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Enhancing Agricultural Education through Virtual Reality: Facilitation, Application, Reflection, and Measurement in the Classroom

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Abstract

This agricultural development methods paper presents the Virtual Reality Facilitation, Application, Reflection, and Measurement (VRFARM) framework, an approach for integrating and evaluating Virtual Reality (VR) in agricultural education to enhance agricultural literacy. The VRFARM framework is adapted from Biggs' three key components— – presage, process, and product. It draws upon the principles of student and teacher characteristics, teaching environments, instructional methods, and reflective and measurement-based evaluations. The framework proposes a mixed-methods approach for evaluation, examining qualitative and quantitative data from teachers and students engaged with VR in the classroom. VR, when appropriately integrated using the VRFARM framework, is designed to improve students' agricultural literacy, engagement, and awareness. Major recommendations include using the VRFARM framework to implement and evaluate professional development programs for educators on VR use and agricultural literacy, along with fostering further research exploring the long-term impacts, diversity of educational settings and geographical locations, and inclusivity of VR in agricultural classrooms. This study establishes the VRFARM framework as a practical and research-based framework for educators, evaluators, and researchers, marking a significant step towards more innovative and effective VR agricultural education.

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Introduction and Problem Statement

An agriculturally literate person is one who understands the food and fiber system and its economic, social, and environment impacts on all Americans (National Research Council [NRC], 1988). A lack of connection, knowledge, and awareness of agriculture from young people impede their motivation and interests to pursue ag-related careers, adding strain to an industry that is already experiencing a shortage of qualified workers (Erickson et al., 2018). In addition, the public's declining understanding and mistrust of agricultural practices can influence legislative changes targeting agricultural production (Ochs et al., 2019). Although a majority of research examining this decline in agricultural literacy has focused in the United States, Cosby et al. (2022) identified that these trends are occurring globally.

Rapid advancements in the agricultural industry have led to more industrialized and globalized agricultural systems (Slocum & Curtis, 2017). Although these advancements offer benefits, such as increased efficiency, sustainability, and food security (Little, 2019), they may unintentionally create barriers between people and agriculture. In addition to shifts in the agricultural industry toward consolidation (Key, 2019), urbanization has changed global human population demographics, such that there are now more people living in urban areas compared to rural areas. These and similar trends continue to create a worrisome and growing disconnect between people and the agricultural industry (Dale et al., 2017; Frick et al., 1995; Kovar & Ball, 2013; Meischen & Trexler, 2003).

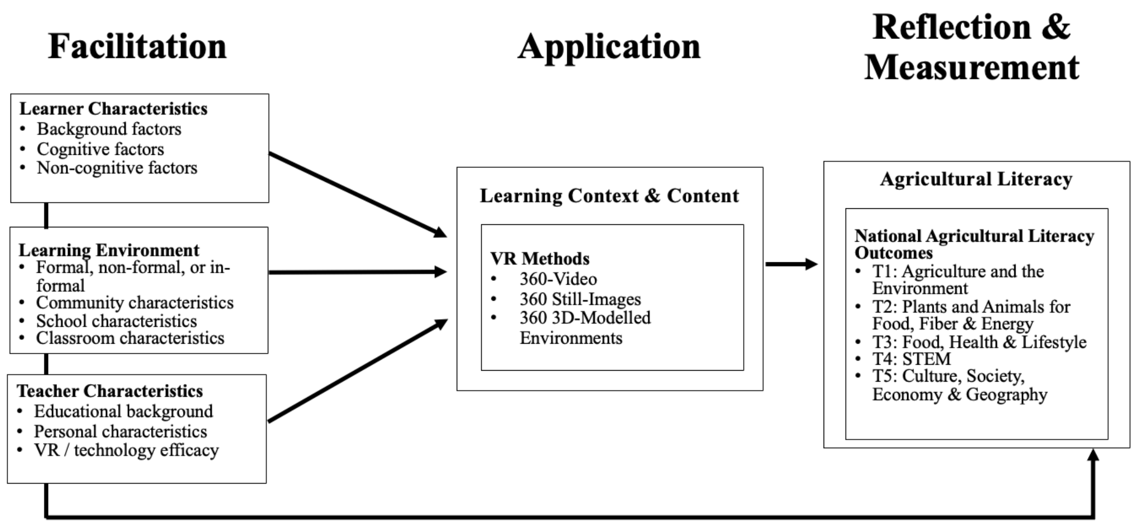
Formal and non-formal agricultural education can be a means to improve agricultural literacy among K-20 youth, educators, school administrators, and policymakers (Spielmaker et al., 2014). Experiential learning has particular value to develop students' deeper understanding of subject matter while building their critical thinking skills and application of gained knowledge (Eyler, 2009). Programs designed for youth that embrace experiential learning have been shown to improve agricultural literacy (Luckey et al., 2013; Pinkerton et al., 2021). The use of field trips that offer direct exposure to agricultural production have been especially useful in this endeavor for K-12 students (Bayer et al., 2020; Murrah-Hanson et al., 2022; Sigmon, 2014), as well as for post-secondary agriculture students through international travel experiences (Chen et al., 2020; Jarrell, 2019; Roberts et al., 2020). However, significant barriers exist that impede instructors' use of such activities, like time, resource availability, school culture, and teachers' knowledge about agriculture (Chang et al., 2013; Perticara & Swenson, 2019).

Knobloch et al. (2007) posited that agricultural literacy professionals should change programming efforts to improve the integration of agricultural topics in the classroom. Modern technologies can be used to infuse agriculture-based, experiential learning to new audiences, while increasing equity and reducing the barriers of time, costs, and resources associated with physical travel. One way to address the growing issue in agricultural literacy while still engaging individuals in experiential learning is through the implementation and utilization of virtual reality (VR), which can be used as an educational tool to allow individuals to be immersed in virtual environments that mimic real life experiences. For instance, immersive VR can facilitate field-trip experiences and skill-based learning, eliminating the need to leave the classroom or rely on costly, bulky equipment that may also pose safety risks. Recent advancements in VR technology have not only reduced its cost but also enhanced its portability and usability. Unlike earlier VR iterations that were expensive and required high-end computers, modern versions, like the Meta Quest, are standalone, more affordable devices. This accessibility has simplified their integration into classroom settings.

The development of VR applications in agricultural education has the potential to improve agricultural literacy, but an effective framework is necessary to guide successful implementation and evaluation of VR to enhance agricultural literacy. To help guide these efforts, the Virtual Reality Facilitation, Application, Reflection, and Measurement (VRFARM) framework was developed (Figure 1). Based on Biggs (2003) 3P model, we replace "presage" with "Facilitation," "Process" with "Application," and "Product" with "Reflection and Measurement."

Figure 1

Virtual Reality Facilitation, Application, Reflection, and Measurement (VRFARM) model



Note. This model is adapted from Biggs 3-P Model (Biggs, 2003*).*

Purpose and Procedure

The purpose of this paper is to detail the (a) Facilitation, (b) Application, and (c) Reflection and Measurement factors related to VR agricultural classroom integration to enhance agricultural literacy and (d) discuss applications of the VRFARM model for both practice, evaluation, and research. Its intent is to equip agricultural educators, evaluators, and researchers with a framework that goes beyond solely evaluating or researching educational outcomes.

To develop a comprehensive understanding of the Facilitation, Application, Reflection, and Measurement (FARM) of VR for agricultural literacy, we completed a comprehensive search of literature on topics related to VR within STEM and agricultural education. Our goal was to define characteristics and measures appropriate for the integration of VR to enhance agricultural literacy. The identified literature spanned topics like assessment characteristics in immersive educational environments, methods of classroom VR application, best practices in the measurement of literacy in specialized domains, and the specific nuances of gauging learning in virtual environments (Hamilton et al., 2021; Isaías et al., 2015; Lee et al., 2021). To ensure a comprehensive approach specific to VR in classroom settings, we also reviewed published research on best practices for VR classroom integration. We identified studies that elaborated on pedagogical strategies, instructional design methodologies, and reflective practices that have been empirically validated in the context of VR-based educational settings. The researchers then worked together to synthesize findings, integrate overlapping theories, and draw conclusions to develop the VRFARM framework.

Facilitation

Understanding facilitation characteristics and assessments in educational settings, especially within innovative platforms like VR an important process for evaluators and researchers. For evaluators, having a clear grasp of these characteristics enables the design of more precise and effective assessments. This knowledge aids in creating assessment tools that accurately measure learning outcomes and other educational metrics as a result of engagement with the VR environment. It also helps in aligning the assessments with the unique interactive and immersive features of VR, ensuring that the assessments are not only relevant but also engaging for the learners. On the other hand, for researchers, comprehending facilitation characteristics and assessments provides a robust framework for analyzing and understanding the dynamics of VR-based educational settings. It offers a lens through which the effectiveness and impact of VR as a learning tool can be studied. Additionally, it aids in the identification of areas of improvement, thus contributing to the advancement of pedagogical strategies and technological features in VR education. Furthermore, it provides a basis for comparative studies, where the outcomes of VR-based learning can be compared with traditional learning environments.

In identifying and measuring the characteristics of students, teachers, and the learning environment within VR settings, various methodologies and frameworks have been employed. The assessment of students' cognitive capabilities, motivation, prior knowledge, and adaptability to VR has been explored through studies aimed at understanding how assessments are constructed to evaluate students' learning in VR (Castenada et al., 2023). A systematic review spanning 20 years of empirical research on VR application in K-12 and higher education also provided insights into the evolving trends in VR literature concerning pedagogical assumptions and technological features of VR interventions (Luo et al., 2021). The immediate feedback characteristic of assessments in VR showcases the potential of real-time evaluation in understanding students' decision-making. On the side of the educators, a large-scale survey investigated teachers' perceptions towards VR technology, shedding light on their technical proficiency, pedagogical knowledge, engagement, and adaptability to VR environments (Khukalenko, 2022). These studies together build a narrative on how the characteristics of all stakeholders and the learning environment can be identified and measured to enhance the educational experience in VR settings.

Possible facilitation factors are outlined in Table 1. A combination of quantitative and qualitative measures will likely provide the most holistic understanding of the effectiveness of VR instruction.

Table 1

Facilitation Factors and Potential Methods of Assessment

Facilitation Factor Category	Facilitation Factors	Assessment Description	Potential Assessment Instruments
Characteristics of the Student	Cognitive Capabilities	Assess students' ability to comprehend, recall, apply, analyze, and synthesize information in a VR environment.	Standard cognitive assessments and specific VR competency evaluations.
	Motivation	Evaluate students' drive to learn in a VR setting.	Self-reported surveys or observations of student engagement and participation.
	Prior Knowledge and Skills	Assess what the students already know about the subject matter and their level of technical skill with VR.	Pre-assessment knowledge/skill tests.
	Adaptability to VR	Ability of students to respond positively to VR learning environments.	Surveys, interviews, and observations of VR use and engagement over time.
Characteristics of the Teacher	Technical Proficiency	Evaluate a teacher's ability to manage the VR technology effectively.	Demonstrations of proficiency, peer reviews, and student feedback.
	Pedagogical Knowledge	Understand the teacher's knowledge of teaching methods and how well they adapt to VR environments.	Teacher interviews, classroom observations, and student evaluations.
	Engagement	Measure how well the teacher interacts with and engages students in the VR environment.	Student surveys, classroom observations, and teacher self-evaluations.
	Adaptability to VR	Determine the teacher's ability to adapt their teaching style to the VR environment.	Peer reviews, student feedback, and self-evaluations.
Characteristics of the Learning Environment	Immersion Quality	Assess the quality of the VR experience, including how real or immersive the experience feels to participants.	Student and teacher surveys or expert evaluation.
	Usability	Evaluate how easy it is for students and teachers to navigate and interact with the VR environment.	Usability testing, surveys, and user error logs.
	Accessibility	Confirm if all students can access and use the VR technology, regardless of their physical or cognitive abilities or access to resources such as reliable internet access.	Accessibility testing and user feedback.
	Relevance	Determine if the VR environment and the tasks presented within it are relevant and appropriate to the learning goals.	Curriculum mapping, student surveys, and teacher evaluations.

Application

VR applications in agricultural education and training are currently less prevalent compared to industries such as medicine, engineering, and industrial careers (Kaminska et al., 2019; Kim et al., 2018). However, the potential uses for VR in agricultural education are diverse and hold promise for enhancing learning experiences across formal and nonformal settings.

Skill-building in Agricultural Systems

The bulk of existing research in VR applications for formal agricultural education has focused on skill-building in power, structural, and technical systems. Although simulation-based instructional methods are well-established in agricultural mechanics education, VR technology has renewed interest in how simulations can lead to more efficient and impactful outcomes for students (Wells & Miller, 2020b). Virtual and augmented reality welding applications in agricultural mechanics courses have emerged as a form of interactive 3D-modeled environments used for technical training, most often used in conjunction with traditional technical teaching methodologies like demonstrations and guided practice with real equipment (Byrd et al., 2015; Wells & Miller, 2020a; Wells & Miller, 2022). Similarly, 3D-modeled simulations for safe tractor operation exemplifies the transformative potential of VR in skill development. These simulations create a secure and simulated environment where students can enhance their technical proficiency in machinery operation. This approach, as highlighted by Pulley et al. (2023), not only ensures the safety of students but also offers a controlled space for them to master the intricacies of tractor operation before engaging with real equipment. In some cases, students would not be able to access any interactions with agricultural equipment without the use of these VR simulations, which allows them an avenue for the concrete experience component of experiential learning (Kolb, 2015; Pulley et al., 2023).

Cognitive Outcomes and Engagement

The use of VR has proven to be a dynamic and transformative tool. While 360º video exhibits varied efficacy for recorded lectures, its impact on student attentiveness and engagement across diverse educational content areas is noteworthy (Ranieri et al., 2022). The immersive quality of 360º experiences significantly contributes to fostering a more interactive and engaging learning environment. Beyond the limitations of traditional lectures, VR offers a multifaceted approach to learning enhancement. Modeling and immersive exploration within educational settings are well-documented, offering students a more vivid and memorable learning experience (Ranieri et al., 2022). These applications provide students with a more vibrant and enduring learning experience, transcending the boundaries of conventional teaching methods.

The cognitive advantages of VR in agricultural education extend to its capability to transport students to physically inaccessible environments virtually. This distinctive feature of VR is a pivotal asset, particularly in relation to experiential learning theory, allowing students to delve into 3D spaces intricately connected to the content being taught (Kolb, 1984; 2015). Examples of experiential activities include virtual field trips (domestic or international) to production or natural resource environments. These can be 360-videos of environments sometimes with audio narration or 360-image tours where users can travel image-to-image through an environment that could include additional interactive elements such as pop-up information in text, audio, or video form. This content can be created by the instructor or found online through various VR content hosting platforms such as YouTube VR or websites such as FarmVR.com. In comparison to conventional visual aids like pictures or videos, this virtual exploration fosters a more profound and impactful learning experience for students (Lege & Bonner, 2020). The integration of VR into agricultural education not only addresses engagement challenges but also propels cognitive outcomes to new heights. The immersive nature of VR experiences, coupled with the ability to explore complex environments, fundamentally reshapes the educational landscape, creating opportunities for deeper understanding and more lasting retention of agricultural concepts through reflection on VR experiences, abstract conceptualization of related ideas and concepts, and learning transfer (Coleman, 2022; Kolb, 1984).

Nonformal Training for Agricultural Producers

In nonformal settings, VR training for agricultural producers addresses complex phenomena such as airflow, humidity control, and temperature distribution within agricultural facilities. The invisibility of these environmental factors and the associated risks of manipulation in real environments make VR applications a valuable tool for experiential learning related to environmental controls (Kim et al., 2018). Similarly, using VR to train operators of unmanned aerial vehicles (UAVs) in crop production reduces the physical and financial risks associated with agricultural UAV crashes through training in a controlled, low-stakes environment prior to real-world practice (Nguyen et al., 2019). Both cases for nonformal VR training allow producers to engage in learning experiences with a strong similarity to the real application and reflect on how their virtual experience will transfer to their production operations, thereby aligning with the recommendations of Coleman (2022) and Kolb (2015).

Despite the potential benefits of VR applications in agricultural education, educators have expressed concerns about familiarity with the equipment and a lack VR-specific pedagogy when considering implementation (Lege & Bonner, 2020; Pulley et al., 2023). These challenges align with the experiential learning recommendations of Baker and Robinson (2016) and Coleman (2022) and are focused on the need for well-developed pedagogical tools for instructors that intentionally draw on experiential learning frameworks. Addressing these concerns is crucial for the widespread adoption and effective integration of VR into agricultural education.

VR Methods

As noted above, VR content can be found online or through VR headset app-stores such as the Meta Quest store. This provides access to ready-made content either through video, images, or 3D modelled environments. In addition to sourcing pre-made content, educators could also engage students, faculty, or staff in content creation. We identified three methods of VR classroom content-creation, 360-degree video, 360-degree still-image (virtual tours or field trips), and 3D-modeled environments. Instruction guidance and required resources are provided in Table 2.

Table 2

VR Content-creation Method, Instructions, and Resources

VR Method	Instructions (steps)	Required resources/equipment
360-video	1. Capture footage using specialized cameras (Examples are Insta360, Ricoh Theta, or GoPro Max) 2. Process and stitch videos together using specialized software (Examples are Adobe Premiere Pro, Final Cut, or iMovie). 3. Upload videos into a virtual reality platform, such as Google VR, YouTube VR, Unity, or specialized educational platforms like zSpace and Labster. 4. Add interactivity like hotspots, audio narration, text, and additional resources. 5. Allow learners to explore the videos using a VR headset (Meta Quest, HTC Vive etc.), a computer, or a mobile device.	Specialized cameras (e.g., Insta360, Ricoh Theta, GoPro Max) VR software/platform (e.g., Google VR, YouTube VR Unity, zSpace, Labster) VR headsets
360 Still-Images	1. Capture images using a specialized camera or smartphone app. 2. Stitch images together using specialized software or online services. 3. Add interactivity and hotspots to the panoramic image. 4. Integrate 360-degree still images, interactive elements, and hotspots with a virtual reality platform, such as Google VR or specialized virtual reality platforms. 5. Test and refine the experience for the target audience.	Specialized cameras or smartphone apps Stitching software or online services Virtual reality platform (e.g., Google VR, Klapty, Kuula)
360 3D-Modeled Environments	1. Develop a 3D model of the environment using specialized software or scanning technology (LIDAR or photogrammetry). 2. Use virtual reality platforms, such as Google VR, Unity, or specialized educational platforms like zSpace and Labster, to develop interactive and engaging virtual reality experiences. 3. Allow learners to explore and interact with the virtual environment using a VR headset and hand controllers or a computer with a mouse and keyboard.	3D modeling software or scanning technology Virtual reality platform (e.g., Google VR, Unity, zSpace, Labster, Meta Horizon Workrooms)

Reflection and Measurement Factors

Assessment Model

VR instruction is a relatively new mode of delivering simulated, experiential learning, and it is imperative that assessment methods be flexible as new research emerges. Therefore, we propose an assessment approach intended to be comprehensive and adaptable to meet such needs. The proposed assessment model will provide a comprehensive evaluation of the impact of VR classroom instruction. The results of this assessment will be used to refine the instruction and improve the effectiveness of VR instruction in promoting agricultural literacy among learners. There are several approaches educators can pursue for evaluating learning outcomes as a result for VR instruction. In this section, we will detail the various avenues. Some educators may find one avenue appropriate over the other, whereas others may find a blended approach more applicable to assessing their educational goals.

Measurement

Educators can evaluate the impact of their VR programming on targeted objectives specific to their content (e.g., delivering VR education on dairy and assessing students' dairy science literacy) or on broader agricultural literacy measures such as the National Agricultural Literacy Objectives (NALO) (Spielmaker & Leising, 2013). In both cases, we recommend a pre-post, post-post design to establish learners' baseline knowledge, as well as knowledge gained and retained following their exposure to the VR educational program. Educators looking to use a formal, written assessment aligning with targeted NALOs might consider using standardized written assessments designed for specific grade levels of learners, such as the Judd-Murray Agricultural Literacy Instrument (Judd-Murray, 2019). These assessments were designed to differentiate proficiency stages (i.e., exposure, factual literacy, and applicable proficiency) across the five national literacy themes.

Reflection

In addition to traditional written assessments, experiential learning requires instructor support and facilitation in the form of providing opportunities for reflection, engagement, and connection of experiences to learning outcomes to ensure transfer of learning beyond the classroom (Coleman, 2022). Kolb's (1984; 2015) experiential learning model positions application in the experiential learning scenario as the action of exploring knowledge in familiar or new settings. In Kolb's model an initial "concrete experience" is followed by a period of reflection. During the reflection, participants assess their experience either individually or with others. In turn Kolb suggests that this can create opportunities to re-engage either with that experience or similar experiences in a new way. This is especially important in 360 VR where the user has the opportunity to choose their areas of attention. Unlike traditional media where the producer chooses the camera angle or subject of focus, in a VR environment the user acts as the operator, choosing what to focus on. For example, if students are shown a lab space in VR some may choose to focus on equipment while others may observe the scientists in the room. As such, experiences could be different for each individual. Thus, reflection offers the opportunity to identify these differences and thus re-engage with the content (or real-life scenario) later with a different point of emphasis. This is what Kolb describes as creating a new concrete experience that supplements or replaces the first. When applied to the learning process, we may conclude a learner's experience, such as learning in VR environments, may not have been an educational one if they cannot transfer concepts learned in one setting to other experiences and settings (Coleman, 2022; Dewey, 1938; Haskell, 2001; Kolb, 2015). For example, when using a skill building tool, it is necessary for the instructor to ensure that the simulated experience provides an outcome where these skills could be transferred to the real-world activity or in an experiential learning scenario where this VR experience contributes understanding to the world beyond the headset. To improve student transfer and align to best practices in experiential learning (Kolb, 1984; 2015), we recommend instructors implement strategies for student reflection and transfer. Such strategies may include facilitating reflective peer dialogue (McLeod et al., 2015), digital story telling (Kim et al., 2021), and student journaling. Furthermore, the content and depth of student reflections can serve as a valuable formative assessment to gauge the impact of VR applications (Han, 2019).

Conclusions, Discussion, and Recommendations

In conclusion, the integration of VR in agricultural education holds significant promise in enhancing agricultural education in the classroom. The comprehensive approach delineated in this paper—encompassing facilitation, application, reflection and measurement—paves the way for a more systematic, efficient, and effective utilization of VR technology within the agricultural classroom environment. By understanding the multifaceted nature of these factors, educators can optimize the VR teaching and learning environment for the benefit of both instructors and learners. Furthermore, by following the practical applications and assessments provided by the VRFARM model, valuable insights will be gained on the potentials and challenges of VR in this evolving pedagogical landscape. The different modes of instruction detailed, their subsequent implementation, and the ensuing evaluation process ensure that this model will foster not only knowledge acquisition but also the capacity for knowledge transfer across varying contexts. The VRFARM model potentially provides a framework that could help guide the way agricultural literacy is taught, suggesting steps towards a more innovative, interactive, and digitally immersive educational future.

Implications and Recommendations for Practice

Professional development for educators plays a critical role in enhancing their competencies, shaping their teaching practices, and bolstering their confidence within specific educational contexts (Colclasure et al., 2022; DiBenedetto & Whitwell, 2019; Walsh & Irving, 2021). Central to these contexts is the emerging field of VR technology integration within the agricultural curriculum, as well as the improvement of K-12 students' agricultural literacy (Frick et al., 1992).

Educational change and innovation hinge on educators' readiness and capacity to adopt new technologies and pedagogical methods. As such, professional development opportunities should focus on preparing teachers for the successful adoption of VR technologies in their classrooms, as asserted by Wells and Miller (2020b). In a rapidly evolving educational landscape, continuous professional growth and adaptability are crucial, and such development programs can equip educators with the necessary tools and techniques.

Furthermore, these programs can also bridge the gap between the current state of agricultural literacy education and its desired state by equipping educators with the necessary skills and knowledge to effectively deliver agricultural education. The end goal of these professional development opportunities should not be limited to mere knowledge acquisition but should focus on the practical application of this knowledge in real-world teaching situations.

However, for such programs to be effective, they must be meticulously designed to encompass both the theoretical and practical aspects of agricultural education and VR technology application. This would entail sessions on the theoretical foundations of agricultural literacy, practical demonstrations of VR technologies, and workshops on the integration of these technologies within the teaching and learning process.

In conclusion, we underscore the significance of professional development as a catalyst for enhancing both agricultural literacy and the use of VR technologies. By embracing this dual-focus approach, we can better equip our educators to meet the challenges and demands of the 21st-century agricultural education landscape.

Implications and Recommendations for Research

The intersection of VR and agricultural education presents an abundance of opportunities for further empirical study. Our findings, built upon the foundation of the VRFARM model, serve as a launching pad for future research. This is an emerging field, and as such research into VR and agricultural education thus far has tended to reflect its emergent nature. However, the field would benefit from longitudinal studies that assess the enduring impacts of VR on pedagogical practices, instructional assessment, and evaluative research (Pelletier et al., 2023). VRFARM can be used as a framework for assessing the long-term effectiveness of VR in agricultural education. Furthermore, this is not a static model and so longitudinal research should also aim to inform potential areas of model refinement.

Given that agricultural education is not limited to the United States and can be applied outside the boundaries of high-school curriculum, the application of VRFARM across diverse educational settings and geographical locations could also be a focus of investigation. This would shed light on the model's effectiveness in various contexts and provide rich data for comparative studies (Ipek & Ziatdinov, 2018).

Finally, the potential of VR in promoting inclusive and differentiated instruction in the agricultural classroom warrants examination. VR's potential to cater to diverse learning styles and promote accessibility could lead to more personalized and inclusive teaching methods (Rose & Meyer, 2002).

We hope this paper inspires future research that can further our understanding of how VR technology can be harnessed most effectively in agricultural education, and we invite researchers to use our work as a steppingstone toward more innovative research in the field.

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