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Developing an R&D Strategy to Integrate Immersive Learning Into the Classroom

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Introducing immersive technologies into classrooms has the potential to make the U.S. education system more effective. But before these technologies are deployed in schools, the federal government should increase R&D investments in key areas that need further research.

KEY TAKEAWAYS

- A steady flow of new research validates the effectiveness of immersive technologies in classrooms, but questions remain that could slow the technologies' deployment.
- Government should invest in R&D to close key research gaps. But to maximize the value of taxpayers' money, government R&D programs should avoid crowding out private investments in R&D. The focus should be on important topics that are underfunded.
- Four key topics governments should focus on are: age-appropriate use, cost-benefit assessment of different educational content formats, accessibility measures, and best practices for training educators.
- Most of the necessary R&D programs are already in place in federal agencies such as the National Science Foundation and the Department of Education, but the specific language to cover immersive technologies is still lacking.

CONTENTS

Key Takeaways 1
Introduction 2
Lessons from the Use of computers and the Internet in education 3
Overview of the Adoption Process of Computers in Schools 3
The Challenges in the Adoption Process of Computers 4
Research Priorities for an AR/VR R&D Strategy 5
Appropriate Age for Using AR/VR Devices 6
Establishing a Cost-Benefit Assessment of Different Content Formats 7
Accessibility and Equity Measures Required for School-Wide Implementation 7
Creation of Educator Training Programs 8
Existing Federal R&D Programs and Grants Need To Be Expanded To Ensure They Cover Immersive Technology 8
Conclusion 9
Endnotes 10

INTRODUCTION

Immersive reality technologies have emerged as valuable tools for educators looking to modernize teaching methods. In recent years, new research has highlighted the benefits of using immersive technologies for educational purposes, such as reducing learning gaps and improving educational outcomes.[1] While there is a steady flow of new research validating the effectiveness and impact of these technologies in the classroom, there remain unresolved questions that could slow the deployment of these technologies in schools.

Resolving some of these questions will require investments in research and development (R&D). The private sector will likely shoulder part of those investments, as most companies developing hardware and software solutions have a financial incentive to invest in R&D that advances the deployment of their products. But that reliance on companies' financial incentives means other key questions might go unanswered if they are not determined to be vital for their bottom line. Thus, there may be a need for government aid in funding R&D efforts to solve research gaps that could arise in the next digital transformation of the classroom.

Past experiences with other digital technologies in education, such as computers and the Internet, shed light on the role of R&D investments in ensuring that the deployment of digital technologies in classrooms is done safely and effectively. Today, computers are a ubiquitous tool in classrooms. Still, their deployment faced multiple challenges in the past, such as a lack of training standards for educators, the acquisition of inadequate devices, and a lack of understanding of the potential educational uses of computers. Some of these problems could have been avoided if educators and school administrators had been given prior access to

research that could have covered those knowledge gaps. To prevent committing the same mistakes of the past, the federal government should create an R&D strategy for immersive technologies in education. Such a strategy should focus on solving critical questions in the field :

- What is the appropriate age for different uses of augmented reality/virtual reality (AR/VR) devices?
- What are the costs and benefits of different content formats (e.g., bespoke immersive experiences vs. standardized apps or 360-degree videos)?
- What accessibility measures will schools need in order to implement these technologies school-wide?
- How should schools train educators for immersive learning?

LESSONS FROM THE USE OF COMPUTERS AND THE INTERNET IN EDUCATION

Computers and Internet technologies have become standard classroom tools, providing students and educators with multiple benefits such as educational games; software tools for word processing, spreadsheets, and slides; the ability to access multimedia educational content; and other digital educational resources and interactive experiences. Digital technologies are considered beneficial educational tools today, but that was not always the case. In the early stages of their deployment, inconsistencies in how these technologies were used, the acquisition of inadequate devices, lack of staff training, and educators' skepticism of their effectiveness held back the technologies' potential positive impact. To this day, some of these issues continue to ail educators and school systems, which are not seeing the expected benefits of using digital educational technologies.[2]

Looking at these past experiences sheds light on educators' potential challenges when introducing immersive technologies into the classroom and highlights areas needing further research. They can also give insight into what adopting these new technologies will look like and which entities are likely to play a role in that process.

Overview of the Adoption Process of Computers in Schools

The introduction of personal computers in the classroom did not see a significant level of adoption until the early 1980s, although schools began experimenting with computer literacy and teaching programming as early as the late 1950s. Between 1981 and 1983, the percentage of elementary and secondary schools that reported having at least on microcomputer on their premises rose from 10 percent to 60 percent and 50 percent for elementary and secondary schools, respectively.[3] But while adoption had increased significantly, this did not necessarily translate into student access. During that time, it is estimated that only one-eighth of elementary school students had access to microcomputers, averaging only 20 minutes of use per week.[4] In the 1990s, student access to computers at school increased significantly, reaching 75 percent by 1998, especially through computer labs.[5] As of 2019, 45 percent of public schools in the U.S. have a computer for every student and an additional 37 percent have a computer for every student in some grades or classrooms.[6]

The push to adopt computers in classrooms was a mix of top-down and bottom-up processes. On one side, the federal government initiated the efforts mainly through funding from the National Science Foundation (NSF) and the Department of Education in the 1950s. Scholars often

mention the Vocational Education Act of 1963 as a critical piece of legislation that boosted the adoption of computers in schools, providing funding for schools willing to teach their students programming languages such as BASIC.[7] While government funding was critical to secure the acquisition of the technology, incorporating computing in the classroom required educators to have the necessary motivation and knowledge of the technology. The pioneering educators who experimented with computers for learning provided valuable insights into the best uses of computers—and their input was critical to ensure that the deployment of computers as teaching tools was effective.[8]

Computer adoption in classrooms highly benefitted from word-of-mouth promotion. Educators sharing their success stories using these technologies provided valuable insights to colleagues who had little understanding of their utility or were skeptical of their effectiveness. There were also spillover effects from adopting these new technologies in educational institutions, mainly from higher education institutions to neighboring K-12 schools. For example, when a university installed a computer lab on its campus, educators from neighboring K-12 schools could get insights from the university's professors on the lab's effectiveness. Universities would also often set up partnerships with these schools to establish a cost-sharing scheme, where school students could visit these computer labs on designated days and the universities would oversee the maintenance of these labs. These schemes offered K-12 school officials a low-cost method to access and test these technologies before deploying them on their own campuses.

The way schools used computers back then looked dramatically different from the present day. The technologies' increased popularity and falling costs explain most of these changes. As mentioned, students could only access computers using their school library or a computer lab, which often had a limited stock compared with the whole student body. Today, students are often expected to have access to their own computer or personal computing device, such as a handheld tablet. These changes create more opportunities for students to use the technology. For example, in the computer lab era, educators had to use limited computer lab time to teach students basic typing, word processing, and computer literacy skills. But as computer availability increased, they could give students more time to use interactive educational experiences or games. Now, as students have continuous access to these devices, educational apps and other interactive content have become ubiquitous in the learning process.

The Challenges in the Adoption Process of Computers

In the early stages of the incorporation of computers in classrooms, the process faced multiple challenges. Most of these issues are a natural occurrence for a novel technology; without prior research, it is difficult for educators and support staff to know how to adequately use these devices, ensure that the equipment acquired is fit for purpose, or contextualize these digital tools into a broader educational objective.

One of the most glaring issues identified in the early stages of adopting computers in education was a need for more understanding of the potential uses of these devices. While some teachers found it useful for word processing, others believed that students might as well use more readily available devices, such as typewriters. Others did not see any potential benefits of incorporating computers into the lecture process but found them useful for class planning or communicating with colleagues via email.[9] This general lack of a standard for use led to an underutilization of the devices in the teaching process, which slowed schools' adoption.

Another recurring issue school systems had to endure during the adoption process of computers was the acquisition of inadequate devices, such as computers with no capacity to reproduce multimedia content. This turned out to be a significant problem for future use, since most of the computers in schools in 1999 could not access graphical information that was prominent on the Internet.[10] The risk of acquiring an inadequate or potentially obsolete device would create additional barriers to adoption, as school systems would become wary of acquiring a device in the first place, thus extending review times and slowing down the acquisition process. Often understaffed information technology departments would have to find workarounds for faulty, underperforming, or inadequate equipment.[11]

Educator training also surfaced as an issue in the integration of computers into classrooms. Educators had difficulties setting aside time during the school day or at home just to train themselves to operate these novel devices. Even if educators owned a home computer and were relatively tech savvy, they often needed more training resources in order to learn how to use the technology in the classroom or contextualize and debrief students after using digital tools such as math games or other educational experiences to make sure that students understood the lessons behind what they saw and did on the computer. This lack of training, combined with the aforementioned lack of understanding of the potential uses of computers, led to contradictory reports on the impact and efficiency of computers in educational outcomes.[12]

Some, if not all, of these issues could have been avoided if the process of integrating computers in classrooms had been preceded or accompanied by an R&D strategy to identify and address these potential issues. While the nascent education technology industry was able to provide evidence of the impact on student educational outcomes back then, it is evident that several other R&D gaps needed to be filled due to the lack of a financial incentive by the private sector to do so. In a 2003 report, the Department of Education recognized a need for more diverse research on using computers in education, educator training, and creating high-quality educational software.[13]

RESEARCH PRIORITIES FOR AN AR/VR R&D STRATEGY

To maximize the value of taxpayers' money, government R&D programs should avoid crowding out R&D investments the private sector would have made itself. For example, there is a robust and growing body of research that evaluates the impact and effectiveness of immersive training tools, as most companies in the sector need this research to be able to market and sell their products. Government R&D should not consider such topics, as they will likely have sufficient funding over time.

Coordinating the multiple government agencies that are involved in the R&D investment process and prioritizing topics by urgency will require the formulation of an R&D strategy. An R&D strategy is a document that provides guidance to the different agencies involved in the R&D process on what challenges or research gaps R&D investments are looking to solve and what topics should be prioritized.

Having an R&D strategy for the use of immersive technology in education will allow government agencies to prioritize urgent topics current private R&D efforts have not addressed. This report suggests that such a strategy prioritize the following topics: determining the appropriate age for the use of these devices, making a cost-benefit assessment of different educational content

formats, the development of accessibility measures necessary for school-wide implementation, and the creation of educator training standards.

Appropriate Age for Using AR/VR Devices

There are various concerns about the use of AR/VR devices by children due to the potential physical and psychological issues that could arise. One of the physical issues that concern experts focuses on the ergonomics of these devices, as they could be too heavy for children to use for extended periods. Meta recently addressed this question when it announced that it was lowering the minimum age of use of its devices, allowing 10- to 12-year-olds to use its headsets. In a statement, the company justified its decision by noting that the weight of these devices—usually between 500 grams and 700 grams—compares to that of other items commonly used by similarly aged children, such as bicycle or football helmets, whose weights range between 500 grams and 2,000 grams.[14]

While this is a positive sign that headsets of similar weight to Meta's could be potentially safe for children 10 and up, weight is not the only variable of concern. Other variables such as weight distribution must be considered. Further research that accurately determines an age for safe use, time limit restrictions to prevent neck strain, optimal weight distribution, and potential solutions—such as alternative straps—is necessary to ensure that schools can implement this technology without potentially causing bodily harm to students.

Another potential concern is the effect prolonged use of AR/VR devices could have on children's vision, especially in young children whose eye development is not yet complete. While the American Academy of Ophthalmology has stated that there are no known issues that could cause harm to children's vision, it has also said that no long-term studies exist due to the novelty of the technology. Nonetheless, it also states that AR/VR devices, such as other devices with screens, can cause eye fatigue or strain when used for long periods.[15] Studies on eye strain focus on 2D screens, and the exact impact of AR/VR tech on users' eyes is largely under-researched.[16] Funding research that focuses on establishing the age at which children's eyes develop for headset use and the necessary screen time limits to prevent eye strain should also be a priority for policymakers.

Aside from concerns for students' physical safety, there are also potential psychological risks when introducing these technologies to young children. Younger children may have difficulty differentiating fiction from reality when immersed in VR content.[17] Some of these concerns can be tackled through appropriate contextualization by educators, software design decisions, or simply establishing an age cutoff for introducing these technologies to children. R&D efforts could help administrators and educators be aware of these issues, allow them to identify correctly designed software and content, and better prepare themselves to contextualize immersive content. Having research of this kind on hand before rolling out these technologies would prevent situations wherein researchers will have to play "catch-up" to potential future concerns of harm, such as with social media. As a recent surgeon general's report highlights, currently available research does not allow experts to determine whether social media has had an impact on youth, while members of Congress continue to voice concerns over harms and push legislation to address them.[18]

Establishing a Cost-Benefit Assessment of Different Content Formats

The adoption process of computers highlights the importance of appropriate software and content in ensuring that new technologies are deemed helpful by educators and students. Educational content in immersive technologies can have various formats, from fully interactive VR experiences to more simplistic, straightforward 360° video. As school systems determine what hardware, software, and content libraries to acquire, administrators need more information to properly evaluate whether the products they are acquiring are adequate for their intended purpose.

Different content formats serve other purposes. For example, a fully interactive immersive VR experience, which behaves like a videogame that allows users to interact with their environment, can justify its higher cost if used consistently throughout the academic year to teach various topics of a determined subject, such as math or science. Conversely, 360° videos—which give users a full range of vision to see, but not interact with their surroundings—are usually found for free on different video platforms. These videos can be helpful when educators only want to use AR/VR tools for a single lesson or to do a quick virtual tour of a particular location.

While it is likely that the private sector—namely, educational content providers—will provide research on the impact or return on investment of their products, additional research that evaluates how these products align with schools' objectives, curricula, and pedagogical approaches would both minimize the risk of acquiring inadequate products and provide a smooth, quick adoption process of immersive technologies in schools. Additional research on this topic would provide a resource for administrators to quickly compare different content formats and see how each format would adapt to their school's teaching methodology.

Accessibility and Equity Measures Required for School-Wide Implementation

Immersive technologies are often referred to as "equalizing machines" due to their tremendous potential to bring down barriers for students with disabilities, neurodivergent students, or students affected by different mental health conditions.[19] But despite their immense upside in accessibility and inclusion, implementing immersive-based education programs throughout a whole school system will require surpassing various accessibility challenges. For example, studies have highlighted that females report a higher level of physical discomfort and motion sickness while using VR headsets compared with males. These differences in reports of discomfort are usually explained by the differences in interpupillary distance between males and females or by the difficulties individuals with long or voluminous hair tend to have while using VR headsets.[20] Immersive technologies' reliance on body movement could also enact a barrier for users with limited mobility, such as being unable to experience certain content due to their inability to operate a particular device.

Conducting R&D efforts for the identification of accessibility challenges and the development of different hardware and software design solutions should be a priority for school systems. Policymakers, administrators, and educators should ensure that no students—particularly those who could benefit the most from the equalizing qualities of immersive learning technologies, such as students with disabilities—are left behind as schools introduce immersive technologies.[21]

Creation of Educator Training Programs

The successful rollout of new technologies largely depends on a school's capacity to train educators in how to operate these devices and integrate them into their teaching. Establishing a training program that goes beyond simply teaching educators how to operate a device and also trains them to help students understand immersive learning materials better and use effective pedagogic methods will be crucial for a successful rollout of immersive technology.

Introducing immersive technologies in classrooms will likely create new challenges in teaching. For example, unlike a presentation at the front of a classroom wherein all students are looking at the same thing and are guided through the material by an instructor, most AR/VR content is a highly individual experience in which teachers do not usually know exactly what a student is looking at. Students may not fully understand what they see in an immersive experience or how it relates to the subject being taught. To address these potential disconnects, teachers will likely need to do short debriefings to help students understand what they see or experience in their devices. Putting training protocols in place will make sure teachers know about the need for these sessions and the best way to conduct them properly.

The experience with the rollout of computers sheds light on the difficulties educators can have finding time to learn how to use such new technologies. Educators often reported not having had time to invest in learning how to use computers, either during working hours or at home. A similar situation might arise with immersive technologies. Any training program proposed should take this constraint into account. R&D efforts should ultimately lead to a training program that provides educators with information on the different uses of immersive technologies in education, guides them on the appropriate pedagogical methods to integrate immersive content used into their classes, and guarantees educators' operational proficiency of these devices.

Advancing R&D efforts in these four pillars will be crucial to lifting potential barriers and removing frictions in the adoption process and increasing the effectiveness of future funding toward acquiring these technologies. By furthering research on these four topics, we can ensure that the inclusion of immersive technologies in the teaching process will be safe, equitable, and cost-efficient.

EXISTING FEDERAL R&D PROGRAMS AND GRANTS NEED TO BE EXPANDED TO ENSURE THEY COVER IMMERSIVE TECHNOLOGY

Implementing the aforementioned R&D strategy will require coordination between agencies and governments at the federal, state, and local levels to determine who should lead and oversee the respective R&D investments. For example, some of the questions and issues highlighted in the previous section are likely to be a priority for all schools nationwide. Hence, these topics could be better covered by a federal agency such as NSF or the Department of Education.

Some of the infrastructure to enact this R&D strategy is already in place—in some cases, it will likely require an update or expansion of the covered topics to ensure these programs also cover research on introducing immersive technologies in classrooms.

A program that could drive R&D investments for the research of some of the proposed topics at the federal level is the NSF's Research on Emerging Technologies for Teaching and Learning (RETTL) program. As its name indicates, this program funds "exploratory and synergistic

research in emerging technologies (to include, but not limited to, artificial intelligence (AI), robotics, and immersive or augmenting technologies) for teaching and learning in the future."[22] On paper, this program could cover some of the suggested topics. Still, the broad nature of the program, the large portfolio of technologies and issues covered, and the yearly cap of 20 grants per year could lead to a situation wherein many of the topics explored in this report are ignored or will need some time before being selected for a grant.

Policymakers should create a specific grant program under the RETTL umbrella that creates a subcategory of grants with more specific criteria to ensure that some of these topics are covered promptly. This could be helpful for time-sensitive issues with the potential for nationwide impact, such as studies on age-appropriate use.

The Department of Education should also have an essential role in this R&D proposal. Certain institutions and offices under their umbrella are a perfect fit to lead the funding and supervision process of some of these R&D investments. For example, the Institute of Education Sciences (IES) will likely be the most appropriate institution to lead the research process on educator training programs or establishing a framework for cost-benefit assessments of immersive content. Other offices, such as the Office of Special Education Programs (OSEP), can lead research efforts on accessibility measures needed to deploy immersive technologies. Both IES and OSEP offer various research grants on training standards, pedagogical approaches, and accessibility measures, but currently none of their programs cover immersive technology explicitly. Congress should pass legislation directing the Department of Education to create new grants that cover educator training and accessibility for immersive technology explicitly to make sure schools and educators are ready to introduce this technology into their teaching process.

Additionally, more specific, smaller-scale studies on accessibility measures might be necessary to look into how to integrate immersive technologies into special needs education. For example, for schools specializing in teaching students experiencing vision or hearing impairments, some classroom-wide measures—such as audio description, closed captioning, or acquiring a different set of devices—could be taken instead of the commonly used individual accessibility solutions.

CONCLUSION

Immersive technologies in classrooms have the potential to boost the effectiveness of the education system in the United States. But as the history of computers in the classroom has shown, introducing new technologies without prior research can slow down their implementation, lead to resource waste, and hold them back from their true potential. Some of the challenges that come with introducing new technologies can be solved by R&D investments by the private sector and the government. R&D dollars need to be invested strategically to ensure that R&D efforts focus on important but possibly underfunded questions that will ensure taxpayers' resources are allocated to their most impactful uses and will avoid crowding out potential private R&D investment. Most of the infrastructure for the necessary R&D investments is already in place in federal agencies such as NSF or the Department of Education. Still, as it remains lacking, introducing specific language will ensure that these critical questions are solved, making the implementation process of immersive technologies in schools smoother and more efficient.

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