

Improving The Middle School STEM Education in Rural China Through Virtual Reality

Jiayun Mo¹

School of Computer Science and Engineering, Nanyang Technological University, Singapore,
639798, Singapore

jmo005@e.ntu.edu.sg

Abstract. Left-behind children in rural China are troubled by educational inequalities and a lack of effective education; STEM education implemented by VR might be an answer to the problems they face. This article discusses the application of VR specifically targeting middle school STEM education in rural China. VR is characterized by its immersive, interactive, multimedia, multisensorial, engaging, authentic, spatial, and social affordances, possessing abilities to offer enhanced learning experiences different than other educational technologies. Specifically, case studies evaluated in this article show how VR can help better deliver STEM content by providing opportunities for practical, collaborative, and problem-based learning essential in effectively conveying the abstract and complicated theoretical knowledge of STEM. Learners are more motivated and achieved better learning outcomes, proving the effectiveness of VR in STEM education. Applying the insights in rural China, the creative and hands-on aspects of STEM education can bring out the left-behind children's motivations and incentives for learning. Among all available technologies, VR is a suitable media choice to implement STEM, given its additional utilities of providing help for the personal and emotional challenges faced by the left-behind children, including their lack of incentives, positive attitudes, and company from parenting figures.

Keywords: Virtual reality; STEM education; left-behind children; educational inequality.

1. Introduction

China's rapid development in recent decades intensified the educational inequality between its rural and urban segments. These inequalities are often viewed as an inevitable consequence of the distinction in social classes and the uneven distribution of resources (Guo, 2022). Among the groups troubled by such disparities, left-behind children, whose parents are migrant workers earning a living in larger cities, occupy a shocking population of over nine million as of 2016 (Wang, 2022).

The large population and the serious issues they face make the education of left-behind children a widely discussed topic. Within the rural schools, teachers mainly adopt a traditional, examination-oriented approach to education limited to the lines of words within the textbooks, resulting in classes lacking both attraction to the students and connections to the real world (Yang, Z., 2022). In addition, the absence of parenting figures in students' daily lives translates to them lacking healthy habits, motivation, and attitudes (Yang, Q., 2022). The absence of sufficient guidance and emotional company further results in them adopting a rather negative approach toward learning without efficiency or effectiveness. However, adding these responsibilities to the teachers is also unrealistically burdensome (Gao & Long, 2019).

Issues related to the education of left-behind children became an urgent concern among researchers, educators, volunteers, and related non-profit organizations, given that the lack of attention and decent solutions would only gradually magnify the seriousness of such disparities and deepen the inequalities. For example, as online learning and technologies occupy an increasingly large portion of education due to changes in global situations, the differences in qualities and outcomes of education between distinct social classes further enlarge (Wang et al., 2020).

However, instead of witnessing technologies becoming one cause of the intensified divergences, the ideal situation is to use technology as a tool that benefits the underprivileged ones as much as the

¹ <https://orcid.org/0000-0001-9274-2893>

more privileged ones, especially in educational settings. Researchers and educators are studying a wide variety of choices for such technologies: the portability of mobile media, connectiveness of online media, visualization and experimentation offered by simulations, motivating and engaging nature of games, and immersivity of virtual reality (VR), in addition to their shared characteristics of multimediality and interactivity, all made them favorable technologies to be implemented in educational settings (Plass et al., 2015; Liu et al., 2021; MacCallum et al., 2017; Dalgarno & Lee, 2010). The implementation of technology to aid education can often boost learners' engagement, collaboration, problem-solving, and emotional reassurances (Dalgarno & Lee, 2010). These are all areas where students receiving education in rural areas of China are struggling with, needing support for, or lacking exposure to, as mentioned previously, and these are only four among the many examples of benefits educational technology can potentially offer.

Within the range of available technologies, VR, characterized by its immersive, interactive, multimedia, multisensorial, engaging, and authentic nature, has an especially promising future in aiding education (Qorbani et al., 2021). Researchers investigated VR's applicability in a wide variety of subjects, from sociology to language learning, and from music to science (e.g. Qorbani et al., 2021). Specifically, its ability to represent three-dimensional spaces, visualize abstract concepts, and even recreate maker space and laboratory setups without the demand of actual space and material all demonstrated its suitability in STEM education (Qorbani et al., 2021).

STEM, or in full, Science, Technology, Engineering, and Mathematics, is an increasingly recognized area of study that is beneficial to learners in ways distinct from the traditional theoretical-driven subjects (Bicer et al., 2019). Starting STEM education in the early stages of education can help learners develop their innovativeness, creative problem-solving skills, and divergent thinking (Bicer et al., 2019). The problem-based learning methods adopted by many STEM subjects offer learners great opportunities to apply the theoretical knowledge to real-life settings, enhance their problem-solving and collaboration skills, as well as visualize and practice acquired concepts through hands-on experiences (Ruamcharoen et al., 2021). Each of the aforementioned traits makes VR an ideal candidate to maximize the effectiveness of STEM education.

To middle school students in rural schools scattered around China, situated in an educational framework with a mechanical, repetitive nature and a core focus on textbook-based theoretical knowledge, STEM is often an alien concept (Yang, Q., 2022). Speculatively, this might partly be due to the high costs associated with purchasing sufficient materials and spaces to support decent STEM education and the deficiency in qualified educators equipped with enough professional knowledge to guide them.

The implementation of VR technology might be a fundamental step toward eradicating these left-behind children's illiteracy in STEM. While sufficient case studies and research papers regarding the use of VR in education and the effectiveness of VR for STEM education exist, few researchers and educators specifically investigated the use of VR in STEM education for those underprivileged students in rural China. The potential VR aided learning can bring and the lack of examples of research in the area together prove the significance of this article; existing case studies and discussions centered around VR, STEM education, and rural education are used to analyze and evaluate VR technology's applicability in this specific educational setting. Thus, this article aims to fill in the blanks with introductory discussions on an unexplored yet potentially promising area of education.

Overall, this article examines the key affordances of VR and uses them as a basis to discuss the applicability of VR in the context of STEM education and in the setting of rural China. The article unfolds into the following three sections: 1) affordances of VR, 2) applying VR in stem education, and 3) applying VR for STEM education in rural China.

2. Applications of Virtual reality

This section examines the application of VR in secondary STEM education in rural China, by first introducing the affordances of VR, discussing its application in STEM education in general, then narrowing down the discussion to middle schools in rural China.

2.1. Affordances of Virtual Reality

VR involves the use of computer technology and the aid of a head-mounted display unit to create a completely virtual environment that is interactive and immersive, where users will feel themselves becoming a part of the environment (Maheshwari & Maheshwari, 2020). Several key affordances of VR make it an especially beneficial tool to be used for educational purposes; eight of which will be specifically discussed in this section.

2.1.1 The Immersive Affordance

VR headsets transits users from the real world to a completely virtual world, where users see and hear with all their attention. This often results in users feeling a high degree of presence within the virtual environment, enriching their experience (Qorbani et al., 2021).

2.1.2 The Interactive Affordance

VR is interactive in ways different than traditional media. Users do not need to interact through mouses or touch screens (Qorbani et al., 2021); instead, they use gestures or press buttons to interact as if they are physically located in the virtual environment. This offers a mode of interaction with higher engagement.

2.1.3 The Multimedia Affordance

VR's ability to display both graphics and texts, moving or still in three-dimensional forms makes its representation of information more diverse and vivid (Qorbani et al., 2021).

2.1.4 The Multisensorial Affordance

VR appeals to multiple senses of the users. In addition to plain sight and sound, users often need to do physical movements when they are holding the VR controllers. More advanced VR equipment even allows users to obtain certain feelings as a result of their corresponding virtual experience.

2.1.5 The Engaging Affordance

The fully immersed environment and the personalized component of VR often make it highly engaging for the users (Dalgarno & Lee, 2010). In addition, the novelty of VR technology adds to its engaging characteristic, contributing to the motivation and appeal VR can provide to users (Qorbani et al., 2021).

2.1.6 The Authentic Affordance

VR is characterized by its ability to recreate settings realistically. The authenticity allows VR to be used as an alternative to dangerous or complicated tasks that needs to be meticulously carried out in the real world. It is a useful tool that allows users to practice impractical tasks that need special permits or rare materials, or even impossible tasks that are not yet achievable in the real world (Dalgarno & Lee, 2010).

2.1.7 The Spatial Affordance

VR ensures users can perceive the correct spatial representation of objects. Users will be able to view and interact with objects from any point in space and from any perspective (Qorbani et al., 2021). In addition, VR provides unlimited space to fit a sufficient number of objects of any size.

2.1.8 The Social Affordance

VR enables social interactions. Similar to the idea of a metaverse, individuals with VR equipment can be connected together within the same virtual environment, regardless of their physical distance.

People all around the world can engage in international collaborations, communications, or even competitions together. Educators have experimented with collaborative activities like scavenger hunts connecting people from different places together in a virtual space and discovered successful results despite participants' real-life backgrounds (Dalgarno & Lee, 2010).

Some of the aforementioned affordances are common among all popular and widely recognized educational technologies, but some are unique to VR. Together, the eight distinctive affordances contribute to providing VR a promising future in education, specifically STEM education in rural China, as will be discussed in the following sections.

2.2. Applying Virtual Reality in STEM Education

The innovative and hands-on characteristics of STEM education and its importance to children have been outlined in detail in the introduction section of this article. This section discusses the application of VR in STEM education, given the affordances of VR and the characteristics and needs of STEM education, in consideration of existing case studies.

STEM education, characterized by its abstract concepts, the proportion of hands-on experience, and the emphasis on problem-based learning, often pose high requirements for the space, guidance, and material educators need to offer to the learners (Bicer et al., 2019; Ruamcharoen et al., 2021). VR is one promising method to deliver STEM content, as it helps to visualize concepts, enables collaborative problem solving, and provides virtual space and material allowing the hands-on experience to take place. With the authentic and immersive recreation of scenarios in the real world, the immersive and social features helping with collaborative learning, the interactive and multisensorial learning approach, and the engaging nature motivating students who might find traditional textbook-based STEM education to be boring or challenging, the affordances of VR and the characteristics of STEM subjects seem to correspond to one another suitably.

In addition to using VR to provide a fresh STEM education experience, VR is also able to solve challenges bothering STEM educators. For example, practical labs are sometimes hard to be implemented into chemistry classes, due to the high demand for space and equipment that are needed in order to let each student contribute and experience an experiment setting (Nersesian et al., 2019). In addition, certain chemical solutions involved in experiments are dangerous if not handled properly, or they might require special permits to acquire, complicating the incorporation of abundant practical labs in curriculums to support the theoretical knowledge learned. Researchers conducted a study in Dwyer Technical Academy in 2019, studying the measurable effects of VR technology in secondary STEM education, focusing specifically on chemistry (Nersesian et al., 2019). Within the study, 1,208 students have been separated into two groups, respectively using monitor-based and VR educational technology, in order to investigate the effectiveness of VR in chemistry education over the course of eighteen weeks (Nersesian et al., 2019). As a result of the novelty and engaging nature of VR, students experimenting with VR were more motivated and displayed higher positive attitudes toward learning, as compared to students learning with monitor-based technologies (Nersesian et al., 2019). After completing the whole learning module, the VR students performed better in cumulative class grades and final examinations (Nersesian et al., 2019). Together, these demonstrate how VR is beneficial in impacting students' positive attitudes and motivations toward learning, as well as improving their measurable learning outcomes.

Similar results have been documented by educators elsewhere. Researchers from Carleton University proved the effectiveness of VR in STEM education compared to traditional methods; students also reported experiencing a high degree of immersion that is a realistic recreation of the real world (Qorbani et al., 2021). Again, the engaging, immersive, and authentic affordances contributed to making VR effective in STEM education. In addition, a scoping review of the application of VR in STEM education documents that students often demonstrate abilities to apply concepts in hands-on exercises, as well as great improvements in their motivations, willingness to acquire knowledge, and learning outcomes (Pellas et al., 2020). Moreover, learners using VR adhered better to a cyclical learning pattern (Pellas et al., 2020), which is likely a result made possible by the problem-based

learning approach taken by most educators when applying VR in education. Within discussions about effective STEM education, problem-based learning approach have been increasingly recognized worldwide. For example, studying a group of 95 high school students in a summer camp, researchers found that problem-based learning with 3D printing can impact learners' perceptions of STEM and increase its creativity and innovativeness, simultaneously boosting students' engagement and motivation for learning (Bicer et al., 2017). With the affordances of VR, such a problem-based learning experience can also be incorporated and enhanced in education to a greater extent.

Overall, the affordances of VR correspond nicely with the characteristics of STEM. Applying VR in STEM education can improve students' learning outcomes and motivations for learning, as shown by case studies done globally. In addition, it also enhances the education experience by bringing in more opportunities for collaboration, problem-based learning, creativity, and innovation, while addressing existing challenges of STEM education. All of these make the application of VR in STEM education an effective and suitable choice.

2.3. Applying Virtual Reality for STEM Education in Rural China

Issues related to the education of left-behind children in rural China are receiving increasing awareness nationally and globally. Conditions both at home and in school do not offer ideal environments for students to learn. At home, the lack of accompanying parenting figures in the students' daily lives often results in their lack of parental guidance (Yang, Q., 2022). Jobs like guiding students to build healthy habits, set moral values, and develop a positive attitude for life and for learning are thus left undone. Without sufficient guidance, it is hard for students to self-develop such values; without incentives and motivations, they might not be able to recognize the merits of learning, and thus adopt a rather negative approach (Gao & Long, 2019).

It is also highly impractical to shift these responsibilities from the parents to the teachers. Teachers' jobs centered around teaching the lines of texts within the textbooks; concepts like individual attention, intrinsic motivations, and holistic education are beyond the scope of their responsibilities due to limitations of time, energy, and abilities (Yang, Z., 2022). Mechanical and repetitive learning can easily bore students (Yang, Q., 2022). When the already negative learning approach meets the lack of attraction to school subjects, most students do not have any intrinsic motivations for learning. Thus, it is hard for them to see the purposes of education beyond achieving nice grades in the examination-oriented education model (Yang, Q., 2022). One of the roots of the issues is exactly this lack of motivation and positive attitudes resulting from the lack of guidance and emotional company both at home and in school.

Given the problems surrounding basic education and given the textbook-based education method, STEM subjects are often alien concepts to students in rural China. However, the merits of STEM education might be an adequate answer to some of the challenges experienced by schools in rural China. For example, the creativity and collaboration involved in problem-based learning might be an approach to bring out the motivations of students to learn (Bicer et al., 2019). With the applicability of VR for STEM education explored in section 2.2, using VR in secondary education in rural China might address their challenges and simultaneously bring STEM to them.

VR's engaging, social, interactive, spatial, and authentic affordances make it a suitable tool that can possibly address these educational issues. The applicability of each affordance will be examined respectively.

1) One of the roots of the issues lies in students' lack of motivation and incentives. With the introduction of the novel VR technology, students will begin to see the fun of learning. Moreover, VR offers a more engaging learning experience that might sustain students' motivations and attitudes toward learning (Qorbani et al., 2021). Making students treat learning with a positive attitude might be an essential first step to take toward minimizing educational issues in rural China.

2) VR's social affordance enables collaborations between students within the same class or around the world. In an examination-oriented learning model, students learn by themselves and learn for themselves. With the introduction of collaborative components, students can experience problem-

based learning and collaborative problem-solving. They can learn to motivate one another, learn from each other, and become more incentivized to learn. Moreover, the social affordance can also be used to potentially connect students with mentoring figures, providing them with support and emotional company, filling in the gaps of guidance they need.

3) VR allows more interactions to take place. Different from the traditional test papers and answers learning method, students adopting problem-based learning with VR will be able to interact with the educational material and educators spontaneously and individually, increasing both the input they need to offer in the learning process and the feedback they can receive (Qorbani et al., 2021). These increased inputs and outputs can help learners improve and develop long-term learning habits.

4) The spatial affordance of VR allows students to comprehend the spatial representations of places they never had the chance to visit (Qorbani et al., 2021). Moreover, with the help of VR, problems like limited access to different settings and materials can be solved altogether. Students can freely explore without fearing being limited by physical material conditions.

5) The authenticity of VR ensures all learning experiences are designed based on real-world theories and settings. This not only provides a realistic learning experience for the students but further enhances the education's connection and applicability to the real world, as compared to the traditional learning methods.

Overall, both VR and STEM education are two areas often untouched by left-behind children in rural China. The inadequate basic education shifts educators' attention away from more advanced topics like STEM education, problem-based learning, and educational technologies. However, with the aforementioned affordances of VR and characteristics of STEM education, VR STEM education might be a tool that can effect changes in the roots of educational issues in rural China, bringing the left-behind children higher-level education, while simultaneously bringing changes to the quality of their basic education.

3. Conclusions

The educational inequalities faced by left-behind children prevailing in the rural areas of China became a widely recognized concern among socially conscious individuals. Effective education methods differing from the traditional examination-oriented approach are needed to bring changes to schools' educational effectiveness and students' attitudes. STEM education and the problem-based learning approach associated with it make it an important field to be introduced to left-behind children. Discussing the implementation of STEM education, many educators have laid eyes on VR for its promising future. Thus, this article discusses the application of VR in improving middle school STEM education in rural China.

To start off, VR is a technology creating completely virtual environments for users to fully engage in, using head-mounted display units. VR is characterized by its immersive, interactive, multimedia, multisensorial, engaging, authentic, spatial, and social affordances. Some of these are unique affordances of VR that cannot be offered by other existing educational technologies, making VR a promising tool to be implemented for effective education. Specifically, STEM education is an area VR might be especially suitable for. The abundance of abstract concepts associated with STEM subjects, as well as its emphasis on hands-on exercises and problem-based learning often pose challenges to educators. However, with VR's authentic recreation of real-world scenarios, social features enabling collaboration, and immersive learning approach, the abstract and complicated concepts of STEM can be effectively taught in practical and collaborative learning methods, even international collaborations, with the help of VR. Researchers around the globe have documented the effects of VR in improving learners' performances and learning outcomes in chemistry curriculums and other STEM subjects, providing concrete evidence proving the suitability of VR in STEM education. These insights can be applied to middle school STEM education in rural China. Major problems faced by the left-behind children in rural China include their negative attitudes toward textbook-based mechanical learning approaches and a lack of intrinsic motivations toward life and

learning, resulting from the absence of parenting figures accompanying them and lack of individual attention from educators. STEM education, implemented with the help of VR, might provide an answer for them. The creativity and collaboration aspects of problem-based STEM learning can bring out the motivations of students to learn; the engaging, social, interactive, spatial, and authentic affordances of VR provide emotional company and mentoring for learners, as well as providing them with motivations and inspiring them to find incentives for learning.

However, it is important to note that the application of VR in rural China is a novel area without much prior research done. This article only discusses the possibilities of such an application given the known promising affordances of VR and the effectiveness of VR for STEM education in past research. The actual effectiveness of applying VR to middle school STEM education in rural China should be evaluated after conducting on-site controlled studies in the future.

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