

Report

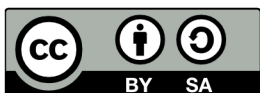
Mapping VR in the School Education Sector

The Future of the Classroom

VIRION

VIRTUAL REALITY APPLIED TO SCHOOL EDUCATION

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VIRTUAL REALITY APPLIED TO SCHOOL EDUCATION

REPORT

MAPPING VR IN THE SCHOOL EDUCATION SECTOR THE FUTURE OF THE CLASSROOM

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TSV, Tsar Simeon Veliki Secondary school (BG)

Premium Cine, Educational VR-content producers (ES)



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1 Introduction

Mapping VR in the Education Sector for the Future of Classrooms

This document is the result of a research work package in the context of the Erasmus+ project "VIRION - Virtual Reality Applied to School Education", n.º 2022-1-ES01-KA220-SCH-000089414. This initiative explores the use of Virtual Reality (VR) as an innovative educational tool aimed at transforming the teaching and learning of the STEM disciplines (Science, Technology, Engineering and Mathematics).

The content presented here is the product of a rigorous research, carried out in four countries - Germany, Bulgaria, Spain and Finland – by five European members, each providing their own experience in education and technology.

- URJC, Universidad Rey Juan Carlos (ES)
- HCU, HafenCity Universität Hamburg (DE)
- LUT, Lappeenranta-Lahti University of Technology (FI)
- TSV, Tsar Simeon Veliki Secondary school (BG)
- Premium Cine, Educational VR-content producers (ES)

With more comprehensive information about the project available (e.g. the project's website, the VIRION White Book), this report will be an in depth documentation on two sub-work packages within the work package 2 "Mapping on VR in the school education sector. The future of the classroom":

- WP2.1 Mapping on the VR in the School Education Sector
- WP2.2 The Future of the Classroom

Objectives of the work packages

The objectives of the two sub-work packages can be described as follows: The Mapping on the VR in the School Education Sector was to be understood as a basic or fundamental research on the state-of-the-art of scientific and technical knowledge of the VR application in school education. It seemed sensible to divide this research into three main components:

- A content-and-solution mapping of existing VR applications in the education sector.
- Interviews with industry experts.
- An analysis of the literature on this issue.

While HCU was the leader of this work package, each academic partner was responsible for the research on the situation in their own country, to which this research was mostly limited in each case. Furthermore, Premium Cine was responsible for an extensive research on VR producers in Europe.

The objective of the Future of the Classroom on the other hand is to summarize the results in a way, that decision makers in the education system can make decisions regarding VR use in schools and create their own visions and strategies. It has therefore been written as a scenario that is supposed to enable the reader and those responsible for the use of VR in schools to gain their own insights and develop their own direction in terms of content in contrast to the scenario available here.

2 Results

Mapping VR in the Education Sector for the Future of Classrooms

The aim of VIRION is to advance virtual reality in the field of school education. However, it is not the case that there has been no progress in this area before. Virtual reality has long been considered a technology of the future, and students, teachers and companies in the field of teaching materials have long since discovered this area for themselves.

As an integral part of the VIRION project, the partners conducted a broad research on virtual reality in school education. This research, referred to as mapping, served to determine the basics of virtual reality in school education. The aim of the mapping was twofold: on the one hand, it served the purposes of the project, for example with regard to the design of the VR apps developed and to align the project materials with the current state of knowledge. On the other hand, this knowledge should be made available to the public in order to inform teachers and decision-makers in the education system and contribute to the public discussion about VR in schools.

Objectives

This chapter comprises the aggregated results of the three sub-chapters described above (content and solution mapping, expert interviews, literature analysis), which together make up the mapping.

Each chapter consists of a brief background to the method used, a summary of the main results and a short conclusion. As described above, the research describes in particular the situation in the respective countries or language areas involved in VIRION, with individual additions for an international perspective. The participating partners were responsible for their respective national research, while the partner HCU was responsible for compiling the overall documentation.

The chosen mix of methods provided a good overview of the state of the art of VR apps, as the respective methods complemented each other well. The interviews made it possible to gain an impression of actors who are intensively involved in the topic and thus also made it possible to gain directions for further research. The content and solution mapping enabled a broad view of the usable applications. The literature research carried out in parallel made it possible to find interview partners, tap into the experiences of other stakeholders and substantiate the results of this work package in the state of the art.

The status of the information is essentially September 2023, when this research was completed.

2.1 Content and Solution Mapping

State-of-art of VR Content and Solutions for Schools

1. Mapping on VR in the school education sector – Solution Mapping

It is important for the members of the VIRION consortium, as well as for interested parties and experts involved with VR in the school sector, to develop an understanding of which VR applications are already available today. This applies all the more if the VR content is limited to the main focus of the VIRION project, i.e. the school sector for pupils between 14 and 16 and the STEM sector.

The development of an overview of the existing solutions makes it possible to assess whether and how they can already be used in school lessons today. An overview of the distribution channels and purchase channels also makes it possible to determine where schools can obtain or acquire them and with which hardware they can use them.

With this in mind, the results of the solution mapping in particular will be presented below, providing an overview of the status of VR content on the market for VR educational content for the school sector. The status of the information is essentially September 2023, when this research was completed. The focus was on applications in the above-mentioned VIRION focus areas and on those that are widespread in the four VIRION countries.

2. Methodology

The search for VR content was carried out by all participating VIRION partners, with a focus on their respective home country. These searches are to be understood as desk research, which included the usual search engines, but also well-known platforms for teaching material or VR.

The initial search was carried out by the partner HafenCity University Hamburg (HCU) comprehensively for Germany and, as far as possible, for the international or English-speaking market. Based on this initial and structural finding (see below), HCU created a framework, in which the partners could perform their national research. Therefore, the mapping is limited to Germany, Spain, Bulgaria and Finland, and to the International

market, to a limited extent. In addition, VIRION partner Premium researched additional VR producers all over Europe.

When attempting to compile a list of VR content for school lessons that is based on quantity and completeness, the problem arises of assessing which content can be described as teaching material: For example, is a VR environment created by a student in their classroom instructional material? Is a guided tour of a museum suitable VR content for history lessons? Is a 3D image of Machu Picchu or Angkor Wat content for geography lessons?

It was not possible to conclusively assess this question because some partners did not have the necessary didactic skills, the technical resources (VR content is available in very different technical formats) and it was not possible to evaluate all available content within the time frame of the project. Instead, all content was taken into account that:

1. is offered as teaching material by a provider from the education sector; or
2. offered by universities or teachers or other trained educators; or
3. are designated as teaching material by didactically trained personnel OR
4. are available on platforms or in databases, where content is described as teaching material.

The market for VR applications appears to be a lively, dynamic and developing market. To understand the market, and cluster and list solutions, it was necessary to first understand and group the market. Therefore, a stakeholder analysis was performed. In the following, the key groups of actors and institutions are discussed, which then served as the basis for the national research.

3.1 Stakeholders in the VR Market

Content Producers

A content producer is responsible for the technical realization of the content. It can be assumed that this entity is usually also responsible for the concept. In some cases, the content producer is also responsible for publishing; by analogy with the book market, this can be regarded as self-publishing.

Content Publisher

A publisher takes over the distribution of VR content that it receives from content producers. A publisher should be understood here as an entity that systematically develops a portfolio of content and has it developed. In the context of this report, these are often providers of dedicated VR content for school lessons (e.g. ClassVR).

Content Resources (Providers/Plattform/Catalogue)

The third, very diverse group of players, which represent places where users can access VR content, is the least tangible.

Content providers can only be distinguished from content publishers to a very limited extent, but were understood as an offer where a portfolio is built up in a much less targeted manner or which is open to offers from other players, especially producers.

Platforms are places where VR content can be made available to providers in a relatively unregulated manner (platform economy), such as the Meta Quest Store or Mozilla Hubs.

Catalogs are collections of references to VR content that are collected in an editorial manner, for which a content review or rating may be available, and whose content may be sortable or filterable.

Other

In addition, there are other applications in the field of VR that seem worth mentioning, such as tools for the independent development of VR environments or VR applications that go beyond the boundaries of what is considered a classic educational VR tool.

3.2 Description of the market

Based on the categories defined above and the research conducted by the VIRION partners into VR applications and players in the field of educational VR content, various formats, models and value chains were identified. Some of these will be discussed in the following.

In addition, the relationship between these stakeholder groups is illustrated in the following diagram :

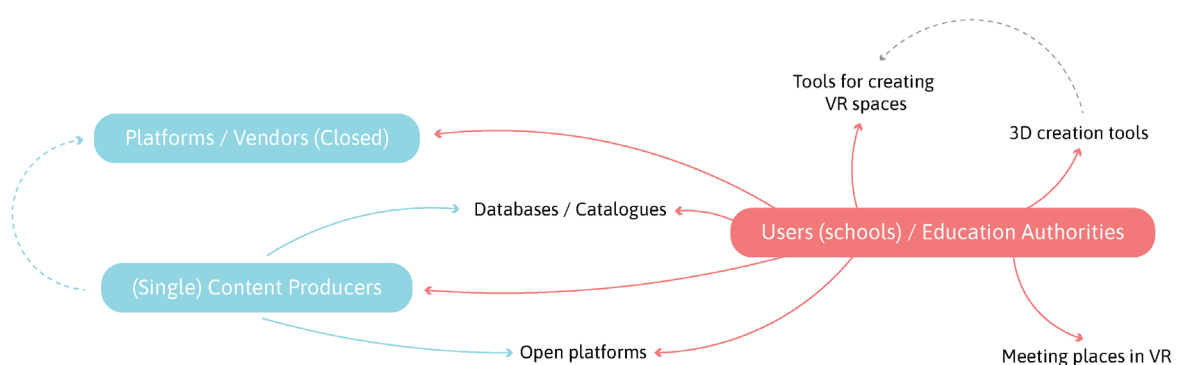


Figure 1: Diagram of the VR market (Source: own illustration, HCU)

What types of offerings are available on the VR application market?

- » Commercially oriented (single) content providers who offer their content on:
 - On their own website: e.g. MelScience
 - Offer on open platforms: e.g. Coatsink offering Shadow Point Puzzle on Meta Quest and PlayStation VR
 - Create for use on (closed) publisher platforms: Content from Insimity offered on Intel Skills for Innovation (SFI)
- » Non-commercially oriented (single) content providers, for example from the field of science, who often offer their content on their own websites
 - Wegfest-App for road safety, published by a scientist
 - A tour through the Anne Frank museum in Amsterdam, published by the foundation of the Anne Frank house
 - German public broadcast stations WDR and SWR publishing content for schools
 - VIRION itself with its four apps can also be named in this category
- » Open platforms where users can provide content to varying degrees, for example free of charge (Mozilla Hubs) or partly for a fee (Meta Quest)
- » (Closed) platforms that were deliberately created for the provision of subscription based teaching materials, sometimes with dedicated hardware (e.g. Class VR, VIL - Virtuelles Interaktives Lernen,

SchooVR, Intel SFI, Intel SFI)

- However, the ClassVR platform, for example, also enables the integration of available free content, where this is technological possible
- » Databases or catalogs that evaluate VR content from a diverse range of providers or are linked externally. Here we found two Germany-based providers:
 - The HAUVI (Hochschulanwendungen mit Augmented Reality und Virtual Reality) tool was created by HessenHub, a digital network for education in the German State of Hesse. It lists AR and VR, and lets users filter for different didactic approaches ("Nutzungswelt"), disciplines, age groups (from Kindergarten to University) and game types. For every content a short description exists.
 - The Center for Didactic Computer Game Research at the University of Education Freiburg offers a data base for educational interactive material like games, videos, and AR/VR content. It lists AR and VR content for primary and secondary education. The user is able to filter by platforms, school subjects, topics, and age groups. For every VR app listed, users find a short description and a "didactic comment"
- » Other
 - VR Content on platforms for self-publishing games and other digital content, e.g. itch.io or Github
 - Meeting places in VR for bi-lingual foreign language teaching/exchange across national borders
 - Tools for creating 3D objects or VR spaces

- Highly specialized applications that may not be able to be used outside of their original purpose, for example Beethoven/Opus 360 ("CLASSIC MEETS RAP. CLASSIC MEETS GAME. CLASSIC MEETS VR."), used in an art project at a school in Hamburg.
- VR environments that interact with other material. For example, the provider Curiscope offers a T-shirt that allows you to use VR to immerse yourself in the body parts that are behind the T-shirt on a real body.
- VR pieces for education that are only available at the location of the provider (e.g. Time Ride)

4. Evaluation of the market for VR applications for School Education

The market for VR applications can be seen as an evolving market. Conceptually, a clear dichotomy can be identified, consisting on the one hand of specialized providers of teaching material with their own ecosystems (full-service providers) and on the other hand of an open market of applications from diverse providers. Such a market is also known from other fields of technology applications (proprietary software/free software; closed system of Apple/IBM PC compatible). These two sides of the current market will be described in more detail below, including the consequences of their use in the school environment.

4.1 Full-Service-Provider

This category includes companies that operate on the market either as a traditional company in the education market (Klett) or as a start-up with a focus on VR applications (ClassVR). They offer a complete ecosystem consisting of dedicated hardware, a variety of compatible VR content for different educational content and a business model based on this. The hardware consists of VR goggles and possibly other hardware, for example for storing and charging the goggles.

What is the advantage of such full-service providers for VR education offerings?

The advantage of such offers is that schools are offered a one-stop shop with the promise of high compatibility and usability as suitability as teaching material. Increasingly, providers are also beginning to tailor their offerings to the curricula of the various school supervisory authorities.

What is the disadvantage of such full-service providers for VR education offerings?

The disadvantage of such closed solutions is that schools may become dependent on a single provider; however, there are also providers that make it possible to offer content from outside their own catalog. This can make it more difficult for schools or educational institutions to switch to other providers or other procurement models if the costs, the content on offer or the technical possibilities only meet their requirements to a limited extent. It should also be noted that the range of non-English language offerings is often (still) limited, especially for smaller countries or less common languages, as the VIRION participants Finland and Bulgaria show.

4.2 Open market for VR educational content

Beyond the full-service providers, there is currently still a diverse market of different offerings (see above) that have been created for different technical platforms. Educational institutions and teachers can choose from a large number of offers, some of which are very specialized, but must first check the suitability of the applications for use in the classroom. Increasingly, however, institutions are also emerging here that create trust, for example providers of catalogs of tested applications (see above and below) or established individuals.

What is the advantage of the open market for VR educational content?

Teachers can use this open market for their own purposes and procure content that may also cover specialized and niche topics. In addition, such an open system makes it particularly easy to exchange and pass on content between schools and teachers in the sense of a “content by teachers for teachers” concept. Another advantage is that many offers are available free of charge.

What is the disadvantage of the open market for VR educational content?

Open market offerings must first be checked by teachers or specialists at the individual schools or educational institutions for their suitability in terms of content and technology, and possible technical incompatibilities must be addressed where possible. Particularly where no specialized VR glasses are used, but standard market glasses (e.g. Meta Quest) are used, school should rely on an appropriate multi-device management tool and also organize appropriate storage.

5. Results Solution Mapping

In addition to the qualitative results of the solution mapping discussed here, the quantitative research results were summarized in a table. In a structured manner, these contain the results relating to the above-mentioned players and categories of the solutions market for the school sector (VR producers, VR publishers, VR resources, VR content). These tables are included as an appendix to this report. For some of these resources, interactive mapping is also available on the VIRION portal.

5.1 Evaluation of the solution mapping with regard to the project objectives

To estimate the range of VR offerings, all available free and fee-based offerings that the project members had access to at the time of the research were collected. They are summarized in the following table. The VIRION content is not included.

These are the main findings:

- There is definitely already content for STEM subjects. However, this is predominantly content from paid providers, for example ClassVR. Free content could not be found at all for some subjects. Some of the paid content is available

for the age group relevant to VIRION.

- Only a small proportion of the content is available in the four languages of the VIRION consortium (Spanish, German, Bulgarian, Finnish). For the latter in particular, there are virtually no offerings at all.
- The example of the provider ClassVR shows that only a small amount of content has been tailored to German curricula to date.

6. Conclusion/Recommendations/Ratings

The VR market for the education sector, and in particular for the field of secondary education, has proven to be dynamic, but also still at an early stage of development. So far, this branch of interactive media tools for school education must still be seen as experimental. In particular, its use in line with curricula is not guaranteed for the time being. For a project like VIRION, there is therefore a good chance that the development of the four VIRION apps in the school subjects of biology, chemistry, mathematics and physics will provide an important impetus for the further develop-

Subject	Number	Free	Age Group (14 - 16)	Languages				
				German	English	Spanish	Finish	Bulgarian
Biology	137	8	50	11	117	5	0	0
Physics	66	5	23	6	60	3	0	0
Chemistry	81	0	18	2	79	0	0	0
Technology	18	0	1	0	18	0	0	0
Engineering	38	0	0	0	38	0	0	0
Mathematics	22	4	3	3	20	1	0	0

Table 1: Available VR content for different STEM subjects, the VIRION languages and age group, based on available content (lists)

ment of the market, particularly for free applications. To ensure the successful further development of this teaching tool, this area must continue to be the focus of attention for decision-makers in the education system and be actively supported.

What recommendations can be given to teachers and schools to expand the use of VR in the classroom?

Sufficient human and material resources must be created in schools for the use of VR in the classroom. As with other digital teaching materials, the introduction should be strategic and planned and, for example, the VR market should be monitored by specialized experts and multipliers. An introduction should take place gradually, from individual experiments to a broader application (see “Future of the Classroom” in the Whitebook) and gradually more teachers should be brought into contact with this tool.

A central question when getting started with VR is whether to use freely available content or to conclude a contract with a full-service provider, see above. Both strategies are justified and depend on the fundamental attitude to this issue. A recommendation for one or the other strategy cannot be given from the perspective of the VIRION project.

What recommendations can be made to school authorities, decision-makers, education authorities and similar stakeholders?

The variety of content, especially that aligned with the curricula, is still very limited. If VR is judged to be a worthwhile subject area, the promotion of its availability should be encouraged in the same way as the availability of digital devices in schools.

Here too, a strategic distinction should be made between full-service providers and the free model. If the full-service provider model is chosen, it would appear to be helpful to further coordinate content with particularly suitable curriculum topics in contact with

individual providers. Such coordination will of course include monetary incentives.

If, above all, the use of freely available applications is to be promoted, appropriate cooperation with developers should be found in which providers and users work together. These should be supplemented by providers of catalogs or databases that make it easier to find suitable offers in an open market. The promotion of such services, as they exist in Freiburg and Hesse in Germany, is also recommended for the other VIRION countries and at European level.

2.2 Interviews

In every participating country, the four academic VIRION project members contacted at least five institutions and interviewed them as part of the Mapping on VR in the school education sector. These interviews were thought to include general directorates of education, academics and others. Within the project consortium, it was understood that these need to be interview partners who already have (first) experiences with VR in school education.

1.1 Methodology and objectives

The aim of these interviews was to find out about the current state of development and the current level of experience in the use of virtual reality in the classroom. The interview partners were selected and the interviews conducted by the respective academic partners in their respective countries. They were conducted by the academic VIRION partners in the respective country as guided interviews.

The following questions were developed as guidelines for conducting the interviews. These could have been expanded on or could have been adapted based on the specific knowledge and/or experience of the interviewee.

- » Usefulness of VR: How do you assess the use of VR and its role in education? How can they imagine the role of VR in the schools in the future?
- » VR in Education: Current role of VR in STEM educations in schools (especially agegroup 14-16)?
- » Content+Providers: Availability of content? Relevant platforms/catalogues/vendors?

- » Schools and VR: How interested are schools? Obstacles? How interested are schools/school leaderships/teachers/students/parents regarding use of VR in education? How do schools right now inform themselves in the field? Where do schools/teachers get information? How can schools be better informed? Which information is needed?
- » In your view, what does a meaningful ecosystem for the use of VR in schools look like?
 - How important do you consider the existence of one-stop providers?
 - How important is the consideration of curricula when creating VR content?
 - What role does the presence of national/teaching language content play?
 - Do you see schools or other public institutions (state institutions, ...) also in the role of content creators?

1.2 Interviews

In the following, for every country the interviewees are named, it is reasoned why they are interviewed and the main findings are given. Finally, the results are summarized.

1.2.1 Interviews/Bulgaria (TSVS)

Interviewees and reasoning (see table)

Name and Surname	Organisation	Sector	Specialist area of field
Ivailo Ivanov	Edusoft, Sofia	Education, Teachers trainings	Former IT teacher at high school, Teachers trainer about new technologies and implementation of IT in school education, Developing methodology for school education,
Todor Georgiev	Kabinata OOD, Sofia	Education, Teachers trainings	Teachers trainer about new technologies and implementation of IT in school education. Development of Concepts for implementation of
Ludmila Popova	SU "Hristo Botev", Ruse	Education	Maths and IT teacher at school education, IT school books
Nikolay Netov, Ph. D.	Sofia University, Faculty of Economics and Business Administration, Department of Statistics and Econometrics	Education	Statistics and Econometrics, Actuarial Science
Plamen Petkov, Ph.D.	134 school, Sofia	Education	IT teacher, Teachers trainer, School books about IT and informatics author

Table 2: Interviewees in Bulgaria and background

Key Findings

Overall results of the application of VR in the areas of VR production and content

- Lack of content interactivity: many VR experiences are still relatively passive, lacking meaningful interactivity. There is the need of enhancing the level of engagement and interaction in VR content and creating more immersive experiences.
- Creating high-quality VR content requires a unique skill set. It is important to provide accessible tools and resources to facilitate content creation.
- Lack of standardized formats and guidelines for VR content creation can make it challenging for developers to create content that is compatible with different VR platforms and devices and can be used by teachers at school.

Overall results of the application of VR in the field of Education

- VR systems can be costly to implement in educational settings, including the purchase of VR headsets, software, and maintenance. This can be a significant barrier for schools with limited budgets.
- Creating VR content that aligns seamlessly with educational curricula can be challenging. Ensuring that VR experiences are not just engaging but also directly relevant to educational goals requires careful planning and collaboration between educators and content creators.
- Teachers will need training to effectively integrate VR into their teaching methods. Providing ongoing support and resources for educators to adapt to new technologies is crucial for

successful implementation.

- Extended use of VR in the classroom may lead to concerns such as eye strain, motion sickness, and fatigue, especially in younger students. Establishing guidelines for safe and age-appropriate VR use is essential.
- Not all students may have equal access to VR technology at home, potentially creating disparities in educational experiences. Schools need to consider how to address these disparities to ensure all students can benefit from VR-enhanced learning.
- The availability of diverse and inclusive VR educational content is limited. VR should be implemented to a wide range of subjects, learning styles, national curriculums and cultural backgrounds and it is important for an inclusive educational environment.
- Schools need to have reliable technical support and maintenance plans to address the possible issues regarding software updates and equipment malfunctions.
- VR platforms may collect student data and that raising concerns about privacy and security at schools and issues regarding school regulations.
- It's essential to ensure that VR experiences align with specific learning objectives rather than being used for novelty purposes. Clear educational goals should guide the development and implementation of VR content.
- Providing tools for educators to tailor VR experiences to their specific curriculum can enhance effectiveness.
- Establish guidelines for safe and responsible

use of VR, considering factors such as recommended usage time, ergonomic considerations, and addressing potential health issues.

- Consider a blended learning approach that combines VR experiences with the other inclusive educational methods at school.

Noteworthy Statements

"We should align the use of VR with the Bulgarian national curriculum. Ensure that VR activities complement existing lesson plans and contribute to the achievement of educational objectives. VR content should be available in Bulgarian or support localization to ensure that it resonates with the students and fits the language of instruction."

Ludmila Popova, Maths and IT teacher at secondary school

"We have to assess the availability and affordability of VR equipment in the school – the number of VR headsets, compatible devices, and the financial resources required for acquisition. And we need to establish guidelines for safe and responsible use of VR, considering factors such as recommended usage time, ergonomic considerations, and addressing potential health issues like motion sickness etc. "

Plamen Petrov, High school IT teacher

"The VR applications could facilitate collaborative learning experiences. Virtual environments can be used to encourage teamwork and problem-solving among students. It is also very important to implement systems for gathering feedback from both teachers and students about the effectiveness of VR in the classroom. This feedback can guide adjustments and improvements. For the schools is also very important from the small age to integrate discussions about digital citizenship and responsible technology use into lessons involving VR. This will help students understand the ethical considerations of using immersive technologies."

Ivailo Ivanov, former IT teacher at high school

"We have to think more how to involve parents and the local community in the VR implementation process at schools. This can help to build support and understanding for the use of technology in education. We also need to encourage the teachers' support in implementation and usage of VR at school. We need to explore the possibility of offering professional development credits or certifications for teachers who complete VR training

programs and want to implement VR in their lessons."

Todor Georgiev, manager of organization, teachers training provider

"We have to assess how VR can enhance the students learning experience. Consider specific applications, simulations, or scenarios where VR can provide a more immersive understanding of learning concepts in different school subjects. Developing of support systems or introductory sessions to familiarize students with VR tools might be also needed. We have to determine how VR can complement traditional teaching methods rather than replace them entirely. We need to consider a blended learning approach that combines VR experiences with the other inclusive educational methods at school."

Nikolai Netov, University professor

1.2.2 Finland (LUT)

Interviewees and reasoning (see table)

Name and Surname	Organisation	Sector	Specialist area of field
Jussi Kasurinen	LUT university	Associate Professor	Software Engineering
Sakari Penttilä	LUT university	Post-doctoral researcher	Mechanical Engineering, welding technology, XR technology
Hannu Lund	LUT university	Junior Researcher	Mechanical Engineering, welding technology
Erno Vanhala	LUT university	University Lecturer	Software Engineering
Mari Jämsen	Konnevesi high school, Lapuanmäki school	Deputy Principal	Member of Administration
Mikko Nikkanen	LUT university	Teacher	Electrical Engineering

Table 3: Interviewees in Finland and background

Key findings

Usefulness of VR: How do you assess the use of VR and its role in education? How can you imagine the role of VR in schools in the future?

- All interviewees agreed that the use of VR technology in education will increase in the future. As the prices become more reasonable due to market competition and mass production public schools are able to invest in the technology. Currently, the obstacles for adopting VR in education are the expenses, the lack of quality content and the lack of standardization. Lack of standardization means that once a school invests in a system, they are committed to one platform but there is no guarantee on how long that platform will last. Public education institutions do not have the funding to then switch systems which makes it an unattractive investment.
- One stated that the importance will become more crucial in the future while others mentioned that they think it will be used more as a supporting tool for visualization and teaching preliminary steps for skills where testing in practice is needed. One suggested that a possible target use is virtual museums which gives more remote schools access to museums and exhibits which are now accessible only to larger city schools. One also proposed that potentially dangerous laboratory sessions could be first held in VR to get the students comfortable with the practices.

VR in Education: Current role of VR in STEM education in schools (especially age group 14-16)?

- Most interviewees stated that they think VR technology used in the age group 14 – 16 is non-existent or very minimal. The deputy principal of Konnevesi mentioned that in their

school VR is used frequently in STEM education and especially in that age group. Although they do agree that it could very well be adapted to STEM education, they have not heard of many actual applications since VR is not significantly implemented in universities either. One interviewee also mentioned that they are part of a teaching team which teaches high schoolers about electricity and that VR could be beneficial for this.

Content + Providers: Availability of content? Relevant platforms/catalogues/vendors?

- Content tailored to schools and school curriculum are scarce and there is definitely room for improvement. Most applications that are available are commercially available to all customers which are usually not directly applicable to specific teaching subjects. Most of this software is games and work life orientated. Still, some device providers allow you to develop your own software for specific use. One interviewee pointed out that simulators are the best content for teaching however they are very expensive and cheap/freeware software that are also of high quality are rare to come by.
- For Finland and for an age group so young the used software needs to be in Finnish so, the content creation has not included localization yet, which will only happen once there are more consumers. In Finland the government or the municipality governments make the purchases for public schools which means that the content needs to be attractive enough to make the investment. Platforms mentioned included SteamVR, Viveport, Meta and SideQuest.

Schools and VR: How interested are schools? Obstacles? How interested are schools/school leaderships/teachers/students/parents regarding the use of VR in education? How do schools right now inform them-

selves in the field? Where do schools/teachers get information? How can schools be better informed? Which information is needed?

- On the question on how interested schools are in VR, the answers were somewhat mixed. Some stated that schools are not keen because the technology is very expensive and there is not enough content to justify the expenses. Most agreed though that higher education institutions are the most interested in the technology and one noted that school leadership could find the investment beneficial for marketing value. One interviewee noted that in the case of practical subjects like welding, the economic expenses are reduced when using VR. It reduces the material and personnel costs while increasing the learning outcome. In Konnevesi teachers are very motivated in learning new ICT skills which the parents have also come to appreciate their children are gaining.
- For obstacles, everyone agreed on money being the first and biggest cause. Investing in VR would mean that the school then probably has to cut from somewhere else. They also mentioned the low life cycle of the hardware and the lack of knowledge the teachers have as well as the need to develop their own applications if there are none available beforehand and that usability is limited (e.g., some get motion sickness and headaches).
- Some mentioned that schools get their information from them using the systems individually in a trial by error method and that there are not many training options available. Others stated that teachers inform themselves through international or national projects and that the ministry of education is fairly active in inviting teachers to different experiments with new technologies. In Konnevesi teachers follow the field's conversations and the related training available which Konnevesi's municipality encourages and strives to enable versatile opportunities for training. The staff then shares their knowledge in their own pedagogical functions. They also mentioned that in Konnevesi they are now focusing their training on how to use AI in education.

In your view, what does a meaningful ecosystem for the use of VR in schools look like?

- A meaningful ecosystem for the use of VR requires content in Finnish and research where VR is seen clearly as a benefit in education.

How important do you consider the existence of one-stop providers?

- All interviewees agree that having a one-stop provider is crucial. It would ease the installation process and it needs to be easy enough to not require sophisticated engineering skills. This is also because teachers do not have the resources to create their own content nor develop VR software.

How important is the consideration of curricula when creating VR content?

- Everyone agreed that there is no great need to change the curricula to include teaching with VR. If VR is not proved to positively affect the curricula, then there is no need to add it although adding it would probably encourage schools to start using it. One also noted that universities are not so strictly connected to a curriculum so when dealing with VR the curriculum does not affect this.

What role does the presence of Finnish language content play?

- The importance of Finnish language content in Finnish schools when adopting VR into their teaching is quite dependent on the age group. Older students most likely already know a lot of English and since English is the mainstream language in technologies, they probably would not mind it. Younger children on the other hand, would need to have Finnish language content and if these technologies do not already have this content, then they are not mature enough to be used in teaching.

Do you see schools or other public institutions (state institutions, ...) also in the role of content creators?

- Interviewees were quite scattered in their opinions for this question. One said that they do not see schools becoming the content creators and that businesses should make the content but with the knowledge and guidance of schools. They think that small content will be created through school projects and student works. Another said that there should be guidelines for content creation which does not exist currently. Then there was a statement that they hope this is the future, that schools have the knowledge, but they do not have the resources currently to make it happen. And another said that students should be able to create their own content as a means to learn actively.

1.2.3 Interviews/Germany (HCU)

Interviewees and reasoning (see table)

Name and Surname	Organisation	Sector	Specialist area of field
Nicole Haferlandt	Institut für Qualitätsentwicklung an Schulen Schleswig-Holstein (IQSH) (Institute for Quality Development at Schools), SINUS-SH initiative	Coordinator	Teacher, School administration, Information and further training for teachers with a focus on STEM subjects
Jana-Maria Keine	Archbishopric of Hamburg, School Board	Advisor on School Development & Digitalization	Educator, the school board had already had experience with VR
Christoph Song	VR Science Lerntechnologie	Founder and CEO	Provider of VR solutions for schools
Stephanie Wössner	Landesmedienzentrum Baden-Württemberg (state media center for education of the state of Baden-Württemberg)	University Lecturer	Teacher, Lead of the staff office for Future of Learning, consultant, runs a private blog on technology in school education
Dr. Dr. Mareike Frevert	Universität (University) Kassel	Research fellow at the chair for the didactics of chemistry	Experience in creating VR for education, mostly in the tertiary sector

Table 4: Interviewees in Germany and background

Key Findings

All interviewees support the increasing use of VR, but it has to be taken into account, that there was a bias in the selection of the interviewees, insofar that all were already engaged in this field

The interviewees could only to a limited extent help with an overview over the general market of VR content and solutions for the education/school sector. The interviewees chosen often had to narrow a view on a specific field in VR (or STEM or school administration)

- a number of interviewees called for more comprehensive information of VR and available content, providers and solutions

A number of interviewees stressed the missing VR content in STEM and/or other fields of education. Together with the experts, we could identify a “chicken-or-egg” problem, where missing VR content offering and demand are mutually dependent.

- One interviewee instead criticized the call for “VR content”. They deemed existing content often didactically traditional and questioned whether in these cases the use of VR actually adds value. Instead, they call for VR worlds that benefit of the opportunities that VR offers, like immersion, collaboration and problem solving. Multiple interviewees call for the usage of quests and challenges in the biology VR content.
- One interviewee experienced in the field has seen a growth in the amount of VR content available in the last 5 years.
- The availability of German content is very important for the school environment.
- The availability of curriculum-integrated con-

tent is relevant for schools, especially due to the increasing formalization and bureaucratization of the school system, or with the decreasing independence of individual teachers.

The experts agree, that VR is not widely used in German schools

- One interviewee sees private schools as especially engaged and destined to take a leader role in VR adoption
- Small school agencies (non-profit/churches/privat schools) profit from their flexibility to successfully test trial VR solutions.

The interest of schools in VR is limited, as schools have to tackle a number of challenges, even a shortage of teachers. VR is even not the only technology that schools have to or can adopt for their needs. The experts usually see VR as only one kind of technology in the future tool kit of schools.

- VR can be seen on the same level as a book or other technology, each dedicated for a specific need.
- Many experts agree that there is often a limited number of teachers in each school that are highly interested or enthusiastic on VR. One interviewee estimates that 90% of teachers are not very interested or knowledgeable on VR, 5% are mostly looking for prefabricated content and another 5% prefer to use VR in a new didactic environment.
- One interviewee emphasizes that the test use of VR often arouses interest among previously uninterested teachers

The experts see the same challenges in an increasing usage of VR in education

- inadequate financial, technical, logistic equipment of schools
- Lack of VR system prevents teachers from getting experience with VR
- lack of content (see above)
- high cost of existing VR software (and hardware)
- Some call for naming/promoting multipliers in each school for the field of VR
- Data protection issues exist with some of the VR systems
- Some see a generally low willingness to try new things in the German education system, even at the risk of occasionally making mistakes (risk-aversion)
- These are the contents that the experts specifically would like to exist as VR content or where they see value in using VR
 - Ms. Haferlandt named the following fields of STEM: Fractions, functional relationships, variables, terms, equation concepts, dealing with fractions, percentages. Primary: place value systems, 1x1 comprehension, multiplication and division.
 - Based on her experience in the field, others see value for VR especially in language education
 - Ms. Frevert sees VR as a good way to communicate concepts of Chemistry that often avoid children due to their nature of being not visible and to the lack of relevance for everyday life events. Nonetheless, she speaks out against non-factual STEM content and simplifying content for the purpose of comprehension, e.g. using colors within parts of an Atom, that do not exist.
 - Multiple interviewees recognizes that students are allowed to handle less and less chemicals themselves, so VR could be used to perform risky experiments.

1.2.4 Spain (URJC)

Interviewees and reasoning (see table)

Name and Surname	Organisation	Sector	Specialist area of field
José Luis Navarro Salinas	Lito & Company	Coordinator	Teacher, School administration, Information and further training for teachers with a focus on STEM subjects
María del Carmen García Villa	IES Carlos María de Valcárcel (High school)	EDUCATION FP (Professional Training)	Development of interactive activities
Álvaro Holguera Gozalo	IES Puerta Bonita (High school)	Education	Animation
Marcelo Fernández	IberPhys / Games Room VR	CEO Content Company	-
Sebastián A. Latorre Montero	IES El Bosco (High school)	Education FP	Lecturer in Electronics. Coordinator of ATECA classroom.
Estafanía Catellanos Otero	IES El Bosco (High school)	Education FP	Health emergencies.
Oscar Chacón Pizarro	IES El Bosco (High school)	Education FP	Mechanical manufacturing

Table 5: Interviewees in Spain and background

Key Findings

Overall results of the application of VR in the areas of production and content

- Need for the industry to describe its usefulness for the education system. To do so, joint work involving both sides is necessary.
- The industry requires the inclusion of Virtual Reality Packs in the educational centers, comprising X number of devices, a specific room with access to contents and the introduction of creation tools for teachers.
- The future is in what has been called “Time2Sync”, in other words, the moment when the manufacturers of hardware, OS software and tools, together with content creators provide solutions which make sense and are useful for the end users of those technologies.

Overall results of the application of VR in the field of education

- VR has had little penetration into the field of education due to a lack of training of teaching staff, the demotivation of the latter when it comes to incorporating new technologies, and unawareness of their use as an educational tool depending on the methodology employed.
- There is a call for greater support and VR creation content tools for teachers, who are currently self-taught.
- A need to extend the catalogue of free and open-access materials.
- The need for financial support for the schools to enable them to implement technology. This technology is very expensive for a teaching institution.
- Improve the relationship between companies and education to help make subject syllabus more suitable.
- Create content by level of difficulty and quality. Extend the catalogue of content in Spanish as there is very little at the moment.
- VR is understood to be a tool which facilitates the learning of those immersive experiments that focus on processes or complex/complicated simulations.

- Individual equipment gives rise to tiredness.
- Large usefulness of the application in distance learning mode
- Possibility of personalizing content.
- Creating collaborative and individual virtual environments.
- A tool of inclusion for disabled persons.
- Training of teaching staff in this type of tools and their inclusion in methodologies.
- Follow-up and after sales services are of vital importance.

Noteworthy Statements

“VR, like any other technology, can play a very important role in education. Both in the simulation of scenarios which would otherwise be inaccessible for students (high altitude simulation or flight simulation), and for persons with mobility, hearing or visual difficulty who, otherwise, would not be able to access the simulated scenarios.”

Sebastián A. Latorre Montero

“It is necessary to actively promote policies which favor the spreading of and research into these technologies applied to any human activity so that EVERYONE can understand them and visualize their potential.”

José Luis Navarro Salinas

“I think technology will become more affordable and there will be more specific solutions for the education sector. But we still have to reach a concept which I use in my classes and which I call ‘Time2Sync’, which represents the moment when manufacturers of hardware, OS software and tools, and the creators of solu-

tions become synchronized so that they make sense and have usefulness for end users who, in turn, will take on the technologies as tools, in a more natural way.”

José Luis Navarro Salinas

“They are the technologies with the most natural interface for humans that have ever been created. By better adapting to humans and their diversity, they provide a much more powerful set of tools than the solutions which are currently available. However, work must be carried out on new methodologies which obtain the maximum teaching and educational potential that can be offered – this is still at the prototype stage all over the world.”

José Luis Navarro Salinas

“I believe we are making a mistake when we analyze immersive technologies as an independent unit which may or may not provide value to the goal of education”.

José Luis Navarro Salinas

“Public institutions should play the role of content creators, since they are the ones who have the greatest knowledge of content and methodology and, in addition, they are working with pupils on a daily basis.”

Estefanía Castellanos Otero

“The most significant aspect of the use of VR in schools is how it enriches methodology. Pupils tend to be attracted to technology and it promotes pupils’ inclusion.”

Estefanía Castellanos Otero

“Although there was great interest at the beginning, in the end they did not produce a good result and we have not used them again. In workshops at the high

school we have equipment for physics (lathes and milling machines) and it is much easier and intuitive to use the real physical machines than the simulator. The VR equipment would have been much more useful if the school board had suggested to the software company the creation of scenarios for which it was very difficult or impossible physically or in real life (either because it was impossible to access the machinery or by creating situations which are difficult to simulate in real life). In that case, the virtual option would have been the perfect solution.”

Óscar Chacón Pizarro

1.3 Summary of the findings

In the following, the main findings of the interviews as part of our Mapping on VR in the school education are summarized. As the key findings do not always fit quantitatively with the guideline questions, a different organization into main topics was used in some cases for the summary. Other topics that were asked about were left out, as there was very little knowledge about them or the feedback was diffuse or indifferent; this included the question of where teachers, schools and decision-makers obtain information about using VR in school education. The findings are presented in a question-and-answer format.

What is the current role of Virtual Reality in School education, especially in STEM education and the age group 14-16?

At the time of research (fall 2023), the use of VR still plays a negligible role and is still in prototype status for the time being. There were isolated reports of particularly committed schools whose pioneering role is due to committed teachers or their school authorities (particularly committed public school authorities; private schools; small, agile school authorities such as schools run by churches or foundations). However, some interviewees also emphasized the growing awareness and availability of technical and content-related solutions in recent years.

Why hasn't VR become more widespread in school education yet? Is quality content available? How is the availability of VR content for school education?

The use of VR still faces many challenges today:

- The hardware is still too expensive, has lifecycles that are still too short for use in schools and is not standardized enough, which makes it difficult for schools to plan reliably
- There is still too little content for school lessons, especially content that considers the respective language of instruction, curricula, or specific educational topics. Until now, for most languages represented in VIRION, there is just a very small number of contents.
- In addition, the didactic quality is repeatedly criticized, especially where the didactic opportunities (immersion, collaboration, problem solving among others) of VR are not used. VR would still be used too often due to its novelty factor.
- Schools and teachers are often not well prepared for the use of technology in general and VR in particular, and the use of new technologies in schools would often take place in a difficult environment. Some call for contact persons for VR in the school's faculty.

Overall, the use of VR in the school context is still at the prototype stage and has yet to prove its potential and suitable fields of application. There are also fundamental problems such as motion sickness that needs to be solved before any widespread use.

In addition, some interviewees perceive a chicken-and-egg problem resulting from a lack of VR supply on the hardware and software side and a lack of demand for VR from schools and school authorities.

How useful is the use of VR in school education? How should the use of VR and its role in education be assessed? How can we imagine the role of VR in the school of the future?

The use of VR by the interviewees was generally

viewed positively. However, due to the selection criteria of the interview participants, this cannot be seen as representative of the entire education sector.

VR is predominantly seen as part of a “blended learning approach”, where the use of virtual reality is complementary to other digital or traditional teaching formats. The opinion is repeatedly expressed that for the further spread of VR, broader alliances must be formed for its use, for example involving school authorities, schools, VR producers and parents, depending on the perspective.

- Particularly suitable areas are repeatedly mentioned as follows:
- Places and activities that are not possible in a normal school context (museums, faraway places, flights in the upper atmosphere, microscopic processes)
- Dangerous experiments, for example in chemistry or physics
- Language teaching, especially when pupils from other language areas meet in a virtual space
- Use in distance learning and for special user groups (pupils with disabilities, etc.)
- In the context of these fields of application, however, some interviewees also warned against neglecting more suitable tangible methods or relying excessively on simplification to teach complex content.

It is also important to continue testing the use of VR and to give all stakeholders involved (school authorities, teachers, pupils, VR providers, etc.) the opportunity to try out the use of VR in schools. Especially in different teachers could gain interest by test-trial VR. In such a process, care should be taken to ensure that

all pupils have equal access to these technologies so that less privileged pupils are not excluded or disadvantaged.

Are schools interested in VR? How well informed are schools? What do schools need for VR to become more widespread in the education sector?

As the topic of VR has only played a minor role in schools to date, the level of knowledge in most schools is also very low, with a few exceptions from dedicated teachers, schools or education authorities.

For increased use in schools, teachers and other interviewees call for more resources, better technical equipment and content that is better tailored to teaching needs (see also other questions). This applies all the more if teachers and schools are also to create VR content themselves in an open system of content production.

A few suggestions were made to draw up recommendations and guidelines for the use of VR in school lessons, particularly with regard to the health aspects of its use with children and young people.

How would a meaningful ecosystem for the use of VR in schools look like? How important do you consider the existence of one-stop providers? Should teachers, schools or public institutions also create content?

Several interviewees pointed out that the diversity of the market for VR applications for schools and the lack of standardization make targeted investment in hardware and software difficult.

As has also been shown in other areas of our research, two significantly different models of an ecosystem for VR applications for the school context are preferable from the perspective of the interviewees:

- An open, standardized model with free or free content, possibly also created at least in part by teachers, schools or public institutions
- The use of one-stop providers that offer coordinated curriculum-related content, hardware and material trolleys from a single source.

The interviewees were of different opinions as to which solution should be preferred.

How important is the consideration of curricula when creating VR content? What role does the presence of national/teaching language content play?

Both the availability of content in the national language and content that is integrated into the curriculum were described by all interviewees as essential for the success of VR in schools. Especially for the age group that is the focus of VIRION (young people aged 14-16), the availability of content in English is not sufficient.

The need for curriculum-related content was also viewed critically by some in the context of a perceived formalization and bureaucratization of teaching content. Others also emphasized that one could consider adapting some of the curricula to the new possibilities of VR.

2.3 Literature Review

Virtual Reality and education in the European context

Scientific literature regarding VR and education has grown exponentially over recent years. In the Scopus database for bibliographic references and the category of Social Sciences about educational VR, the first study was recorded in the USA in 1992. Since then, numerous works have been published in that field, with most of them being recorded in the last decade.

The USA and China lead the ranking of published works however Europe, taken as a whole, boasts a significant role in research in the field. Specifically, the UK, Spain, Germany and Turkey are the most prolific countries. All four countries appear in the top ten for publications about VR applied to education in the aforementioned database.

The academic output of the countries which feature in the VIRION project generally reveal that research focuses more on the educational effects of VR, normally analysed using quasi-experimental methodologies. A significantly higher volume of studies being applied to the university sector has been observed, as opposed to Secondary or Primary education.

Based on the level of scientific output on the subject studied in Scopus, the main results of the academic literature and projects in which VR has been applied in the field of education in the four participating countries in the VIRION project are set out below.

Spain

Virtual Reality and education in the context of Spain. Summary of the literature review

In Spain, scientific writings on Virtual Reality (hereafter “VR”) and education have increased prolifically in recent years. Spain is the 6th country in the world in terms of academic production on the subject, behind USA, China, Germany, Japan and the United Kingdom. The number of published texts reveals highly significant growth in the last 15 years, going from 15 articles in 2008 to 141 in 2021, the latter being the year with the highest number of publications in the last decade and a half. The UNED, the Uni-

versidad de Barcelona and Valencia Polytechnic are the universities with the greatest production.

In general it could be said that there is a scarcity of studies about the penetration and use of virtual reality in the field of education in Spain. Scientific texts focus more on the educational effects of these immersive tools, tending to carry out analysis based on quasi-experimental methodologies. There is also a significantly greater volume of studies applied to the university sector as opposed to Primary or Secondary education.

Application of VR to education

Most of the conclusions gathered in articles are, in general, positive, indicating a significant improvement in learning, an increase in the efficiency of the teaching-learning process and an improvement in motivation as a consequence of using VR (Marrero Galván and Hernández Padrón, 2022). Most authors point to cognitive (knowledge acquisition) and affective (motivation, cooperation, etc.) advances, with these technologies, thus justifying the use of VR to motivate students. Similarly, other positive aspects of the use of VR have been revealed, such as an improvement in commitment, access to inaccessible environments, distance learning or even training empathy (Marrero Galván and Hernández Padrón, 2022). Along the same lines, studies such as Giakoni-Ramírez et al. (2023) show that both VR and Augmented Reality (hereafter, "AR") have promising benefits which can support the teaching process.

From the point of view of the strategies for designing the content of VR for education, research in Spain concludes that gamification content helps students in their learning process (Castellano et al., 2023). That is the conclusion reached by, among others, Lucena-Antón et al. (2022), who encourage teachers to include games when choosing their VR-based teaching approaches to improve interaction and active learning in the delivery of subjects such as physiotherapy. Similarly, VR, when combined with problem-solving

techniques for learning or research, is highly useful in the teaching of STEM subjects (Marrero Galván and Hernández Padrón, 2022).

Another high-profile strategy when designing educational material in VR is the creation of simulators and virtual laboratories. The studies of, among others, Tatiana Cox et al. (2022) show that groups which work with virtual laboratories obtain significantly better results than those using traditional methods. These pieces of work highlight the fact that these technologies stimulate students' motivation and are a tool which must be considered for in-class work, thus confirming previous studies such as that of Mercado et al. (2019).

Along the same lines, Pontes Pedrajas (2022) carried out an experiment about the educational use of a simulation program to help students overcome the considerable difficulties of significant learning and favour an adequate understanding of a model of an electric current, with tasks of oriented discovery in a virtual environment. After using a virtual laboratory as the main educational resource, in this experiment it was observed how the mental models of students evolved very positively when it came to the workings of electric circuits. A considerable improvement in the quality of participants' explanations of the problems set out in this subject after the educational action was implemented was detected.

Arce et al. (2022) developed an experiment in a virtual laboratory for teaching STEM subjects. According to their results, this realistic environment of real-time simulation and 3D visualization gives students flexibility, helps them in the organization of their tasks and allows them to work autonomously. One of the most interesting findings of this research has to do with the importance of the role of the teacher in following tasks. Students can have a wider contextual appreciation if they are forced to carry out individual tasks while at the same time being supervised by their teacher (in situ and on virtual platforms) and in the company of the other members of the group.

In the same way, other studies reveal high levels of motivation during teaching sessions with this technology, which facilitates interaction and optimum results in learning (Cabero-Almenara et al., 2023). Similarly, the studies of Bermejo et al. (2023) conclude that the application of VR improves immersion in the learning process, especially when studying the hotel industry, medicine and science, to university level.

Finally, studies such as that of De Moraes Rossetto et al. (2023) offer an interesting comparison between VR and AR. VR-based material obtains better results than AR-based ones when it comes to acquiring knowledge. It is also clear that students perceive the VR experience as being more immersive and interactive, whereas the AR experience is considered more intuitive. In general the evaluation of material in VR is better than the work of AR. Having said that, both materials tend to be highly valued, with VR modules generally stimulating greater interest.

Assessment of teachers and students

By means of a questionnaire-based quantitative study, Cabero-Almenara et al. (2022) observe that students who work with VR show a high level of acceptance of these technologies as well as a favorable disposition to their usage. Similarly, the work of Marín et al. (2022) suggests that secondary school pupils believe VR may be used in class to promote learning, although a low level of penetration of these technologies has been witnessed in the context of Spain. Given that this study was applied to secondary school pupils (the phase on which our project was focused), it is particularly relevant to highlight some of the main conclusions:

1. At secondary school age, gender is not a variable which gives rise to significant differences when it comes to the use of VR in the learning process. Age is not a major element either when distinguishing between students and their ease of use of these technologies.
2. VR helps motivate secondary school pupils to learn syllabus content. However, the use of VR is not seen as an element which promotes working in groups in certain subjects.
3. Pupils, despite the fact that they do have the feeling that they are playing while using these technologies, do not consider their use to be easy nor do they link the usage with their curricular pref-

erences. Similarly, even though teenagers feel that they are playing when using these technologies, they do not feel that they enable them to work with more autonomy nor to be more creative.

4. Students do not feel that in subjects where they tend to work individually (such as, Spanish Language) the use of these technologies allows them to approach the subject content as a group, or in a more innovative way.

On the other hand, the study by Castaño-Calle et al. (2022) analysed the attitudes of teachers towards these tools. In general, they have a favourable opinion of them but their knowledge of them is still limited. The results support the relevance of increasing teachers' knowledge and improving their skills, thus generating positive attitudes towards these tools.

The work of Marín-Díaz and Sampedro-Requena (2023) applied to secondary school teachers reveals that, as far as issues related to teaching methodologies are concerned, VR will promote autonomy and initiative in pupils at this stage of education, at the same time making the classroom and the learning process more active and, consequently, more participative. For that reason there exists the need to promote the training of teachers in the appropriate use, as expressed by participants. Training in the use of this technology is, precisely, another of the concerns expressed by teachers, who indicated that both teachers and pupils at secondary school level require training to enable them to implement VR in the classroom and promote significant learning (Palomo, 2020).

Aspects to be improved

The research carried out in the context of Spain indicates that VR activities put a greater mental strain on pupils and require a greater adaptation to make them fit into students' activities. As regards the drawbacks, cyber sickness and a lack of resources and time are

the most prevalent ones. Cyber sickness is a sensation of dizziness and nausea similar to seasickness, and it is mainly caused by a flawed design of the VR application (Marrero Galván and Hernández Padrón, 2022). The same conclusions were reached by Bermejo et al. (2023), who insisted on the existence of negative effects of the use of these technologies, such as visual exhaustion and mental fatigue.

The limitations in the application of these technologies in educational contexts are diverse, both for experiments (unclear aims, logistical problems, technical problems and a flawed design) and research (lack of comparison of VR with other means or technologies). On the other hand, the main difficulties or limitations which are mentioned are those which are intrinsic to the use and availability of technology, in addition to the fast changes which are produced in this area. Consequently, teachers are unable to integrate VR regularly into the teaching-learning process. For the use of these tools to be really effective, investments must be made in the training of teachers. If they are not trained appropriately, many educators may feel intimidated or unable to use these technologies in their classrooms (De Moraes Rossetto et al., 2023). Other authors, such as Arce et al. (2022) state that the possible reluctance of teaching staff to apply new technologies and transform their teaching approach may be the main obstacle to promoting this type of tools.

Finally, there must be investment in technology in public schools, which mostly serve students from low-income families. These pupils are often the victims of processes of social exclusion and they have less access to technology. As stated by Giakoni-Ramírez et al. (2023), it is also crucial to recognize the existing barriers in impoverished communities where public schools face limited investment in their technological infrastructure. These limitations make the widespread implementation of this type of immersive experiences and their potential for encouraging the acquisition of new knowledge difficult to bring about.

Bullet points (by way of conclusion)

1. There is a shortage of studies into the degree of penetration and use of the virtual reality in the educational field in the context of Spain.
2. Scientific literature focuses on the educational effects of these immersive tools.
3. A considerably higher volume of studies are applied to the university sector than to secondary and primary education.
4. Part of the scientific output focuses on a comparative analysis between augmented reality and virtual reality:
 - Virtual reality has shown itself to be more effective than augmented reality in the teaching-learning process.
 - There are studies which state that students consider virtual reality more immersive and interactive but augmented reality more intuitive. That suggests that there may be a possible problem of the ease of use and design of virtual reality tools.
5. The creation of gamified situations can be seen as relevant, i.e., the virtual reality tool should provide some sort of fun experience in the presentation of the content or the strategy. In the same way, the use of simulators and virtual laboratories has proven to be useful.
6. Learning results. In general, it has been shown using experiment designs that the use of virtual reality improves students' acquisition of knowledge and motivation.
7. Students:
 - Give a positive evaluation of the use of virtual reality in educational environments.
 - Reckon there has been a low penetration of these technologies in Spain.
 - Do not necessarily consider them useful for activating group work.
 - -Despite the use of gamified environments, they do not consider them to be easier to use (once again, this point indicates a possible

shortcoming in user-friendliness).

8. Negative aspects (to be improved):

- Tiredness and mental fatigue.
- Lack of training of teaching staff.
- Shortage of teachers' time when it comes to designing activities with these technologies.
- Teaching staff's reluctance to use them. This problem could be solved by improving training.
- Pace of the development in the industry making it difficult to implement in classrooms and keep teachers up-to-date.
- It is surprising to report no problems detected when it comes to the integration of these applications in the syllabus at any of the levels of education, suggesting that it is easy to adapt content and aims into the technological scenario.

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Germany

Internationally/General Findings

Findings by articles

Stecula (2022) performs a market analysis on Virtual Reality applications on the (mostly) gaming platform Steam. Therefore, the article mostly discusses gaming apps. In an overview on papers discussing the VR app market, the author concludes based on a literature review on her own finding that there is a “research gap in the field of the quantitative analysis of data on virtual reality applications available on the market”. However, the author mentions a small number of papers on the state of art of VR apps for the education sector (see below). Furthermore, even though education material actually exists on Steam, they do not appear in the top-rated apps (Stecula 2022: 6).

Radianti et al. (2020) confirm the rising importance of digital devices in general and Virtual Reality devices specifically for the field of learning and education (Radianti et al 2020: 1-2). While they state that literature on VR is “abundant” (ibid.: 8), the others aim at an extensive mapping on VR applications for higher education, where they see a “research gap” (ibid.: 4). They compare VR apps for education based on published literature and regarding technology, design elements, research design, learning theory, application domain and further questions. It is worth mentioning that 68% of papers finally investigated in detail (n=38) do not specifically name an applied learning theory, while the most frequently mentioned method was “experiential learning” with 11% (ibid.: 16). Engineering is the most widely addressed application domain with 24%, Computer Science (10%), Astronomy (7%) and Biology (5%) follow (ibid.: 17). The article further discusses the identified design elements, the learning content and lists the relationship between learning content and design elements (ibid.: 18-19).

Summary

The literature discussed seems to confirm the research gap on the status quo of educational VR apps, that VIRION to a certain degree aims at reducing. Still, as the VIRION partner mostly work on the findings from their relevant countries, an exhausting literature review on the international/English-language literature remains as a task for the scientific community.

In Germany

Findings by articles

A research on the German literature on Virtual Reality confirms the international findings, that there is a research gap in the scientific discussion of existing VR content and solutions and its usage in schools. In the following the authors discuss the relevant pieces of literature.

Horn et al. (2021) in a conference paper discuss the setting up of an educational AR-VR-catalogue within the “Digital gestütztes Lehren und Lernen in Hessen” (“Digitally supported teaching and learning in (the state of Hesse)”) project and its AR/VR workgroup, predominantly composed of university researchers and lecturers. The catalog will be further discussed in chapter 3.3.2. The authors discuss the steps undertaken for finding and evaluating AR and VR pieces for both school and higher education. In a first step, 308 pieces of content were identified that were further narrowed down. For the final selection, content had to fulfill three main criteria:

1. direct teaching content available or creation of own teaching content possible
2. one of the following criteria is fulfilled:
 - a. the software or its use is (freely) accessible
 - b. the software or its use is (freely) accessi-

ble. The content enables the development of novel tasks or teaching scenarios that were previously unimaginable (...), alternatively strong unique selling point

3. Use in a teaching scenario is allowed and/or desired" (Horn et al. 2021: 81)

Finally, the authors further describe the process of developing criteria and adding additional information and commentary. No figures are given about the final amount of AR-VR-content available at the time of publication, but on September 29th, 2023, it includes 71 VR pieces for both school and university education (compare chapter 3.3.2).

A second catalog has been established at Freiburg University of Education's Center for Didactic Computer Game Research (compare chapter 3.3.2). The authors of this report were not able to find any publications about the catalog.

VR eduNet was an EU-funded Interreg project in two regions of Austria (state of Upper Austria) and Czech Republic (South Bohemian Region). The project's main report is available in German, Czech and English and while it is not a scientific source per se, some of the results (VReduNet 2022) will be presented in the following. It is important to understand that VReduNet was a project from the perspective of regional economic development and the implication of VR for teacher training, curriculums and teachers. Available VR content and solution was not a major focus and there was a lot of attention on vocational schools.

One of the findings was that the majority of companies surveyed in the Austrian region (n=20) already deal with this new technology, but mostly still on a more experimental stage (VReduNet 2022: 7, 9). Therefore, using VR in schools is also seen as an important step to prepare students for a professional world in which VR could play an increasingly important role. Another survey was aimed at schools, even though in the selection of investigated schools there was a bias to schools with an implied interest in technology and VR, e.g. vocational schools in the age group of 15-18 (ibid.: 10). It was found that in the Southern Bohemian Region 54% of the participating respondents had already at least tested a VR system, while the figure for Upper Austria is 91%. Still, the project found that both VR and AR are not widely used in both regions, and the schools with a higher degree of use are technical schools with close cooperation with industry (ibid.: 11-12). Still, 64% of responding schools in Upper Austria have some form of VR equipment available, while this is only true for 14% of responding schools

in Southern Bohemia (ibid.: 12-13). Schools use mostly Oculus and HTC hardware, and also systems by Class VR in the Czech region. In technical oriented schools, more specialized VR systems are also in use (ibid.: 13). A longer chapter discusses the teacher training at University level (ibid.: 16 - 34). On pages 24 – 26 it names relevant topics for the use of VR in school education.

With regard to an increasing use, the authors see major hurdles (ibid.: 35) in:

- the financial cost of VR implementation, for both businesses and schools,
- the lack of knowledgeable personnel for businesses,
- the lack of teacher training and know-how transfer for schools,
- the “lack (of) examples of meaningful use, concrete applications for specific subjects and lessons”
- Implementation of VR in the educational process

The Büro für Technikfolgen-Abschätzung beim Deutschen Bundestag (Office of Technology Assessment at the German Bundestag) in 2019 prepared a report for the German parliament on the status quo, challenges and future development of VR. In a short chapter on education it only discusses some google VR products and also points to a cooperation between Samsung and textbook publisher Cornelsen that has led to the development of an application example in biology (Kind et al. 2019: 58-59). However, according to research by the authors of this report, there have been no further reports of this cooperation since around 2017.

As part of a book on WebQuests, Spiegel (2022) mainly discusses Quests in the context of VR. While she points

out that VR is already being used more intensively in business, she assesses that there is still little use of VR in the classroom (Spiegel 2022: 137). She sees the cause in the lack of digital equipment in schools, of personnel capacity for the maintenance and management of the hardware in schools, of training for teachers and the inadequate financial resources (ibid.: 142). The author also points to the comparatively intense activity of educational institutions on the VR platform Second Life (SL) while it was at its peak in the past and gives examples how SL was used in an educational context (ibid.: 140 – 142).

Schollän (2019: 1-2) cites from a Kantar-Emnid survey from 2017, that 48% of survey teachers are interested in using VR in teaching. Only 18% of responding teachers had their own experience with VR and only 4% had VR hardware available at this point. The author expects this to change in 2019 with the Digitalpakt, a federal funding for digital equipment in schools.

Summary

With two available catalogs in the German language/ by German institutions, this partner country made great strides in developing a quantitative overview of VR apps. Also both catalogs add categorization and educational commentary. However, it must be considered that these catalogs only include free available content. Schools being interested in the whole picture have to also take into account the existing for-profit content only available to customers.

On the other hand, a more qualitative approach on evaluating the VR content or a more current data on distribution of hardware or usage of content in school seems to remain a research gap.

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Finland

Findings by articles

With excellence and deftness in engineering, Finland is great for adopting and developing new technologies. Since the launch of Oculus Rift and HTC Vive in 2016 Finland has been in the forefront of VR development. While many new companies in this field have emerged and a lot of research has been done on the usefulness of VR in education, this has not transferred to use. (Suominen, Takala, & Sinerma, 2017). Cases where VR has been applied to studies are small in numbers and in most cases the application was very narrow. A study by Kosmas et al. (2021) found that while the interviewed higher education officials think VR to be a good motivational and helpful tool in teaching, the technology is not yet mature enough. They stated that the main obstacles for adoption to be the lack of content available to justify the expenses related to the equipment and staff costs. Nonetheless, here follows some instances of VR used in Finnish education as reported by articles.

VR glasses have been used in Laurea University of Applied Sciences in nursing since 2019. They have had the most success with teaching internal medicine, examining anatomy and physiology of the human body. Laurea University has also produced several 360 videos for VR glasses. These videos help students to visualize different aspects of their studies. For instance, Laurea University created a video on how a patient with schizophrenia experiences visual and auditory hallucinations. (Heikkinen, 2022). According to a questionnaire where Laurea University mapped the students' experiences with the VR glasses in their studies, the majority expressed that the VR glasses were useful, promoted their learning and made the subject more interesting (Nikula et al., 2022).

A mixed Reality Hub – group in the University of Helsinki has been researching on how to best use mixed reality in various different studies. They report that an

immersive teaching method can greatly help motivate students and give them a better understanding of their studies. They state that the target fields span vaster than the typical science and technology departments, and hint to possible opportunities in studies of philosophy and business. (Media, 2018).

The University of Helsinki has tested VR technology in the teaching of forest sciences, educational sciences, and medicine among others. They report that while most students enjoy using VR in their studies, it is not suitable and appealing to all students. Still, to make the use of the technologies easier, they have had digitutors available for help and guidance. (Vairimaa, 2018; Aalto, Halonen, & Paatela-Nieminen, 2017). It is good to highlight that while VR helps motivate and visualize the information for most students it can also be the opposite for other students which is why teaching should leave room for options.

One field where VR glasses are tested and used for teaching abundantly is welding. Sampo University of Applied Sciences boasts the most modern virtual welding environment in Finland (Tähkä, 2020). A virtual teaching environment for a relatively dangerous subject is very useful since the students get to learn and make mistakes in a way that does not harm their person.

While most cases are from higher education institutions some high schools have also invested in VR technology. For instance, Konnevesi high school has 30 pairs of VR glasses and can bring a whole class into the virtual world simultaneously. Konnevesi is one of the most advanced in the way of utilizing VR technology in high schools (Savela, 2022). According to Mari Jämsen, the deputy principal of Konnevesi, they use VR glasses in STEM education regularly and have found this to add concreteness, interest, and motivation toward the taught subject.

Summary

Most educational advocates are interested in the possibilities and opportunities presented by VR technology, but the use cases are smaller than what this interest would suggest. This is due to the lack of content available, the cost of the hardware and the competence of the staff. The institutions that have implemented VR in their education have reported positive outcomes and are looking to do more with it in the future.

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Bulgaria

VR and education in Bulgaria. Scientific Literature Review

The scientific literature on the confluence between virtual reality (VR) and education in Bulgaria has primarily focused on the university setting, although interesting works are also detected in secondary education, particularly focusing on STEM subjects. Likewise, there is a prevalence of studies on augmented reality (AR) and the use of holograms for educational purposes, with a frequency much higher than the application of VR. In this regard, the positive perception of students towards the use of mixed reality (MR) and AR is noteworthy. According to studies conducted in this country, learning by holograms gives students an experience that is really close to reality. The simulation teaches students how to act, how to think, how to predict situations. In this sense, MR has the potential

to change the location and timing when it comes to learning. Moreover, this technology is able to introduce new and additional ways and methods of learning and solving problems. Furthermore, it can be concluded that MR applications developed for education increase student participation in classes, improve and increase memory.

Two main areas gather scientific evidence on the use of these technologies (VR and AR) for educational purposes: (1) the study of medical areas and (2) training in historical and cultural heritage. In both medical education and the field of engineering, a third essential element emerges in research on VR and education in Bulgaria: (3) the use of virtual laboratories.

VR in medical training

Studies by Spiriev et al. (2022) evidence that AR and VR allow users to zoom, pan, and rotate the models, which may facilitate learning. These tools have the potential to help with a better understanding of complex anatomy, what opens the field for further research in medical education.

Moreover, the research conducted by Georgieva-Tsaneva and Serbezova (2020) shows that students and teachers in the professional field of health care assess virtual learning as an important factor in the process of acquiring new competencies. They believe that virtual resources are important to them, especially when it comes to building clinical psychomotor skills.

In this field, some works focus on the analysis of the application of virtual clinical laboratories. The research conducted by Georgieva et al. (2021) emphasizes that the use of these immersive spaces allows the trainees to explore, to make mistakes and learn from them before ultimately applying the real procedure on a patient. These technologies have potential for creating authentic learning environment close to reality and with context that simulates real life workplace.

Virtual laboratories in engineering education

Similar benefits have been detected in the use of this type of laboratories in the field of electrical engineering. In this sense, Evstatiev et al. (2019) demonstrated the potential of these spaces for the use of virtual cables and to manipulate it. Therefore, the students can gain experience, like that obtained through traditional laboratories, including the opportunity to safely experiment, without risks of electric shock or equipment damage.

Another relevant research conducted by Ivanova et al. (2019) compared the application of a virtual laboratory with traditional ones in the field of engineering training. The results conclude that the virtual learning environment is more effective compared with the traditional lab setting in helping students to understand long measuring process with more than 20 stages, too long even for the real lab conditions. The virtual space significantly increased the possibilities for mathematical processing and analysis, storage and documentation of all student's measuring results.

Educational VR in historical and cultural fields

Research focused on the integration of VR in the teaching of Fine Arts show the applicability of the proposed approach and satisfaction with the acquired knowledge among the students (Staneva et al., 2022). On the other hand, Georgiev and Nikolova (2021) observed that the presentation of cultural artifacts in a more realistic, attractive, and accessible for children manner creates a newer and more exciting experience for them, which builds their national identity and patriotism. Finally, the research by Peteva et al. (2020) found that young people studying historical education are open to the new 3D technologies. They want to touch this unfamiliar world and are eager to get involved in such research projects. This type of students wants new technologies to become an invariable part of their courses.

AR in secondary school for STEM

While studies on the impact of AR and VR in secondary education in Bulgaria are not frequent, interesting work has been identified, particularly in STEM subjects. According to the research conducted by Petrov and Atanasova (2020), it can be affirmed that the integration of AR has significant effects on the learning of the associated content. This research shows that the AR technology, especially when used in STEM education, allows students to explore, practice and interact with STEM content without worrying about financial or ethical issues, such as costly consumables or animal

injury. It provides opportunities for experiments and recovery from failure, while working in a safe environment. This research found many benefits to using AR in teaching STEM subjects, especially biology. Among them are: (1) the ease of use, (2) the high level of personalization, and (3) the possibility to run many different applications. AR technology offers an immersive experience that (4) also allows for collaboration.

To conclude, as has been observed in other countries, an important issue that should be investigated as further step is the possible discomfort for users during viewing the models in VR (Petkov et al., 2019). This includes the commonly reported VR side effect of motion sickness but also other forms of discomfort such as tired eyes and disorientation.

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3 The future of the classroom – with VR

We would like to look into the future with you – the Future of Classrooms in which VR plays an increasing role.

This vision of the Future is based on our findings from an analysis of the literature, a large number of interviews with industry experts and our own experiences in the VIRION project. It identifies the prerequisites and framework conditions that are necessary for the success of VR or that are already emerging today. We leave it up to the reader to decide whether this scenario is desirable or how realistic the framework conditions discussed are. Instead, it is intended to inspire readers to spin their own tales of the future of our classrooms.

Classrooms of the Future take advantage of the opportunities offered by new digital tools and methods. These will be integrated into lessons and everyday school life and lead to an improvement in learning outcomes. Virtual reality in the classroom builds on pupils' current media experiences and offers them contemporary learning environments for subject areas that particularly benefit from virtual reality: In virtual spaces, complex interrelationships are demonstrated that cannot be conveyed in normal school life, or only with great effort. This includes experiments and demonstrations in STEM subjects, excursions to faraway places in geography courses, or to historical places. The design of virtual spaces is reminiscent of the design of virtual environments that students are familiar with from their leisure media consumption, such as historical, futuristic or

fantasy-like environments.

The VR content of the Classrooms of the Future will utilize the didactic and technical potential of virtual reality. This includes problem solving, collaboration and immersion. The content to be taught is not simply presented. Instead, students learn to understand problems independently and acquire solutions. They often use the learning scenarios in virtual rooms in teams and can thus support each other in working on quests. This also leads to completely new constellations in which VR brings together students from different locations. The ability to work together over long distances has introduced the use of VR in foreign language teaching and intercultural education, one of the most important fields of application of VR in the Classroom of the Future. VR has also enabled the integration of sick and disabled pupils.

In the Classroom of the Future, virtual reality is just one digital tool among others that will continue to be supplemented by traditional formats and modern non-digital methods. This mix of methods utilizes the strengths of different formats and their topic-appropriate combination to convey school content. It is true that in the Classroom of the Future, pupils and teachers have gained increasing experience in dealing with virtual reality and the equipment available to them enables increasingly seamless integration into lessons. Nevertheless, virtual reality has also proven to be unsuitable or too complex in some situations in the Classroom of the Future.

To ensure that virtual reality is used as seamlessly as possible in the school context, schools have been equipped accordingly by their school authorities. This includes transport trolleys with which the headsets can be brought to the place of use and charged, as well as the use of appropriate software solutions for the management and targeted use of the devices in lessons. Teachers are given the opportunity to provide targeted assistance to pupils in need of help on request and to provide didactic, content-related or

technical support where necessary. The necessary personnel and other capacities have been created for the maintenance and care of the devices. This includes technical support staff and teachers who act as multipliers in their teaching staff. The classrooms have been prepared for the use of VR by setting up sufficiently powerful Internet and charging facilities in the rooms used for VR.

The right setting was found during a phase of intensive testing of virtual reality in the classroom. In recognition of the opportunities offered by virtual reality, a process was set up in which school authorities, model schools, hardware and software manufacturers, VR producers and distributors, pupils and parents were all involved, with close support from educational research. In this iterative process, not only was the right hardware equipment tested, but also the right scenarios for its use. As a result, didactic concepts were developed that utilize the strengths of virtual reality. This process has also created a framework in which demand for VR content in schools has been created, which has led to increased content production on the provider side. The previously perceived chicken-and-egg problem in terms of demand and supply of VR software for schools has therefore been broken up. In the context of this process, it was also possible to gain additional experiences of how hardware and software comfort can be further improved, for example by avoiding motion sickness. This experience was then continuously integrated into new applications.

Even if it has been shown that there are subject areas in which teachers are happy to freely choose from an extensive portfolio of available teaching content, this process has also underlined how important standardized teaching content is as part of a curriculum. For this reason, school boards and school authorities from different school districts, regions and European countries have come together over time to align curricula and jointly develop VR content that also takes into account the language requirements of all participating regions and countries.

The previously perceived chicken-and-egg problem in terms of demand and supply of VR software for schools has therefore been broken up. In terms of the available content, the school authorities in the participating countries can essentially choose from two license models: In the integrated model, national and international providers offer inclusive packages of hardware and software and the procurement office in the school administration can then purchase the bundle of content that suits them best. The matching VR headsets, device trolleys and management tools promise a seamless and integrated user experience for teachers and students. These proprietary or closed systems are often not compatible with open applications, even if there are providers with open interfaces.

At the same time, there is an open model in which hardware and software content is standardized. This makes it possible for smaller VR providers, educational scientists, teachers or other educational institutions such as museums to develop open VR content. Some school authorities prefer this licensing model and have promoted or commissioned the development of standards-compliant, open-interface and curriculum-related content. Content is available in corresponding catalogs or databases and can be filtered for suitable content, which is often free of charge. Over time, institutions have emerged that act as gatekeepers, checking VR content for suitability in terms of content, functionality and data protection, for example, and then recommending it for use in schools. In parallel, there are applications that allow teachers and students to build VR content themselves, use it collaboratively and share it with their classmates and other schools. This model uses commercially available devices, so the schools benefit from the high number of units sold. However, as with open systems, occasional incompatibilities remain and require increased resources for management at schools. In addition, some questions remain about the legal classification of content that is freely available on the internet.

Classrooms of the Future are classrooms in which virtual reality plays an important role in teaching content. Virtual reality immerses students in engaging learning environments, enables problem-based learning and brings students together. With the experience we have gained in VIRION, we can create such a vision. However, in order to get closer to the Future of the Classroom, further efforts are needed from those involved in the education sector, particularly for the didactic improvement of concepts, for the development of curriculum-related content and to gain experience in schools. We hope that the experiences from our VIRION project will provide a good basis for setting up further comparable iterative processes.

VIRTUAL REALITY APPLIED TO SCHOOL EDUCATION

REPORT

MAPPING VR IN THE SCHOOL EDUCATION SECTOR

THE FUTURE OF THE CLASSROOM



**Virtual Reality
Applied to
School Education**

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