated from the ICT approach, given that most students already have an ingrained familiarity with these technological tools, which contributes significantly to cultivating a more solid and lasting motivation in the educational environment [29,30]. In this sense, improved motivation is closely related to improved academic performance. The adoption of XR in the educational context has been widely praised due to its effectiveness as a teaching method. Following this line, the present research coincides with studies mentioned in the theoretical framework, as the use of XR provides an improvement in student motivation and information retention [20,21]. This approach has been shown to offer multiple benefits for students, including increased understanding of content, stimulation of creativity and a notable increase in academic performance [31]. This technology is postulated as a tool to support training, given its undeniable potential to enhance teaching and learning processes when effectively incorporated with traditional educational approaches [32].

However, the use of XR is not only limited to improved motivation and academic performance, as numerous studies have contributed to the scientific literature that they are increasingly being implemented due to the various opportunities they present to raise the quality of education. One of them is related to the ability to facilitate interaction and personalisation of the teaching and learning process, creating an attractive environment for students. The individualised adaptation of the training process, considering the initial level of the students, implies that the learning speed and teaching methodology are adjusted according to the particular needs of each student [33,34]. In addition, the use of diverse methodologies through multiple activities has allowed the integration of the application of co-operative approaches with the use of ICT, which are often well received by students [35], in turn allowing for an improvement in the teaching and learning process. The combination of co-operative work and the use of ICTs favours the development of motivation among students, which is a key component in the learning process [36].

Despite the multiple benefits, the teachers interviewed also point out that the use of this technology presents some challenges. In this sense, addressing the category of "Obstacles" of the extended reality applied in the educational context, the results revolve, fundamentally, around the lack of teacher training and support from educational institutions, coinciding with previous studies [37]. Participants point out the scarcity of pedagogical knowledge for its incorporation into educational practice, a finding that coincides with other authors [38,39].

However, the presence of a robust technology infrastructure in schools plays a crucial role in the successful implementation of technologies in the classroom. Lack of access to high-speed connections and hardware obsolescence represent obstacles that directly impact the successful implementation of XR in the classroom [40]. Along these lines, it is noted that obtaining educational equipment and software involves substantial costs. The lack of resources allocated for the acquisition and maintenance of educational devices and software can hinder the creation of a technological environment conducive to learning [41]. In this sense, the studies mentioned above agree with our results, as it has been restricted by

economic considerations linked to the price of tools or the scarcity of these in educational environments [42].

In relation to the second research question on future recommendations for integrating XR into Primary Education classrooms, teacher perceptions highlight several key considerations to ensure effective and beneficial implementation of this technology in the educational environment.

From a practical perspective, one of the key recommendations of the teachers interviewed is the formulation of educational policies designed to drive the successful integration of XR in primary classrooms. These policies should recognise and support the value of XR as an essential curricular tool in primary education, ensuring that both students and teachers can take full advantage of this technology in the educational process [43]. The aim is for XR to be not simply a complement but an integral and transformative part of the educational process.

However, prior to the incorporation of XR in teaching, it is necessary to improve teacher training in the use of these tools [37]. To address this need, the implementation of teacher training programmes that equip educators with the necessary skills to effectively integrate XR content into their classes is proposed [44]. This training needs to address both technical and pedagogical aspects, thus ensuring an effective implementation aligned with educational objectives.

The implementation of XR into educational settings involves several key technical considerations, such as the selection of XR hardware and devices appropriate to the infrastructure and the needs of students [45]. Key factors to ensure an effective XR implementation experience include the compatibility, performance, and usability of these devices, as well as the acquisition of teachers' skills in XR-specific software development or the ability to integrate XR technology [46].

At the same time, measures must be taken to ensure that all primary schools have equitable access to the technological resources needed to implement XR experiences [47]. These measures include finding sources of funding to enable the acquisition of resources and ensuring adequate Internet connectivity [48]. Institutional support is therefore necessary, especially in view of the economic constraints or infrastructural limitations commonly faced by primary schools.

6. Conclusions

The present research reveals valuable findings on the implementation of XR in primary education. The research developed seeks to close a gap in existing studies by focusing on the implementation of XR in Primary Education, thus providing a solid basis for the design of effective educational strategies and offering significant contributions to the research field, as most research on XR in education focuses on tertiary education. The analysis of the responses of the primary education teachers has allowed us to analyse the opportunities, obstacles, and future perceptions in relation to its incorporation in the classroom. Among the opportunities, it stands out that teachers recognise XR as a versatile tool capable of boosting motivation, improving academic performance, personalising learning and encouraging co-operative work. However, when exploring the obstacles, there is a shared concern about the lack of technological knowledge among teachers and the limited availability of resources, mainly due to economic or infrastructural constraints. The lack of these essential elements is perceived as a barrier to quality education. In terms of prospects, teachers' expectations focus on the development of educational policies that support the integration of XR in the classroom, the improvement of teacher training and the search for viable solutions to ensure the availability of resources. These recommendations underline the need for institutional support to overcome the challenges identified and to ensure the successful and effective integration of XR in primary education.

The limitations of this research include the following. On the one hand, given the exploratory nature of this study and its focus on the perceptions of Primary School teachers in Seville, the conclusions derived cannot be fully generalisable at a national level. Further research with stratified samples covering different autonomous communities and provinces in Spain would be beneficial to obtain a completer and more representative picture. Furthermore, the research is based solely on teachers' perceptions. To obtain a more holistic understanding, it would be advisable to include the students' perspectives, as their views could provide additional dimensions and enrich the analysis. On the other hand, the instrument used collects information based on teachers' self-perception of their knowledge and experience, which could introduce biases in their comments. Finally, the study was carried out with a limited number of participating teachers. Although it provides valuable insights, the generalisability of the results may be conditioned by the sample size. It is recommended that the research be replicated with a larger sample to reinforce the validity of the findings.

The findings obtained in this research suggest several recommendations and areas for future research that could contribute to the advancement and improvement of the integration of XR in the Primary Education educational environment, highlighting the development of educational policies, implementing teacher training programmes or seeking viable solutions to ensure the availability of these resources through various funding sources.

Future Lines of Research

Among the future lines of research, apart from conducting additional research that expands the geographical scope, replicating research with larger samples or extending research to include student perspectives, future research should be directed towards evaluating the pedagogical impact of XR in terms of improvements in academic performance, student engagement and the development of specific skills in the context of Primary Education. These recommendations and future lines of research aim to strengthen the theoretical and practical basis around the implementation of XR in the educational setting, thus contributing to the enrichment and optimisation of teaching and learning experiences in Primary Education.

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Appendix A

Table A1. Participants of the Delphi method.

Participants	Speciality	University	Position
Expert 1	Educational Technology	University of Seville	Professor
Expert 2	Educational Technology	University of Granada	Professor
Expert 3	e-Learning	University of Seville	Professor
Expert 4	Educational Technology	University of Pablo de Olavide	Professor
Expert 5	Gamification	University of Pablo de Olavide	Professor
Expert 6	Virtual/Augmented Reality	University of Seville	Professor
Expert 7	Distance Education	University of Córdoba	Professor
Expert 8	Artificial Intelligence in Education	University of Huelva	Professor
Expert 9	Educational Technology	University of Málaga	Professor
Expert 10	Educative innovation	University of Granada	Professor
Expert 11	Virtual/Augmented Reality	University of Huelva	Professor
Expert 12	Educational Technology	University of Málaga	Professor
Expert 13	Educational Technology	University of Almería	Professor
Expert 14	Technology and gamification	University of Almería	Professor

Appendix B

A document containing a series of open-ended questions linked to the interview script was provided. Each expert contributed detailed and specific answers based on their experience and knowledge in the field of Educational Technology. Some examples that the experts provided were as follows.

Table A2. Responses—Open Questions.

Questions	Expert Response 1	Expert Response 2	...
Do you think that the questions addressed in the script are relevant for evaluating the application of Educational Technology?	Yes, the questions are relevant and cover key issues.	Some questions might be more specific to my area of expertise.	...
What suggestions do you have for improving or adding additional questions to the script?	A question on the respondent's previous experience with specific technologies could be included.	I propose to add a question related to the expectations of applying this tool in the future.	...

References

1. Granados Romero, J.F.; Vargas Pérez, C.V.; Vargas Pérez, R.A. La formación de profesionales competentes e innovadores mediante el uso de metodologías activas. *Rev. Univ. Soc.* **2020**, *12*, 343–349.
2. Cukurova, M.; Luckin, R. Measuring the impact of emerging technologies in education: A pragmatic approach. In *Second Handbook of Information Technology in Primary and Secondary Education*; Voogt, J., Knezek, G., Christensen, R., Lai, K.W., Eds.; Springer: Berlin/Heidelberg, Germany, 2018; Volume 1, pp. 1–19.
3. Margrett, J.A.; Ouverson, K.M.; Gilbert, S.B.; Phillips, L.A.; Charness, N. Older adults' use of extended reality: A systematic review. *Front. Virtual Real.* **2022**, 2. [CrossRef]
4. Pomerantz, J. Teaching and Learning with Extended Reality Technology. In Proceedings of the BOBCATSSS 2019 Conference, Osijek, Croatia, 22–24 January 2019; pp. 138–146.
5. Meirieu, P. El futuro de la Pedagogía. Teoría de la Educación. *Rev. Interuniv.* **2022**, *34*, 69–81. [CrossRef]
6. Simon-Liedtke, J.T.; Baraas, R. The Future of eXtended Reality in Primary and Secondary Education. *Stud. Health Technol. Inform.* **2022**, *2*, 549–556.
7. Doolani, S.; Wessels, C.; Kanal, V.; Sevastopoulos, C.; Jaiswal, A.; Nambiappan, H.R.; Nambiappan, F. A Review of Extended Reality (XR) Technologies for Manufacturing Training. *Technologies* **2020**, *8*, 77. [CrossRef]
8. Çöltekin, A.; Lochhead, I.; Madden, M.; Christophe, S.; Devaux, A.; Pettit, C.; Lock, O.; Shukla, S.; Herman, L.; Stachoň, Z.; et al. Extended reality in spatial sciences: A review of research challenges and future directions. *ISPRS Int. J. Geo-Inf.* **2020**, *9*, 439. [CrossRef]
9. Milgram, P.; Kishino, F. A Taxonomy of Mixed Reality Visual Displays. *IEICE Trans. Inf. Syst.* **1994**, *E77–D*, 1321–1329.
10. Milgram, P.; Takemura, H.; Utsumi, A.; Kishino, F. Augmented reality: A class of displays on the reality-virtuality continuum. In *Telemanipulator and Telepresence Technologies*; Das, H., Ed.; SPIE: Bellingham, UK, 1995; Volume 2351, pp. 282–292.

11. MacCallum, K. The integration of extended reality for student-developed games to support cross-curricular learning. *Front. Virtual Real.* **2022**, *3*, 888689. [CrossRef]
12. Bacca, J.; Baldiris, S.; Fabregat, R.; Graf, S.; Kinshuk, G. Augmented reality trends in education: A systematic review of research and applications. *J. Educ. Technol. Soc.* **2014**, *17*, 133–149.
13. Di Natale, A.F.; Repetto, C.; Riva, G.; Villani, D. Immersive virtual reality in K-12 and higher education: A 10-year systematic review of empirical research. *Br. J. Educ. Technol.* **2020**, *51*, 2006–2033. [CrossRef]
14. Radianti, J.; Majchrzak, T.A.; Fromm, J.; Wohlgenannt, I. A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Comput. Educ.* **2020**, *147*, 103778. [CrossRef]
15. Kuleto, V.; Stanescu, M.; Rankovic MSevic, N.P.; Paun, D.; Teodorescu, S. Extended reality in higher education, a responsible innovation approach for generation y and generation Z. *Sustainability* **2021**, *13*, 11814. [CrossRef]
16. Liu, D.; Bhagat, K.K.; Yuan, G.; Chang, T.W.; Huang, R. The potentials and trends of Virtual Reality in education. In *Virtual, Augmented and Mixed Realities in Education*; Springer: Berlin/Heidelberg, Germany, 2017.
17. Meccawy, M. Teachers' prospective attitudes towards the adoption of extended reality technologies in the classroom: Interests and concerns. *Smart Learn. Environ.* **2023**, *10*, 36. [CrossRef]
18. Fernández Batanero, J.M.; Montenegro Rueda, M.; Fernández Cerero, J.; García Martínez, I. Digital competences for teacher professional development. Systematic review. *Eur. J. Teach. Educ.* **2020**, *40*, 513–531. [CrossRef]
19. Montenegro-Rueda, M.; Fernández-Batanero, J.M. Adaptation and validation of an instrument for assessing the digital competence of special education teachers. *Eur. J. Spec. Needs Educ.* **2023**, 1–17. Available online: https://www.tandfonline.com/doi/abs/10.1080/08856257.2023.2216573 (accessed on 3 February 2024). [CrossRef]
20. Redondo, E.; Fonseca, D.; Navarro, I.; Villagrasa, S.; Peredo, A. Educational Qualitative Assessment of Augmented Reality Models and Digital Sketching applied to Urban Planning. A: Technological Ecosystem for Enhancing Multiculturality. In Proceedings of the TEEM'14 Second International Conference on Technological Ecosystem for Enhancing Multiculturality, Salamanca, Spain, 1–3 October 2014; Association for Computing Machinery. ACM Press: New York, NY, USA, 2014; pp. 447–454.
21. Prendes, C. Realidad Aumentada y Educación: Análisis De Experiencias Prácticas Augmented Reality and Education: Analysis of Practical Experiencies. *Pixel-Bit. Rev. Medios Educ.* **2015**, *46*, 1133–8482.
22. Urquiza Mendoza, L.I.; Auria Burgos, B.A.; Daza Suárez, S.K.; Carriel Paredes, F.R.; Navarrete Ortega, R.I. Uso de la realidad virtual en la educación del future en centros educativos del Ecuador. *J. Sci. Res.* **2016**, *1*, 26–30.
23. 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]
24. Cabero Almenara, J.; Barroso Osuna, J.M. Posibilidades educativas de la Realidad Aumentada. *J. New Approaches Educ. Res.* **2016**, *5*, 46–52.
25. Álvarez-Gayou, J.L. *Cómo Hacer Investigación Cualitativa. Fundamentos y Metodología*; Paidós: Barcelona, Spain, 2003.
26. Fernández Batanero, J.M.; Tadeu, P.; Cabero Almenara, J. ICT and disabilities. Construction of a diagnostic instrument in Spain. *J. Soc. Stud. Educ. Res.* **2018**, *9*, 332–350.
27. Martínez Cepena, M.C.; Cruz Ramírez, M.; Nápoles Valdés, J.E. Problemas de validez y métodos de experto en investigaciones de la educación especial. (Original). *Roca. Rev. Científico-Educ. Prov. Granma* **2021**, *17*, 527–547.
28. WMA. World medical association Declaration of Helsinki: Ethical principles for medical research involving human subjects. *JAMA* **2013**, *310*, 2191–2194. [CrossRef]
29. Area, M.; Cepeda, O.; Feliciano, L. Perspectivas de los alumnos de Educación Primaria y Secundaria sobre el uso escolar de las TIC. *Rev. Educ. Siglo XXI* **2018**, *36*, 229–253. [CrossRef]
30. Amores-Valencia, A.; De-Casas-Moreno, P. El uso de las TIC como herramienta de motivación para alumnos de enseñanza secundaria obligatoria estudio de caso Español. *Hamut´ay* **2019**, *6*, 37–49. [CrossRef]
31. Campos Soto, N.; Ramos Navas-Parejo, M.; Moreno Guerrero, A.J. Realidad virtual y motivación en el contexto educativo: Estudio bibliométrico de los últimos veinte años de Scopus. *Alteridad* **2019**, *15*, 47–60. [CrossRef]
32. De la Torre Cantero, J. Aplicación de Tecnologías Gráficas Avanzadas como Elemento de apoyo en los Procesos de Enseñanza/Aprendizaje del Dibujo, Diseño y Artes Plásticas. Ph.D. Thesis, Universitat Politècnica de València, Valencia, Spain, 2013.
33. López-Rupérez, F. El currículo y la educación en el siglo XXI. In *La Preparación del Futuro y el Enfoque por Competencias*; Narcea: Madrid, Spain, 2020.
34. NEPT. *Reimagining the Role of Technology in Education*; U.S. Department of Education: Washington, DC, USA, 2017. Available online: https://tech.ed.gov (accessed on 3 January 2024).
35. Herrada, R.I.; Baños, R. Aprendizaje cooperativo a través de las nuevas tecnologías: Una revisión. *@Tic Rev. D'innovació Educ.* **2018**, *20*, 16–25.
36. Chamorro, P.P.; Luque, B.; Reina, A.; García-Peinazo, D.; Ojeda, D.; De la Mata, C.; Calderón-Santiago, M.; Gutiérrez-Rubio, D.; Antolí, A. Desarrollo de metodologías de aprendizaje cooperativo a través de Tecnologías de la Información y la Comunicación (TIC). *Rev. Innovación Buenas Prácticas Docentes* **2020**, *9*, 1–16.
37. Barroso-Osuna, J.; Gutiérrez-Castillo, J.J.; Llorente-Cejudo, M.C.; Valencia-Ortiz, R. Dificultades para la incorporación de la realidad aumentada en la enseñanza universitaria: Visiones de los expertos. *J. New Approaches Educ. Res.* **2019**, *8*, 131–147. [CrossRef]
38. Billinghurst, M.; Duenser, A. Augmented reality in the classroom. *Computer* **2012**, *45*, 56–63. [CrossRef]

39. Bower, M.; Howe, C.; McCredie, N.; Robinson, A.; Grover, D. Augmented reality in education-cases, places and potentials. *Educ. Media Int.* **2014**, *51*, 1–15. [CrossRef]
40. Barrett, P.; Treves, A.; Shmis, T.; Ambasz, D. *The Impact of School Infrastructure on Learning: A Synthesis of the Evidence*; World Bank: Washington, DC, USA, 2019.
41. Delavande, A.; Zafar, B. Elección universitaria: El papel de los ingresos esperados, los resultados no pecuniarios y las restricciones financieras. *Rev. Econ. Política* **2019**, *127*, 2343–2393.
42. Otero Franco, A.; Flores González, J. Realidad Virtual: Un Medio De Comunicación De Contenidos. Aplicación Como Herramienta Educativa Y Factores De Diseño E Implantación En Museos Y Espacios Público. *Rev. Científica De Comun. Y Tecnol. Emerg.* **2011**, *9*, 185–211. [CrossRef]
43. Marín-Díaz, V.; Sampedro-Requena, B.E. La realidad aumentada en Educación Primaria desde la visión de los estudiantes. *Rev. Educ.* **2020**, *15*, 61–73.
44. Fernández, M. Augmented Virtual Reality: How to Improve Education Systems. *High. Learn. Res. Commun.* **2017**, *7*, 1–15. [CrossRef]
45. Guo, X.; Guo, Y.; Liu, Y. The Development of Extended Reality in Education: Inspiration from the Research Literature. *Sustainability* **2021**, *13*, 13776. [CrossRef]
46. Marengo, A.; Pagano, A.; Ladisa, L. Towards a mobile augmented reality prototype for corporate training. In Proceedings of the 16th European Conference on e-Learning, Porto, Portugal, 26–27 October 2017.
47. Álvarez, S.; Delgado, L.; Gimeno, M.Á.; Martín, T.; Almaraz, F.; Ruiz, C. The Educational Sandbox: Augmented Reality a new resource for teaching. *EDMETIC Rev. Educ. Mediática TIC* **2017**, *6*, 105–123. [CrossRef]
48. Jhurree, V. Technology integration in education in developing countries: Guidelines to policy makers. *Int. Educ. J.* **2005**, *6*, 467–483.

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