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Implementation of a Statewide Youth Ag Safety Immersive Virtual Reality Program

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ABSTRACT

Objectives: The purpose of this pilot study was to examine the feasibility and effect of an Immersive Virtual Reality (IVR) Ag Safety Education mail-out program to secondary school-based agricultural education programs. The following aims were addressed: a) develop an IVR Ag Safety game, b) implement a mail-out program for the Rollover Ranch Ag Safety game, and c) evaluate the effectiveness and engagement of an IVR Ag safety program.
Methods: We enrolled 44 schools. Participants were invited to complete a pre- and post-knowledge assessment, and students and faculty evaluations of the experience.
Results: Statistical analysis was completed using an independent t-test. The Pre scores ($n = 423$) had a Mean = 72.2% (S.D. = 15.2) and Post scores ($n = 174$) had a Mean = 79.8% (S.D. = 17.2) Post test scores were significantly higher than pre-test scores t (595) = 5.36, $p < .001$, d = 0.48. The test questions were then divided into subsets of Tractor Safety, ATV Safety, and Electrical Safety, and all subset scores showed statistically significant increases. The students scored highest on ATV safety, Pre score mean = 89.1% (S.D. = 17.3) and post score mean = 93.1% (S.D. = 15.7). Tractor Safety Scores had a pretest Mean = 71.2 (S.D. 22.7) and a post-test score mean = 78.3 (S.D. = 23.4). The lowest performing questions were on electrical safety with a pre-test mean = 40.6% (S.D. = 37) and a post-test mean = 57.2% (S.D. = 40.8). The students' evaluations reported the game was entertaining (85.63%) and increased their understanding of Ag Safety (63.8%). Most students (79.64%) wanted to continue to use IVR. The majority of faculty (77%) indicated that IVR assisted in teaching, and 92% indicated they would want to continue using IVR as a teaching modality.
Conclusion: IVR can be delivered to serve all geographical areas, allowing dissemination throughout a rural state. Students learned and were engaged; faculty found it easy to use and both would desire to use it again. Further research is needed, including long-term follow-up on retained knowledge and, more importantly, if it translates into appropriate behavior when operating agricultural equipment and electrical safety.

KEYWORDS
Ag Safety; IVR; Tractor Safety; ATV safety; education

Introduction

A youth dies in an agriculture-related incident about every three days in the United States, with the leading source of fatalities being transportation, including tractors and All-Terrain Vehicles (ATVs).[1] An estimated 893,000 youth under 20 years of age lived on farms in 2014, with just over half (51%) also performing work on the farm. In addition to the youth who live on farms, an estimated 266,000 youth were hired to work on US farms, and 25 million visit farms at least occasionally.[1] This large population is at risk.

Tractor accidents are the leading cause of fatalities and injuries in agriculture. Although fatalities are most frequent in the older populations, there appears to be an increased risk in children as well. Agricultural injuries are not only a national concern but also a global concern and are often underreported.[2] Non-fatal injuries are frequent and have been difficult to count; states have developed multisource surveillance systems to help identify and learn more about non-fatal work-related agricultural injuries.[3]

ATVs have become a valuable agricultural tool and popular recreation vehicle, but with use comes risk. ATVs are also a significant source of fatalities. One agriculture study reported an incidence of 37 ATV deaths per 100,00 vehicles, compared to 2 deaths per 100,000 vehicles for cars.[4] In a report on pesticide applicators, 8% reported they had been in a crash while spraying with an ATV.[5] These crashes were mostly attributed to traveling on inappropriate sloped terrain or changes in center of mass by rear-mounted tanks. Although many users are older,

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there is also a significant number of youth who are using ATVs, creating a need to educate the youth. The *"Gear up for Ag Program"* identified a need for increased attention to ATV Quad safety when surveying youth.[6]

Another potential risk that places farming among the more dangerous occupations includes the potential for encounters with electrical hazards. Fatigue during harvest and assist devices such as GPS auto-guidance increases the need for mindfulness, alertness, and awareness of surrounding electrical hazards. Farm machinery is vulnerable to hitting power lines because of the large size, height, and extensions. Being aware of the location of overhead power lines and planning a safe equipment route can help reduce accidents. Knowledge of hazards and safety tips to utilize when encountering these hazards can lead to a decrease in injuries and deaths.[7,8] According to the National Ag Safety Data Base, approximately 62 farmers die every year after being electrocuted. This includes youth; annually, 3.6% of the deaths among youth under 20 years-of-age are caused by electrocution.[9] The most common cause of electrocution is contact with overhead power lines, which can cause death, burn injuries, amputations, internal injuries, or heart disturbances.[10]

Youth education

With the highest fatality rates for young workers across industries belonging to the 15–17-year-old agricultural youth,[2] we must take action directed towards this population. Future Farmers of America (FFA) programs are an invaluable tool for reaching future farmers and gaining insight into how to educate this population. FFA (https://www.ffa.org) is a youth organization that prepares members for leadership and careers in the science, business, and technology of agriculture. At the 2018 national FFA conference, attendees who participated in an ATV safety workshop identified the best places to reach youth were at the schools, while the least effective methods were lengthy, non-interactive presentations, printed materials, and lots of facts/statistics.[11]

A short, interactive way to reach youth is through immersive virtual reality (IVR). IVR is created using interactive software and hardware, providing a realistic, immersive simulation of a 3-dimensional environment controlled and experienced by body movements and hand controllers. The learner is transported into the IVR environment via a head-mounted apparatus that prevents the learner from perceiving surrounding elements of the real world.[12] The realism and authenticity of IVR contribute to learning through engagement and experiential learning.[13] Many sectors of industries have used IVR for training and specifically for safety education. Examples include healthcare, aerospace, defense, construction, engineering, transportation, utilities and mining.[14,15] The benefits of IVR as an experiential learning modality include content that can be reviewed at a convenient time for the learner, flexibility, scalability, decreased effort in simulation setup, and coordination of resources and expenses associated with hands-on simulation training.[16–19] IVR has been used in the agricultural sector to educate the agricultural community, demonstrating commercial and industrial fall protection systems, showing the dangers of tractor roll-overs, simulating grain bin rescues, and outreach education on grain handling safety.[20,21]

This pilot study examined the feasibility and effect of an IVR mail-out program to area high school Ag programs. The IVR simulations focus on agricultural safety of tractor rollover, ATVs, and electrical safety. The following aims were addressed:

(1) Develop an IVR simulation including Tractor, ATV and Electrical Safety.
(2) Create and implement a mail-out program of Oculus headsets loaded with the Ag Safety game Rollover Ranch delivered to the state's high school agricultural programs.
(3) Evaluate the effectiveness and engagement of an IVR Ag safety program, Rollover Ranch, in the state's high school agricultural programs.

Methods

Aim 1

The research team partnered with a Computer Science and Engineering Senior Design team from the University of Nebraska to develop an

IVR game: Rollover Ranch. Phase 1 included Tractor Safety. The team consisted of content experts, computer science and engineering students and faculty from the Colleges of Public Health, Agriculture, Computer Science and Nursing. Resources from the National Institute for Occupational Safety and Health, the Occupational Safety and Health Administration, and the university tractor museum were used to design the initial game. The game was tested at agricultural field days with the public, and feedback was gathered. Phase II was based on identified needs through the preliminary feedback. ATV and electrical safety were added based on input from the agricultural community and the state's public power company. The final version of Rollover Ranch focuses on tractor, ATV and electrical safety. It is an engaging game that has the participants completing tasks around the ranch, requiring the participants to follow appropriate safety practices or adverse events will occur, such as a tractor rollover, ATV, or electrical accident. If they are not using appropriate safety principles and an accident occurs, an alert will appear, letting the participants know why they had an accident, how to prevent it, and how severely they were injured. Experts in the field of Ag safety and electrical safety reviewed the development of the game's content to validate it.

Aim 2

After the development of Rollover Ranch, an implementation plan was developed. Using resources from the University of Nebraska Lincoln (UNL) Agricultural Education Teacher Preparation program, current Ag Educators across the state were sent a group email explaining the program and inviting their school to participate in the program. Once the school requested the program, the school was placed on a calendar and the secondary agricultural education teachers were emailed the dates they would be mailed a set of five headsets with a packet of instructional materials. The response was overwhelming, and within the first day after the email was sent, the academic calendar year was full. The authors were able to secure three more headsets, and a second set of headsets with the same instructional materials were made available, this allowed a second set with three headsets to be mailed out throughout the year, filling the remaining requests. There were 44 schools enrolled, and a final calendar was developed and sent to all participating schools to allow for curriculum planning. Each school then received a reminder email a week before the headsets would arrive with the expected delivery date. When the headsets arrived, teachers were instructed to read all materials before starting. Instructional materials in the packet that accompanied headsets included:

- Rollover Ranch Invitation (welcome paragraph, instructions for pre and posttest, student evaluation and teacher evaluation, mailing information and contact information, website address with all documentation available at the site)
- Rollover Ranch: How to guide (Headset instructions, Menu options, hand controller information, game information)
- Game Activities Sheet (list of games/activities in the headset, task to accomplish and implement to use)
- Tractor Controls (illustrations on how to drive equipment)
- ATV Controls (illustrations on how to drive equipment)
- Tractor Safety Tips (Educational Information sheet and references)
- ATV Safety Tips (Educational Information sheet and references)
- Electrical Safety Tips (Educational Information sheet and references)
- Downed Powerline Infographic
- Student Pre-Quiz on Ag Safety Hard Copy
- Student Pre-Quiz on Ag Safety QR Code and URL for online version
- Student Post-Quiz on Ag Safety Hard Copy
- Student Post-Quiz on Ag Safety QR Code and URL for online version
- Teacher Evaluation Hard Copy
- Teacher Evaluation QR Code and URL for online version
- Student Evaluation Hard Copy
- Student Evaluation QR Code and URL for online version

A mailing label and instructions were emailed to the schools 2 days before they were to mail the headsets to the next destination, and instructions on who to contact for pick up were provided. They referenced the checklist to pack up the headsets and send the box to the next participating school.

Aim 3

Each school received materials as outlined in Aim 2. Students were asked to voluntarily complete a knowledge assessment before using the IVR game. Students then participated in the Rollover Ranch IVR. Teachers, the school scheduling, and student involvement determined how the headsets were used, Students' use of the headsets varied from school to school, individualized usage was designed to demonstrate that the IVR could be implemented in many ways, and the schools could choose the methods best for their students. Students were asked to complete a post-assessment at the end of their use of the IVR program. Also, at the completion of the schools assigned time with the headsets, both the students and teachers were asked to complete evaluation surveys.

Tools

Pre and Post Assessment: The knowledge assessment was an eleven question survey about the fundamentals of tractor (5 questions), ATV(4 questions) and electrical safety(2 questions). Question content was derived from key safety resources and reviewed by content experts.

Student Evaluation Survey

The student evaluation questions were adapted from a previously published questionnaire addressing learning, immersion, and engagement, answered with a 5-point Likert scale.[22] Additional questions regarding the desire to continue using IVR as a learning modality, previous experience with IVR, and symptoms while in the headset were also included.

Faculty Evaluation Survey

The faculty evaluation questionnaire contained a nine question survey including questions regarding delivery of the headsets and materials, IVRs assistance in the delivery of Ag safety education, their experience with Headsets, would they want to use the modality in the future, did they have the headsets long enough, future applications and what would have improved the experience. Multiple choice format as well as comment sections were included.

Results

The Rollover Ranch IVR Safety education program was successfully developed and validated by Ag Safety experts. A mailout headset program was established with significant interest across the state. The headsets traveled a total of 7,936 miles throughout the year, being distributed to 44 schools with Ag programs across the state. See Figure 1 for an illustration of the path across the state the boxes traveled.

Data were completed through an online data management program, with one school opting to send paper copies to the researchers, and this data was hand entered into the data management system. Statistical analysis was completed using an independent *t*-*t*est to analyze the students' pre and post-knowledge exam scores. The Pre scores ($n = 423$) had a Mean = 72.2% (S.D. = 15.2), and Post scores ($n = 174$) had a Mean = 79.8% (S.D. = 17.2). Post-test scores were significantly higher than pre-test scores $t\ (595) = 5.36$, $p < .001$, $d = 0.48$. The test questions were then analyzed using the subsets Tractor Safety, ATV Safety, and Electrical Safety, and all subset scores showed statistically significant increases in safety knowledge (See Table 1). The students scored highest on ATV safety, with a pre-score mean = 89.1% (S.D. = 17.3) and a post-score mean = 93.1% (S.D. = 15.7). Tractor Safety Scores had a pretest Mean = 71.2 (S.D. 22.7) and a post-test score mean = 78.3 (S.D. = 23.4). The lowest performing questions were on electrical safety, with a pre-test mean = 40.6% (S.D. = 37) and a post-test mean = 57.2% (S.D. = 40.8). Electrical safety did show the highest subset increase. Finally, each individual question was analyzed to evaluate the change in scoring by specific content within the subset scores. All individual questions showed an increased performance, with five questions demonstrating statistically significant changes. Individual questions results are displayed in Table 2.

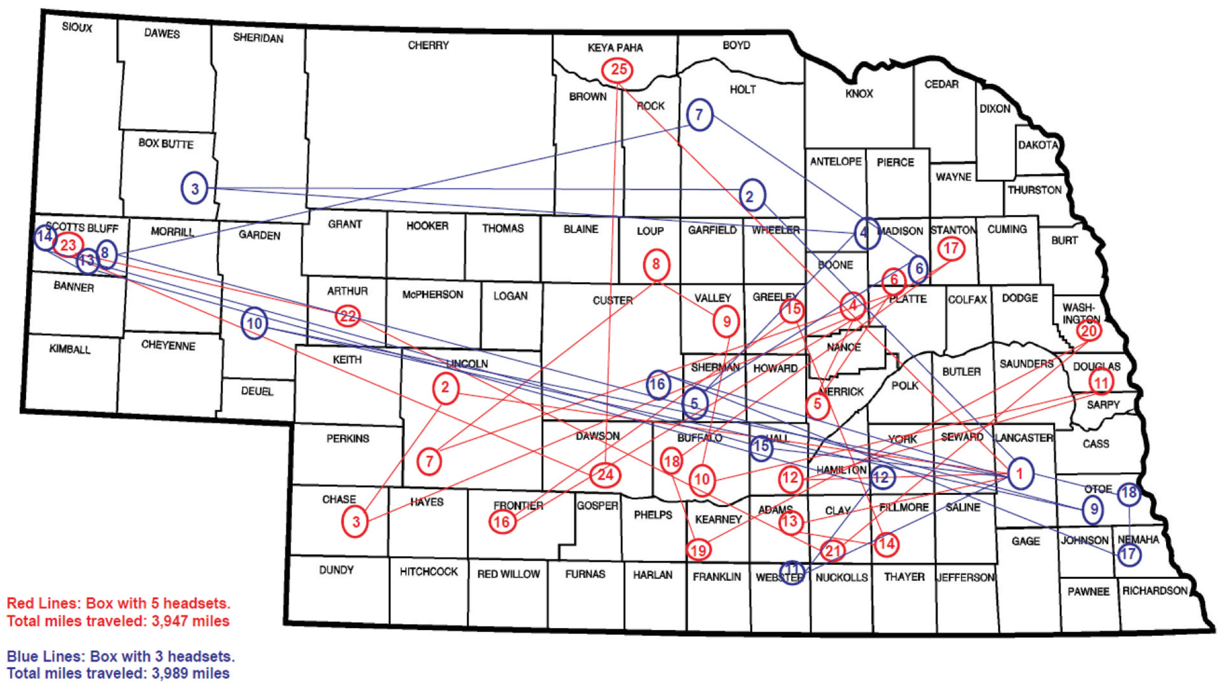

Figure 1. Travel path of IVR headsets.

Table 1. Subset scores.

Variable	Sample Size	Mean	S.D.	*t*-test	*df*	*p*	Cohen's *d*
Tractor Safety (5 items)	Pre-test n = 423	.71	0.23	−3.399	595	.001	−0.306
	Post-test n = 174	.78	0.23				
ATV Safety (4 items)	Pre-test n = 423	.89	0.17	−2.610	595	.009	−0.235
	Post-test n = 174	.93	0.16				
Electrical Safety (2 items)	Pre-test n = 423	.40	0.37	−4.815	594	.000	−0.434
	Post-test n = 174	.57	0.41				

Student use

The Rollover Ranch Ag Safety game was installed on a manager platform (Arbor XR) that provided analytics on the headset application use. According to Arbor there were 2,357 sessions logged and over 1,398 hours of student use for the fleet of 8 headsets during the year.

Student evaluations

Students were asked to complete an evaluation of the IVR Ag Safety game, and 167 students voluntarily completed the survey. The majority of the students indicated they found the game entertaining, and the experience increased their understanding of Ag Safety and helped them learn and found the game entertaining. See Table 3 for results.

Most students (63.47%) had used a virtual headset previously, and 79.64% wanted to continue using IVR as a learning modality. Some students did experience mild symptoms while using the IVR headset. Symptoms included headache, motion/car sickness, and dizziness.

Teacher evaluation

Of the 44 schools involved, 13 teachers completed an evaluation of the experience (29.5% response rate) Of

Table 2. Individual item scores.

Question	Pre-Test Score N = 423	Post-test Score N = 174	X^2	p
Q1 You do not need to wear a seat belt if you have rollover protective structures (ROPS) present on your tractor	81%	82%	0.08	.779
Q2 You can turn your tractor more sharply when turning if you have the front-end loader raised.	**55%**	**69%**	**10.16**	**.001**
Q3 The risk of a tractor overturn decreases as the angle of the slope increases.	70%	76%	2.42	.119
Q4 Always travel with a loaded bucket as low to the ground as possible. Use a wide front-end tractor for loader work rather than a narrow front wheel tractor to improve stability. Consider if the tractor needs more ballast added.	**76%**	**85%**	**5.50**	**.019**
Q5 To maintain tractor stability, the "angle of pull" should be kept low as possible by hitching to the drawbar only.	75%	80%	1.44	.23
Q6 ATV riders should wear DOT-compliant helmets, goggles, long sleeves, long pants, over-the-ankle boots, and gloves.	87%	93%	3.5	.061
Q7 ATVs are designed to be operated off-highway and never ridden on paved roads except to cross safely and permitted by law.	**81%**	**88%**	**4.62**	**.032**
Q8 Never ride under the influence of alcohol or drugs.	97%	98%	0.64	.423
Q9 Never carry a passenger on a single-rider ATV, and no more than one passenger on an ATV specifically designed for two people.	92%	94%	0.69	.408
Q10 If your machinery is in contact with a downed power line and you MUST get out of the machinery immediately	**44%**	**58%**	**9.35**	**.002**
Q11 Call 411 before digging to find underground lines.	**38%**	**57%**	**18.82**	**<.001**

Table 3. Student evaluations.

Question	Strongly agree/agree	Neither agree or disagree	Disagree/ strongly disagree
Student Evaluation (*n* = 167)			
Playing the game increased my understanding of Ag Safety	63.86%	23.49%	12.65%
The simulation helped me learn	63.47%	24.55%	11.98%
It provided content that focused my attention	72.73%	22.42%	4.84%
Interacting with it was entertaining	85.63%	10.78%	3.59%
Interacting with it was fun	83.24%	12.57%	4.2%
	A great deal/A lot	A moderate amount	A little/Not at All
Did you feel bored with playing the game?	1.8%	16.87%	81.33%
Did you wish you were doing something else?	6.63%	10.84%	82.53%

those responding, 77% indicated IVR assisted in teaching the students about Ag Safety, and 92% indicated they would want to continue to use IVR as a teaching modality. Only 8% had used a virtual headset before this experience. When asked if directions were useful, 100% indicated yes, and suggestions for the future included a troubleshooting guide, screenshots, and directions on casting to a computer screen. Most (70%) reported having the headsets for a sufficient amount of time, which was approximately 4–5 days. Teachers were also asked what future applications they would want developed. Suggestions included grain bin safety, vaccinations, "anything farm, animal or plant science related," and virtual field trips.

Discussion

The first aim was to develop an IVR safety game to be used in the mail-out program. This was completed by partnering with the Computer Science and Engineering Senior Design team from the University of Nebraska- Linocln. The team consisted of computer science and engineering students, their faculty advisor, Ag Safety experts from the University of Nebraska Medical Center (UNMC) College of Public Health, a technical consultant, and nursing faculty from UNMC College of Nursing. The game was made available on Sidequest© and Itchio© and installed on eight headsets that were available to use for education.

The second aim was also successfully met, and it is feasible to establish a headset mail-out program. Recruitment through email was an effective recruitment strategy, and working with the University Agricultural Education Teacher Preparation to do this added credibility to the email. Within one day, the entire academic year was filled with requests, and we were able to add more headsets to the fleet. Teachers are searching for ways to engage their students. Teachers reported the instructions they received were helpful, and the time they had to use the headsets was adequate. Scheduling was sometimes difficult, as some schools requested the headsets on similar dates. The schedule was developed and sent to all participating schools prior to the school year starting, allowing the schools to adjust their curriculum accordingly. Only twice did the project team receive communication about the headsets not working properly, and the issue was resolved from a distance. The headsets traveled well and remained functional throughout the academic year. The headsets traveled a total of 7,936 miles throughout the year. See Figure 1 for an illustration of the path across the state the boxes traveled.

Teachers and students could easily use the headsets and begin learning using the information and instructions provided in the mailings. Hardcopies of safety education to be used with the headsets, instructions on how to use the headsets, and all surveys were included in the mailings as well on the website created with the headsets and also available online on the website created for the project. The students found the learning pedagogy engaging, entertaining, fun, and based on pre and post-tests learned from the Ag Safety game. This is consistent with the literature and further supports the previous findings on teaching with IVR.[16–21] Based on scores, there appears to be a need to continue education, especially in electrical safety. This may be due to the lack of exposure to the concept, as many in rural areas have driven tractors and ATVs and have an innate awareness of these hazards. Electrical safety may not be encountered as frequently. Although electrical safety scored the lowest at baseline, it did have the highest increase in scores compared to the other subsets. As addressed in previous studies, education does not always translate into a change in behavior, but awareness is the beginning.

When asked how to improve the program, teachers did indicate they would have liked more screenshots in the directions to have a visual aid and to include a troubleshooting guide. Teachers were also asked if there was anything they would like to share about the experience. Comments included:

- "They were really neat, but it was hard to get my kids used to them and then the bell would ring, and they would have to start all over again. I also wasn't really sure how to actually teach it. I wish there was a score at the end, and they could compete to get the highest score."
- "This was awesome! All of our students had a ton of fun with these. Some students found out that they could cut chickens with chainsaws they spent more time doing that than they did trying to complete missions. Multiple students said that they were getting nauseous from the graphics."
- "It was fun."
- "Great use of technology and valuable learning experience for students."
- "It would have been cool to be able to see what the students saw and be able to help them work through the game easier and have more talking points with students that were not playing."
- "Palmer students loved them and begged to use them every day of the week that we had them!"
- "My students really enjoyed using the headsets. Some of them were less focused on completing the tasks and more on exploring the game field, but for the ones that played the game seriously, it was great!"

The comments reflect the need for teacher guidance and limitations. Expanding the instructions on the process of "casting" content from the headset may have increased success. The instructions for casting were included, but the team needs to examine how to make it stand out.

Figure 2. High school student sharing Ag Safety with younger student.

Figure 3. High School student using Rollover Ranch in the gym.

Several teachers also reached out after the study to request the headsets for the following year, demonstrating their interest in using technology as a teaching modality. Teachers shared that the FFA students were excited to share the technology, and a number of schools then had the high school students teach the younger students how to use the headsets and teach them safety with the IVR. It

Figure 4. High School student driving his tractor in IVR.

became a snowball effect in education. Students are shown in Figures 2–4.

We did offer technical assistance, but teachers shared through communications that they would have tried to problem solve on their own if we had included more instructions on problem-solving. We also included a checklist in the equipment and, at some point, lost a cable but did not figure out a better way to track the equipment. A method to double-check equipment may have been helpful.

Our final aim of "evaluating the effectiveness and engagement of an IVR Ag safety program, Rollover Ranch, in the state's high school agricultural programs" was met. Not only did the students show improvement in scores, but they also indicated they had fun while they were learning. It also identified areas we need to address in the future. The technology is not a stand-alone education modality. It was accompanied by education fliers and handouts as well as very important guidance and information from the teachers. Teachers also shared that the students can wander around in an immersive game and that teacher guidance is extremely important.

Teachers also reported cybersickness as well as the student evaluations. This is a documented problem in the literature when using IVR and can negatively affect the participants.[23,24] The project team will need to evaluate this and take steps to include information on how to decrease cybersickness and offer alternate learning plans when others are using IVR.

Limitations include the variability in the numbers between the pre and post-test, bias of repeated measures, and use of a knowledge test without psychometrics or established validity and reliability.

The Ag Safety Game Rollover Ranch is available to load on a Meta (formerly Oculus) headset. It is published on Sidequest© and Itchio©. All the materials and links to the game are housed on the Safety in Agriculture for Youth (SAY) National Clearinghouse and the Rollover Ranch website https://rolloverranch.com.

Conclusion

IVR can be delivered to serve all geographical areas, allowing implementation throughout a rural state. Students learned and were engaged, and teachers found it generally easy to use and would use it again in future years. Further research is needed that would include long-term follow-up on retained knowledge and, more importantly, if it translates into appropriate behavior when operating agricultural equipment and electrical safety.

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