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A Review of Virtual Reality Applications in Agriculture Education and Recommendations for Future Research

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Abstract

The rapid advancement of virtual reality (VR) technology offers significant potential to address the skills gap in agricultural education and workforce development. This integrative review examines existing literature on the application of VR in educational settings, with a specific focus on agricultural education at the secondary and postsecondary levels. Immersive VR environments provide unique learning affordances, including enhanced spatial knowledge, increased engagement, and improved skill transfer to real-world situations. While industries such as medicine, construction, and manufacturing have integrated VR for training, it is still in the early stages of adoption in education. Findings reveal that while there is limited research on VR in agricultural education, promising examples, such as virtual welding simulators and virtual field trips, demonstrate its potential to offer safe, cost-effective, and flexible training solutions. The review identifies key areas for future research, such as the development of pedagogical content for VR, user experience evaluation, and the adoption of VR technology by educators. This review also presents a research agenda aimed at expanding the use of VR technology in agricultural education, emphasizing the need for further empirical studies to explore its effectiveness in bridging the skills gap and enhancing workforce readiness.

Introduction

The need for skilled workers in agriculture is a concern worldwide, as skilled labor exists across all facets of the industry (Christiaensen & Even, 2024). Within the United States, there are approximately 59,400 job openings in agriculture each year between 2020 and 2025, with 40% of those positions going unfilled (Goecker et al., 2015). Employers struggle outside the agriculture industry to find individuals with qualified experience and skills (Klein et al., 2023). Future employees' skills and training rely on workforce education and development (O'Lawrence, 2017). Workforce development and training is critical for agricultural education to mitigate a skills gap. One solution is to utilize virtual reality for education and training. However, with virtual reality being a recent development in SBAE and CTE, we want to present a review of the literature to offer a framework for future research, completing a conceptualization and synthesis of work (Torraco, 2005).

Over time, traditional workforce training has evolved due to innovation and increased demands for skilled labor from employers (Haviland & Robbins, 2021). One form of workforce training is career and technical education (CTE) (O'Lawrence, 2017). CTE, which includes agricultural education, provides

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workforce training through formal schooling and hands-on training (ACTE, 2022). Coursework within CTE offerings is designed to serve as a bridge connecting students with careers that require additional training after high school or postsecondary programs of study; these options can result in apprenticeships, certificates, employment, or postsecondary degrees (U.S. Department of Education, 2019). One way school-based agricultural education (SBAE) and other CTE programs provide workforce training is through technology. This technology integration is usually something as simple as a digital presentation or using a computer in some capacity (Farmer, 2011). While this technology is useful, current labor shortages and lack of adequately prepared skilled workers entering the workforce indicate CTE teachers could be seeking different avenues to ensure their students are adequately trained (Tharpe, 2022).

One solution to the ever-widening skills gap could lie in the rapid evolution of educational technology. Educational technology has evolved through the integration of virtual reality (VR), "a three-dimensional, computer-generated environment which can be explored and interacted with by a person" (*What Is Virtual Reality? - Virtual Reality Society*, n.d., para. 1). A virtual environment allows a user to become immersed in an alternate reality, which could be real-world or fictitious places created by the developer. Users can walk around, interact with other objects, and maintain a social presence with other users' avatars. Augmented reality (AR) and VR date back to the 1960s, but as technology advanced, they have become more commonplace and cheaper to acquire (Lee, 2012).

There are three types of VR: virtual reality, which is fully immersive; mixed reality, which is semi-immersive; and augmented reality, which is non-immersive and more of an overlay of virtual components onto the real world (Bamodu & Ye, 2013). Virtual reality replaces the real world with a computer-generated environment anchored to the user's head and hand movements using head-mounted displays (HMD; i.e., Meta Quest brand headsets). Mixed reality blends the user's real-world environment and a virtual environment, and the user interacts with it through glasses such as Google Glass or Meta Quest 3 (Gandhi & Patel, 2018). Augmented reality is similar to mixed reality in the sense that it overlays digital information onto real-world elements, but the digital content in augmented reality typically does not interact with the real world (Craig, 2013). Examples of augmented reality include games like Pokémon Go or training simulators with a control station interacting with a screen or projection.

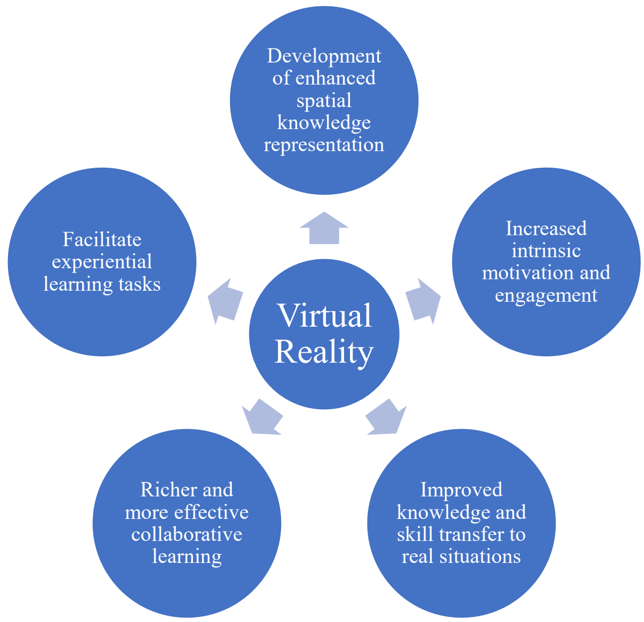
Virtual reality has proved to be an efficient tool for K-12, colleges, and universities to provide students with knowledge and skills related to complex mechanisms and theories (Dalgarno & Lee, 2010). The five affordances that VR can provide to learning environments, according to Dalgarno and Lee, include:

- Facilitate learning tasks that lead to enhanced spatial knowledge representation of the explored domain.
- Facilitate learning tasks that lead to increased intrinsic motivation and engagement.
- Facilitate learning tasks that lead to improved knowledge and skill transfer to real situations through contextualization of learning.
- Facilitate tasks that lead to richer and more effective collaborative learning than possible with 2-D alternatives.

Facilitate experiential learning tasks that would be impractical or impossible to undertake in the real world. The learning affordances outlined by Dalgarno and Lee (2010) can be seen below in Figure 1.

Figure 1

Virtual Reality Learning Affordances (Dalgarno & Lee, 2010)



These affordances provided enhanced educational value to students in many different studies. For instance, virtual learning environments with positive features of immersion, ease of use, and help-seeking have shown to have positive effects on students' perceived cognition through learning languages in VR (Chen, 2016; Davis, 1989). Other studies have reported beneficial features such as using full-body interaction in a virtual environment to promote students' active learning (Maes et al., 1997); using storytelling can improve user involvement and engagement (Cavazza et al., 2004); promoting psychomotor development by allowing users to practice dismantling a crane (Li et al., 2018); and promoting skill transfer by learning to juggle in VR (Kahlert et al., 2015; Sportillo et al., 2015). These studies show the use of the learning affordances described by Dalgarno and Lee (2010). These same affordances can be integrated throughout multiple industries to enhance training efforts.

Industries such as medicine, construction, manufacturing, and military have incorporated VR into their training programs, allowing learners to benefit from these same positive features and learning affordances. For example, studies have shown that experienced surgeons who had prior experience with VR training were significantly faster and used significantly less contrast fluid than the inexperienced group (Aggarwal et al., 2006). A separate study used a desktop VR program to teach pedestrian safety to students, which showed the use of the VR program increased their gain mean scores, indicating they learned the main four lessons of pedestrian safety (McComas et al., 2002). Another training program used in the construction industry reported that workers showed a significant difference between pre- and post-tests in hazard ID and prevention (Sacks et al., 2013). Mining is also an industry that is trying to make use of VR primarily around safety and reducing the number of accidents on the job. A range of mining equipment simulators, including dozers, draglines, haul trucks, shovels, and continuous miners, are available commercially (Tichon & Burgess-Limerick, 2011). Studies have also shown that using a 3-D VR application was more effective than a lecture-only delivery method and just as good as lecture with a physical laboratory (Nakayama, 2014).

School-based agricultural education and postsecondary agriculture training have begun incorporating VR with many other opportunities for future incorporation into coursework. VR is a recommended form of technology for teachers, with examples of the technology needed ranging from VR headsets and computers to smartphones (McCubbins & Specht, 2023). Examples of classroom applications of VR include digital simulations and evaluating a digital artifact (e.g., a model of DNA; McCubbins & Specht, 2023).

So far, the central area of VR inclusion within agricultural education is agricultural mechanics. Agriculture teachers have trained high school students using VR for tractor safety and operation. These teachers found the virtual training to be as practical as the traditional training (Pulley et al., 2024). Virtual welding simulators provide a safe environment and personalized feedback during welding (Heibel et al., 2024a, 2024b). Additionally, virtual reality welding trainers positively influence preservice SBAE teachers' self-efficacy and welding ability (Thompson, 2024).

Aside from Agricultural Mechanics, VR has been used in other areas of Agricultural Education. VR is invigorating agricultural literacy programming by providing virtual field-trip experiences (Greig et al., 2024; Harlan, 2023) and teaching, for example, the basics of beekeeping (Strousopoulos et al., 2023). To promote the use of VR, Greig et al. introduced a model for practitioners to incorporate VR into educational settings, the Virtual Reality Facilitation, Application, Reflection, and Measurement (VRFARM) model. This study developed a framework for educators, evaluators, and researchers to integrate and evaluate VR in agricultural education (Greig et al., 2024).

For educators, the benefits of using VR include removing financial and time restraints as well as safety hazards (McCubbins & Specht, 2023). However, depending on the type of VR equipment required, the inclusion of VR is potentially expensive (Pulley et al., 2024). Additionally, depending on the level of immersion, the users of VR may potentially react and have symptoms of simulator sickness (Kennedy et al., 1993). Agriculture teachers indicated they are not opposed to using VR, but they are uncertain about the technology and how to incorporate it into their classrooms (Wells & Miller, 2020a). Likewise, college students who used VR technology in a welding class (Wells & Miller, 2022) and students who participated in an interactive virtual tour of the cotton ginning process (Harlan, 2023) provided positive feedback, but did not believe VR experiences should completely replace the real experiences.

Purpose and Research Questions

While VR applications are wide ranging, and the advantages within CTE and SBAE are apparent, it is in its infancy with both practice and research. With so many options for research and application within VR, even within the context of SBAE, a synthesis of the literature to guide future research is needed. Therefore, this integrative literature review describes current studies related to virtual reality and within the conclusion, proposes a research agenda for the application of virtual reality applications in agricultural education and implementation of VR technology in agricultural education, both broadly and within SBAE at the secondary and postsecondary levels. By exploring how VR immersive technology is used, it will help us understand the new technology and teaching practices available to support the needs of a new generation of students. This study was guided by the following research objectives:

1. Describe the focus of studies regarding virtual reality within education and agricultural education.
2. Describe the types of virtual reality researched within education and agricultural education.

Methods

Torraco's (2005) approach for integrative literature reviews was used to review scholarship published on virtual reality in education, specifically agricultural education. One use of an integrative literature review is to address new and emerging topics to provide a conceptualization of the subject that has not yet occurred (Torraco, 2005). Although virtual reality (VR) is not a new form of technology, its integration and application into educational settings is a recent development, especially in agricultural education. While an integrative literature review can be approached in different ways, this literature review focuses on synthesizing literature on virtual reality to advance a research agenda to stimulate future application and research in agricultural education (Torraco, 2005).

We utilized the framework provided by Torraco (2005) on how to conduct an integrative literature review, including how literature was identified, analyzed, synthesized, and reported. To identify literature on virtual reality technology and its broad use in educational settings, the research team identified two journals, the *Journal of Virtual Reality* and the *Journal of Educational Technology Systems*, due to the prevalence of articles focused on virtual reality in educational settings. Within agricultural education, *the Journal of Agricultural Education* was chosen based on the specific focus on SBAE. Additionally, the research team hand-searched through career and technical education journals (e.g., *Journal of Career and Technical Education* and *Career and Technical Education Research*) and related SBAE journals (e.g., *Advancements in Agricultural Development* and *Journal of Southern Agricultural Education Research*). Still, we did not identify any articles meeting the criteria of our study (Cranane and Dikstra, 2012).

The inclusion criteria for articles included articles published between 2010 and 2023. We set this time frame due to 2010 being the beginning of a new decade, the more recent prevalence of VR technology, and providing a reasonable amount of data. The selection criteria for relevant articles included the article's focus, the use of virtual reality, and the use of virtual reality within an educational setting. The following terms were used to search for specific articles from within their host journal sites: virtual reality (VR), mixed reality (MR), augmented reality (AR), agricultural education, and agriculture education. After using the journal site search feature, we conducted a hand search of all journal issues within the study's parameters to ensure all relevant articles were included, ending with 170 relevant articles. Table 1 identifies the number of articles identified by year and by journal. The *Journal of Virtual Reality* published the most relevant articles, with 147 studies published from 2010 to 2023, with 202 having the highest number (n = 41) published in one year. The *Journal of Educational Technology Systems* only published up to three articles per year, with the *Journal of Agricultural Education* having only four relevant articles published between 2020 and 2023. Table 1 quantifies the number of articles from the J*ournal of Virtual Reality, Journal of Educational Technology Systems*, and *Journal of Agricultural Education* by year.

Table 1

Articles from the Journal of Virtual Reality, Journal of Educational Technology Systems, and Journal of Agricultural Education from 2010-2023 (n = 170)

Year	Journal of Virtual Reality	Journal of Educational Technology Systems	Journal of Agricultural Education
2010	0	0	0
2011	0	0	0
2012	0	0	0
2013	1	1	0
2014	4	1	0
2015	6	2	0
2016	3	0	0
2017	3	1	0
2018	5	3	0
2019	13	2	0
2020	22	3	2

2021	41	2	0
2022	18	1	1
2023	31	3	1
Total	147	19	4

The lead coder identified the articles, they were downloaded, stored in a cloud-based server, and reviewed by the research team. The abstract was analyzed by the research team to determine if this study applied to and fit the inclusion requirements. To meet the research questions, we utilized content analysis (Neuendorf, 2017) and inductive coding (Saldaña, 2016) to identify the focus of the articles and the type of VR technology. The lead coder and the other author split the articles to review and kept track of coded articles in an Excel sheet. Regular check-ins were scheduled to ensure inter-rater reliability. We identified the following foci of the research studies: theoretical, pedagogical, review, design, or evaluation of VR application. Additionally, we categorized the articles on the type of VR used by the three types of immersive experiences: augmented reality, mixed reality, and virtual reality.

To identify the focus of the articles published, the studies' problem statement and purpose were analyzed to determine how the studies were coded. Some articles contained codes related to two themes, these were combined to make new themes. Articles were then coded into the following themes: application evaluation, design, design/application, pedagogical, pedagogical/design, review, and theoretical. The themes and definitions can be found below in Table 2.

Table 2

Themes and Definitions

Themes	Definitions
Application Evaluation	The *application evaluation* theme focused on the evaluation of student or user performance to understand how the application performed.
Design	The *design* theme revolved around applications that were being designed and piloted with users. Studies in this category did not have a main focus on evaluation.
Design/Application Evaluation	*Design/application* is a combination of *design* and *application* evaluation; these studies focused on the design/development of applications and their evaluation in the same study.
Pedagogical	*Pedagogical* studies focused on the use of previously developed applications from a pedagogical perspective where it improved teaching and learning.
Pedagogical/Design	*Pedagogical/design* focused on the development of applications with a pedagogical focus on teaching and learning.

Review	*Review* articles were literature reviews related to virtual reality technology.
Theoretical	*Theoretical* articles focused on the evaluation of components related to theoretical components related to the use of VR technology.

To set aside our subjectivity related to this project, it is important to note that two members of the research team actively work with VR technology in the classroom setting, and all three authors are involved with preservice SBAE teacher education programs.

Findings

Objective 1: Describe the focus of studies regarding virtual reality and education, including agricultural education.

Objective one sought to identify and describe the focus of studies regarding virtual reality and education, including agricultural education. From 2010-2023, 170 journal articles met the inclusion criteria. Table 3 provides an overview of each theme with the frequency of articles per journal in that theme.

Table 3

Articles from the Journal of Virtual Reality, Journal of Educational Technology Systems, and Journal of Agricultural Education by Article Theme

Theme	Journal of Virtual Reality	Journal of Educational Technology Systems	Journal of Agricultural Education	Total
Application Evaluation	55	7	1	63
Design	10	2	0	12
Design/Application	27	0	0	27
Pedagogical	6	0	0	6
Pedagogical/Design	1	1	0	2
Review	24	6	1	31
Theoretical	21	0	2	23

Application Evaluation

Articles in the *application evaluation* category (n = 55) referred to studies that focused on evaluating the user's performance of a VR application, the usability of a VR application, or to gather feedback of a VR application. In science and STEM education, VR has been used to promote higher motivation, engagement, and interest in organic chemistry (Edwards et. al., 2019). Students indicated virtual experiences, such as field trips, felt were more educational than the real trip (Klippel et. al., 2020), and provided a virtual space which had higher usability and learning effects for students to perform chemical experiments (Pan et. al., 2022). Within mechanics and engineering, VR provided opportunities for students to visualize engineering rationale and intent in product design and life cycle (Raymond et. al., 2012) and has been used to increase knowledge recall and service steps with workers on train car service procedures

(Borsci et. al., 2016). The studies all had higher effects of motivation, interest, engagement, and learning when compared to other MR applications, live trainings, or field trips.

In the medical field, virtual reality has been used in a variety of ways to enhance students' learning and provide experiences without them stepping into an operating room. In studies focused on workforce training, especially in the medical field, AR has been used to positively enhance students' learning and understanding of heart anatomy (Alfalah et al., 2019), create an enjoyable and useful assessment for nursing students in stroke assessment (Liang et al., 2021), provide better outcomes for groups who trained with VR in neurosurgery training (Lin et al., 2022), and to improve examination scores and aiding understanding regarding diagnosis and treatment planning in dental patients (Sakowitz et al., 2020). All of these studies saw increased scores and outcomes, and groups who used this technology showed more improvement over the groups who did not use it.

In educational settings, a virtual classroom allowed teachers to train and increase speaking skills related to intensity, pausing, and frequency (Remacle et. al. 2021). Other articles focused on teaching adult learners' facilitation strategies and empowering foreign language learning (Kallioniemi et al., 2015; Speed et al., 2015). Speed et al. (2015) used a mixed reality environment that offers a digital puppetry approach, which allowed a puppeteer to control several virtual students. The system was found to be an effective method of delivery, testing strategies and giving feedback. Kallioniemi et al. (2015) used Berlin Kompass, a mixed-reality Cave Automatic Virtual Environment (CAVE) system, that allowed one user to act as a tourist and the other as a tour guide. The application was well received, and students felt it was effective in delivering feedback. These articles further reinforce the positive impact of virtual reality technology application in educational settings.

One article from the *Journal of Agricultural Education* focused on the application evaluation of VR technology on welding skill performance (Wells & Miller, 2020b). This study was an experimental study that compared different welding groups to evaluate the effectiveness of a VRTEX 360 against traditional training procedures. The researchers determined the VR technology did not improve or take away from students' total welding scores, indicating it improved just as well as traditional training. It is important to note, the students who participated in the full VR group had the highest mean total scores for their welds. Overall, articles labeled as *application evaluation* focused on improving student performance and experience, even if there was not a difference in performance between groups. They also enhanced usability, engagement, and motivation for different educational topics.

Design

Articles under the *design* (n = 10) category focused on the development and design of immersive experiences with limited to no evaluation of the experience. Several experiences within the medical industry focused on recovery from brain injury or stroke by having them complete exercises to promote stimulation (Gervasi et al., 2010) and teaching palpatory diagnosis (Karadogan & Williams, 2013), where students responded positively to the potential of future use of VR in other trainings. Other experiences ranged from firing range training (Bhagat, et al., 2016; Wei et al., 2019) which improved users' motivation, learning outcomes, and overall live firing achievement scores; electrical circuitry training (Parmar et al., 2016) they compared HMD's and desktop simulations and found HMD's provided a significant increase in cognition and a higher learning benefit; reconstructing artwork using ancient tools(Koutsabasis & Vosinakis, 2018) which led to; lifeboat launch and boat operations (Jiang et al., 2018); and training on manual milling operations (Yang et al., 2020). These experiences focused on the creation of applications with different purposes without full evaluation tying back to pedagogical outcomes nor a predetermined pedagogical focus. If student learning was a part of the evaluation in the article, it was introduced as an afterthought. These studies highlight the need for a more robust evaluation tied to the design of experiences.

Design/Application Evaluation

The articles categorized as *design/application evaluation* (*n* = 27) focused on the development and evaluation of different applications. Several studies focused on the development of medical applications related to diagnosis training, patient room design, and cataract surgery (Karadogan & Williams II, 2013). Experiences have been developed for different military purposes such as landmine detection (Arisoy & Kucuksille, 2021), live fire training (Bhagat et. al., 2016), and firearm training (Wei et. al., 2019). The aforementioned applications focused creating cost effective trainings that could replicate realistic training environments. Results from these studies show these experiences were effective and did provide an increase in learning outcomes. Other applications were developed for physical education (Cao et. al., 2021), biology (Tarng et. al., 2015), music education? (Johnson et. al., 2020), and cultural activities (Bruno et. al., 2018; Koutsabasis & Vosinakis, 2018). These studies, while from different areas of education, all focused on the development of experiences to give users realistic spaces to interact with. While Cao et. al. (2021) was trying to promote physical activities with their exercise experiences, Bruno et. al. (2018), Koutsabasis & Vosinakis (2018), and Tarng et. al. (2015) found increased learning outcomes. Johnson et. al. (2020) created a MR musical instrument training that significantly reduced performance error. All articles in this category highlight the different areas experiences may be designed for and the evaluation of developed applications to ensure performance, usability, and pedagogical needs of the users.

Pedagogical/Design

The *pedagogical/design* articles were found to have a pedagogical use for VR. One focused on creating effective virtual reality learning environments with theoretical underpinnings, and the other focused on ethical considerations when designing immersive products with students in mind (O'Connor & Domingo, 2017; Steele et al., 2020b). O'Connor and Domingo (2017) outlined the steps for "selecting a virtual environment, considering the research on simulations and environments, understanding the virtual features, designing basic learning environments, designing for motivation and involvement, and assessing and evaluating". Steele et al. (2020b) interviewed AR/VR designers and determined "they may be aware of the impact that educational products can have on the end consumer… and industry guidelines may assist in the development if grey areas exist". They also determined that conversations with end users, such as teachers and students, may alleviate issues that may arise before beta testing or rollout.

Pedagogical

Articles classified as *pedagogical* (*n* = 6) identified specific components of VR-related theories and their influence on learning. While all articles included in this study have an educational focus, explicitly how immersive technology could influence learning. Articles in this category focused on spatial learning in virtual environments (Pollard et. al., 2020); knowledge retention and learning performance (Lam et al., 2021b; Souchet et al., 2022); and the effects of learning experiences as influenced by presence (Kwon, 2021). The results from these studies all showed VR positively increased learning, knowledge retention, and the effects of presence on learning performance. Therefore, reinforcing that immersive technology can provide positive learning outcomes.

Review

Several *review* articles were identified (*n* = 31), these articles focused on the review of VR experiences and applications in a variety of educational areas. Reviews focused on identification of games used in cultural heritage education, VR use in social learning spaces, surgical training systems, and industrial operator training (Abich IV et. al., 2021; Anderson et. al., 2010; Hong et. al., 2021; Patle et. al., 2019; Scavarelli et al., 2021). Other reviews focused on the effects of VR, such as estimating cybersickness and the unequal effects of VR sickness (Howard & Van Zandt, 2021; Rebenitsch & Owens, 2021); as well as the risks VR poses to children and adolescents (Kaimara et. al., 2022). Some reviews sought to identify the overall educational uses of VR (Atsikpasi & Fokides, 2022; Garzon et. al., 2022; Papanastasiou et. al., 2019; Pellas et. al., 2019; Pellas et. al., 2021). Additionally, other reviews identified frameworks or priorities to focus training development or application development for VR applications (Gasper et. al., 2020; Liberatore & Wagner, 2021; Zahabi & Razak, 2020). Other articles reviewed smartphone apps for teaching engineering (Jain et al., 2018), reviewing the studio thinking framework and its integration into virtual experiences (Steele et al., 2019; Steele et al., 2020a), the pedagogical foundations of existing VR applications (Johnston et al., 2018), computer simulations in teacher education (Bradley & Kendall, 2015). These reviews highlight key educational uses of VR, share risks of VR and offer remedies to the effects, and of VR, and identify areas for continued work in VR experience design.

Theoretical

Lastly, articles that fell into the *theoretical* category (*n* = 23) focused on theoretical components regarding the use of VR. Cheng et. al. (2014) determined that flow of content in the experience can be increased by finetuning vividness and interactivity. Other studies described how users develop presence and identified the effects display lag can have on presence (Bilgin & Thompson, 2022; Kim et. al., 2022). Some studies explored the emotions of users during and after VR use and what evoked them (Lipp et. al., 2021; Magdin et. al., 2021; Lipson-Smith et. al., 2021). Most of the studies focused on the acceptance of VR technology and the development of technology acceptance frameworks (Bunz et. al., 2021; Chirico et. al., 2021; Fussel & Truong, 2022; Hammady et. al., 2021; Huang, 2020; Iqbal & Sidhu, 2022; Shen et. al., 2019; Toyoda et. al., 2023). These studies outline the theoretical work surrounding VR and the influence of different variables, such as flow, presence, and acceptance, on the user. The only theoretical article from the *Journal of Agricultural Education* described teachers' opinions about virtual reality technology in school-based agricultural education (Wells & Miller, 2020a). Although this study did not use VR technology, it conducted a census of Iowa SBAE teachers regarding their perceptions of VR. Wells & Miller (2020a) concluded that teachers "did, for the most part, view VR in a favorable light" (p.104).

Objective 2: Describe the types of virtual reality researched in virtual reality and education, including agricultural education

Objective two sought to describe the types of virtual reality studied in education, including agricultural education. Table 4 quantifies the number of times different immersive technology was researched from the J*ournal of Virtual Reality, Journal of Educational Technology Systems*, and *Journal of Agricultural Education.*

Table 4

Type of VR Technology Used (n = 170)

Type of VR	Journal of Virtual Reality	Journal of Educational Technology Systems	Journal of Agricultural Education	Total
Augmented Reality	24	2	0	26
Mixed Reality	24	6	0	30
Virtual Reality	92	9	2	103

Of all the articles analyzed (*n = 170),* 159 articles identified the use of the immersive technologies mentioned above. Virtual Reality was identified in 103 articles, Mixed Reality was identified in 30 articles, and Augmented Reality was identified in 26 articles. Virtual Reality was the most utilized immersive technology used across all three journals, while Augmented Reality was the least utilized immersive technology across all three journals. Mixed Reality was utilized slightly more than Augmented Reality.

Conclusions and Recommendations

The goal of this study was to provide a synthesis of literature to guide future research. Additionally, after reviewing the emerging themes of content, a research agenda can be proposed for other areas of research. After reviewing all the articles (*n = 170*), it can be concluded that VR has a wide use across all training areas, including medicine, safety, rehabilitation, military, and many more. Virtual reality can also provide many benefits to the user as well as the one deploying the technology and the experience.

Conclusion 1: Lack of published articles in agricultural education using VR technology as an educational tool.

When searching the Journal of Agricultural Education for the use of VR technology only four articles met the search criteria, one focused on describing teachers' opinions of VR technology, one evaluated preservice teacher participants welding skills using virtual welding equipment, and the other evaluated undgraduate students perspectives of VR in a agricultural mechanics course (Wells and Miller, 2022; Wells & Miller, 2020a; Wells & Miller, 2020b). The last one was a literature review, but it focused on VR welding training and education (Heibel et. al., 2023). We recognize that using only the Journal of Agricultural Education as a limitation of our study, but a preliminary investigation of agricultural education-based sources identified the Journal of Agricultural Education as the only acceptable source. We hope these articles provide a source of VR-based application research that may be cited to begin research in this area.

Conclusion 2: VR Technology can provide unique opportunities for students to engage with educational content.

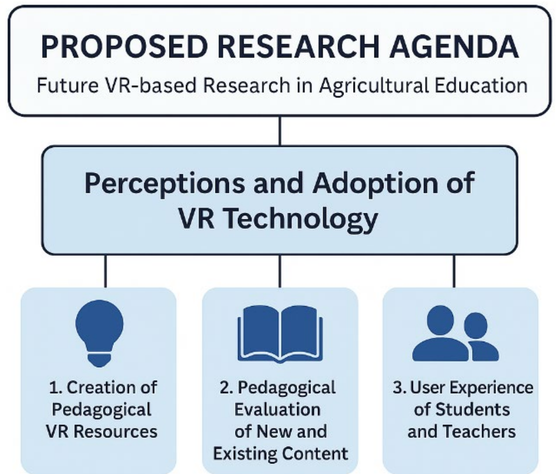
The articles identified in this review provided a sense of the different industries that VR technology is being in, such as medical (Karadogan et. al., 2013; Lam et. al., 2014; Wahlstrom et. al., 2010), military training (Arisoy & Kucuksille, 2021; Bhagat et. al., 2016), in chemistry for experiments (Edwards et. al., 2019), and most commonly immersive field trips (Klippel et. al., 2020). There are some agriculture related VR experiences, such as tractor operation experience (Pulley et. al., 2024) and a variety of VR welding experiences put together by Lincoln Electric and Miller Welding. One of the benefits described by Pulley et. al. (2024) was teachers appreciated the experience because it provided them access to a tractor that they would not have normally been able to access.

As agricultural educators, we can make the connection between content experts in horticulture, animal science, and mechanics who can provide the content, and developers that create the VR environment and models, while we provide the pedagogical evaluations necessary to assess student performance. It is recommended for future research to make connections with content matter experts and VR developers to begin the development of new agriculture related VR experiences.

Throughout this review, articles (*n* = 170) were reviewed to determine what type of VR technology had been used and the type of research conducted. Based on the themes of articles identified, we believe the following areas should be considered for future research related to VR-based technology. Figure 2 identifies the areas of focus for future research.

Figure 2

Proposed Research Agenda for Future VR-based Research



Perceptions and Adoption of VR Technology

An overarching category, that factors into each area, focuses on the Perceptions of VR Technology and the Adoption of VR Technology into Agricultural Education as educational tools. This work should not only focus on SBAE students and teachers at both the secondary and postsecondary levels, but also the administrators as well who have purchasing power at the school.

Creation of Pedagogical VR Resources

The authors of articles mentioned above focused their research into developing content for VR technology related to medical training, military and active shooter training, physical education, music, and cultural experiences. Each of these experiences provides the user authentic and real-life experiences to learn new skills, hone existing ones, or to provide experiences they otherwise would never be able to obtain. Agricultural Education has a wide array of interdisciplinary content that could be integrated into VR.

Pedagogical Evaluation of New and Existing Content

Most of the articles identified focused on the development of the VR experiences and evaluated how the participants performed in the experience. One component they did not focus on was how the participants performed to the traditional means of completing the task. Very few were pedagogical in design, these focused on learning in a focus on pedagogical evaluation was missing from these articles. Evaluation of how the participants did in the experience is an important component, but how do these experiences perform compared to real or traditional training.

User Experience of Students and Teachers

The user experience of both students and teachers is important to their overall perceptions of VR technology and whether they will use it again, but also to their performance in the experience. Tcha-Tokey et. al (2016) determined that Presence, Engagement, Immersion, Flow, Skill, Emotion, Usability, Judgement, Experience Consequence, and Technology Adoption could adequately describe a user's experience in a VR experience. Research should focus on describing SBAE students' and teachers' user experience, additionally, this can be conducted with postsecondary institutions as well. Focus should be placed on further research into the effect user experience has on participants' performance and perceptions.

As a discipline, we should discuss the potential uses of VR technology in the educational setting, and how we may support our SBAE educators with the adoption of this technology. The proposed agenda above should provide researchers with a beginning point to begin their research. Publications, reviews, and professional development opportunities should highlight the methods, equipment, and costs of VR technologies. Perhaps, we could even invite an expert in VR technology to conduct a professional development workshop at a national research meeting.

Limitations

There are potential limitations in all studies. Our analysis is limited to those studies we included within our frame with specific VR and agricultural education related journals. Therefore, we may have missed conference presentations or other peer-reviewed research that was not published in a journal.

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