Work in Progress: Grace Platform: Enhancing Pedagogy with Gamified AR and VR in Agriculture Education

Ms. Maryam Bigonah, Auburn University

Maryam Bigonah is a Ph.D. student at Computer Science Department of Auburn University, specializing in cutting-edge research on Augmented Reality (AR) and Virtual Reality (VR) technologies. Her commitment to bridging theory and practice has led to notable achievements, including receiving one of the awards at the Graduate Engineering Research Showcase 2023 and being nominated for excellence within her department. Currently involved in an NIFA project aimed at revolutionizing agricultural education, Maryam's expertise in artificial intelligence and machine learning is driving innovative solutions for sustainable farming practices. Her contributions to publications and conferences, such as IGI Global Publisher, SIGCSE 2024(ACM Conference), ASEE Conference 2024, the Grace Annual Symposium 2024, 2024 NSF Workshop on Sustainable Computing and 2024 CRA-WP Grad Cohort for Women, showcase her passion for advancing educational pedagogy through emerging technologies, solidifying her reputation as a leading researcher in the field.

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Fatemeh Jamshidi is a Doctoral Candidate in computer science and software engineering at Auburn University. Her research is on machine learning and artificial intelligence in computer science education and music education.

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Aparana Pant is a graduate student at the Computer Science and Software Engineering Department at Auburn University, where her passion for transformative technology takes shape through the development of immersive AR/VR learning experiences. She is currently engaged with a NIFA-funded project focused on developing an inclusive agricultural educational platform that leverages augmented and virtual reality to innovate and enrich the way agricultural sciences are taught and learned. With her skill set and dedication, she is poised to make significant contributions to both tech research and the broader industry landscape.

Dr. Daniela Marghitu, Auburn University

Dr. Daniela Marghitu received her B.S. in Automation and Computing from Polytechnic University of Bucharest, and her Ph.D. degree in Automation and Computing from University of Craiova.

She is a faculty member in the Computer Science and Software Engineering Department at Auburn University, where she has worked since 1996.

Her teaching experience includes a variety of Information Technology and Computing courses (e.g., Object-Oriented Programming for Engineers and Scientists, Introduction to Computing for Engineers and Scientists, Network Programming with HTML and Java, Web Development and Design Foundations with HTML 5.0, CSS3.0 and JavaScript, Personal Computer Applications, Spreadsheet-Based Applications with Visual BASIC, Web Application Development).

Her research areas include STEM K12 Inclusive Computing Research and Outreach; Web Applications Design and Development; Education and Assistive Technology; Software Engineering; Web and Software Engineering Usability and Accessibility.

Dr. Marghitu has received funding for research and education projects from National Science Foundation (e.g.Co-PI of NSF RET Site: Project-Based Learning for Rural Alabama STEM Middle School Teachers in Machine Learning and Robotics; Co-PI of NSF INCLUDES Alliance: The Alliance of Students with Disabilities for Inclusion, Networking, and Transition Opportunities in STEM (TAPDINTO-STEM); Co-PI of NSF EEC "RFE Design and Development: Framing Engineering as Community Activism for Values-Driven Engineering"; Co-PI of NSF CISE "EAGER: An Accessible Coding Curriculum for

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Dr. Marghitu has mentored over one thousand high school, computing undergraduate, graduate students including representatives of underserved/underrepresented communities, women, and people with disabilities.

Dr. Marghitu has participated in numerous administrative activities at Auburn University. Among these activities are the following: Auburn University Board of Trustee Faculty Representative; Auburn University representative for National Center for Women in Information Technology, AccessComputing, Access10K, and AccessEngineering Alliances; Auburn University Persons with Disabilities Committee chair; Founder and Director Auburn University Laboratory for Education and Assistive Technology; faculty representative Auburn University Core Curriculum Oversight committee and Multicultural Diversity Commission.

Dr. Marghitu also served as World Usability Day Web Site Committee Chair; Alabama STEM Education board chair, Panel member for the National Science Foundation; member of the congressionally mandated Committee on Equal Opportunities in Science and Engineering; member of the Committee on the Future of NSF EPSCoR; and member of the Computer Science for All (CSforAll) Accessibility Board.

Dr. Marghitu published seven Information Technology books at Pearson Publishing Co., articles at International Journal On Advances in Software, International Journal On Advances in Internet Technology, Journal of Women and Minorities in Science and Engineering, National Science Teaching Association Journals, Journal of Computer Science Education,International Journal on Advances in Internet Technology Transactions of the SDPS: Journal of Integrated Design and Process Science, User Experience Magazine, Journal of Computing Sciences in Colleges, International Journal for Virtual Reality, Journal of SMET Education and Research.

Dr. Marghitu has published peer reviewed papers and gave presentations at numerous international conferences(e.g. ACM Special Interest Group on Computer Science Education Technical Symposium, International Technology and Persons with Disabilities Conference, International Conference on Software Engineering Advances, EDUCAUSE, Association for Advancement of Computing in Education, International Society for Technology in Education, Society for Design and Process Science, American Society for Engineering Education, Human Computer Interaction International Conference, and International Academy, Research, and Industry Association) in USA, Canada, England, France, Germany, Spain, Italy, Portugal and Romania. Her work was also presented by co-authors at conferences in Brazil, Taiwan and S. Korea.

Among Dr. Marghitu's honors and awards are the following: 2011 AccessComputing Capacity Building Award, the 2012 Auburn University Access award, the 2012 Society for Design and Process Science Outstanding Achievement Award, the 2013 Microsoft Fuse Research award, the 2015 DO-IT Trailblazer award, the 2017 International Academy, Research, and Industry Association Fellowship, the 2017 Society for Design and Process Science Fellowship, and the 2019 Samuel Ginn College of Engineering 100+ Women Strong Leadership in Diversity Faculty Award.

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Abstract

Controlled environmental agriculture (CEA) is often referred to as a sustainable food supply solution and the future of food [1]. This approach is particularly important in the face of global challenges such as climate change, population growth, and the increasing scarcity of arable land. Consequently, there is a critical necessity to educate and cultivate the younger generation in CEA concepts. However, conventional teaching approaches might struggle to render complex concepts such as CEA. This ongoing study presents a framework incorporating Augmented Reality (AR) and Virtual Reality (VR) technologies for educating high school students and aspiring entrepreneurs on CEA principles. The study aims to assess the effectiveness of the framework through rigorous testing and improvement, gathering formal surveys and informal input from both high school students and educators in the local area. The expected results of this initiative are anticipated to aid in the promotion of a sustainable food production system.

Introduction

Over the past century, agricultural education has undergone continuous transformation propelled by advancements in technology and shifts in societal norms. Initially emerging in the late 19th century, formal agricultural education primarily concentrated on enhancing production techniques and fostering rural development [2]. The 1914 Smith-Lever Act established cooperative extension to disseminate the best farming methods [3]. Consequently, early educational curricula and textbooks placed significant emphasis on subjects such as soil science, agricultural machinery, and livestock management to equip prospective farmers [4]. The 1917 Smith-Hughes Act established vocational agricultural education [5], leading to thousands of high school programs centered on hands-on career preparation through supervised farming projects. This momentum culminated in the formation of the Future Farmers of America in 1928 (now known as the National FFA Organization), aimed at fostering youth leadership and cultivating interest in agricultural careers [6].

CEA is forecasted to undergo a substantial fivefold expansion in its market size [7]. CEA represents a notable advancement in agricultural methodologies, presenting a sustainable and efficient alternative to conventional farming practices. By meticulously managing environmental variables like climate, water, and nutrients, CEA facilitates crop cultivation within controlled settings, resulting in enhanced crop quality and yield, prolonged growing seasons, and reduced resource inputs. This approach gains significance amidst global challenges such as climate change, population growth, and diminishing arable land availability. Consequently, there arises a critical imperative to educate and empower the younger generation, equipping them with the necessary skills and knowledge to engage effectively in CEA practices.

The Need for Transformation in Agricultural Learning in recent years, the intricacy of CEA systems and the demand for specialized expertise have posed educational hurdles. Traditional teaching methods, such as lectures and practical training, might fall short in adequately imparting the nuanced comprehension essential for managing these sophisticated agricultural systems [8,9]. Additionally, educator training programs frequently overlook the need for adequate preparation in instructing on emerging technologies like data analytics and Artificial Intelligence (AI), which are pivotal drivers of contemporary innovation. Consequently, there are persistent appeals for the development of expanded curricula and innovative classroom strategies aimed at tackling present-day challenges [10].

Method

This study introduces the Green-Reimagining of Agriculture in Controlled Environment (Grace) platform that integrates AR, VR, and AI into agricultural learning, specifically focusing on CEA. The research is an interdisciplinary collaboration among multiple landgrant institutions. The platform comprises an AR and VR learning application alongside an educational website. We employ this innovative framework to educate the CEA concepts to high school students and new entrepreneurs through gamified and interactive online learning modules, addressing the limitations of traditional teaching methods.

The objective of this research is to establish CEA as a sustainable food production system capable of efficiently producing nutritious foods within a low-carbon economy. For this purpose, students can explore fundamental modules in water quality assessment, insect pest management, pH level evaluation, precipitation-related issues, and nutrient imbalances through this platform, ensuring effective learning.

The platform consists of four primary panels: an administrative panel, an educator panel, a student panel, and a general learner panel. Administrators oversee various tasks, including managing educators, courses, content, users, real-time and non-real-time educational quizzes, and adjusting platform settings within the administrative panel. The educator panel is focused on student monitoring and course assignments. The student panel incorporates essential features including informal learning modules featuring a gamified virtual greenhouse, interactive slides with drag-and-drop game and quiz controllers, interactive image controllers, real-time and non-real-time educational quiz controllers, a gamified avatar tour guide, progress tracking, rewards, and achievements. Both interfaces are designed to be intuitive and engaging, enhancing the overall learning experience. The general learner panel is identical to the student panel and is intended for individuals enrolling in courses.

To enrich the learning process, the modules will implement the concept of dynamic stochastic gaming probabilistic (DSGP) [11] and integrate gamification strategies [12], enabling students to engage with greenhouse scenarios and make decisions influenced by unpredictable events. Therefore, the study will visually depict essential modules in CEA, ensuring comprehensive learning experiences. In addition, it will introduce students to the financial aspects associated with operating as a Controlled Environment Agriculture (CEA) entrepreneur.

Furthermore, AI serves as a strategic tool for devising adaptive learning pathways, enabling students to advance at their own pace. Recognizing the uniqueness of each student's learning journey, the study facilitates the customization of educational content to address individual needs. This approach involves an initial assessment of students' learning styles, preferences, and proficiency levels, which are then integrated into AI algorithms. This thorough comprehension of each student's distinctive learning journey empowers the system to personalize educational content, ensuring alignment with individual needs.

Accessibility

Addressing accessibility is a fundamental aspect of website and application design, ensuring that the platform remains accessible and functional for all users, irrespective of their physical or cognitive capabilities. Legal obligations also emphasize the necessity of accessibility, with regulations such as the Americans with Disabilities Act (ADA) mandating compliance in various jurisdictions. Additionally, accessible design not only benefits individuals with disabilities but also enhances the overall user experience for everyone, incorporating features like text alternatives and adaptable navigation that cater to diverse user needs.

Our research highlights the significance of inclusivity for students with disabilities, aligning with legal frameworks such as Section 504 of the Rehabilitation Act of 1973 [13], the Individuals with Disabilities Education Act (IDEA) [14], and guidelines for Universal Design for Learning (UDL) [15].

Evaluation

Several studies have assessed the effectiveness and suitability of various systems [16,17,18,19]. AR and VR educational systems are not exceptional in this regard, and qualitative and quantitative evaluation of them is essential. In this study, we will employ a comprehensive evaluation framework to assess both qualitatively and quantitatively the impact and effectiveness of AR and VR learning modules, as well as the virtual gamified greenhouse, designed specifically for secondary school students in the realm of Controlled Environment Agriculture (CEA). In this process, we will address the research questions below:

- Question 1: To what extent do AR and VR learning modules contribute to improving comprehension of CEA concepts in alignment with the Next Generation Science Standards (NGSS) among secondary school students?
- Question 2: What is the influence of gamified elements and dynamic stochastic gaming probabilistic concepts on the level of engagement and learning experiences of students in CEA education?

The assessment process consists of two crucial stages, during which students can conduct testing by either accessing the URL or installing the application. Firstly, in the Module Testing and Refinement phase, extensive testing and improvement of the developed modules take place, utilizing both formal surveys and informal feedback from high school

students and teachers in the region. Following this, the National Dissemination and Continuous Monitoring phase involves the nationwide launch of the online modules via a server hosted at Auburn University. Throughout this period, detailed tracking of usage statistics will be conducted, and users will be encouraged to provide feedback actively.

The evaluation will encompass both qualitative and quantitative measures, utilizing a combination of formal surveys and informal feedback gathered from regional high school students and educators. The evaluation process will consist of two crucial phases. Initially, the Module Testing and Fine-Tuning phase will involve thorough testing and refinement of the developed modules. Insights from formal surveys and informal feedback from regional high school students and teachers will guide this iterative process, ensuring continuous enhancement of the learning resources. This iterative approach aims to align the modules seamlessly with educational objectives and effectively engage the target audience.

Discussion

This study discusses CEA as a revolutionary approach to food cultivation. This method not only promises a consistent supply of fresh, local produce but also stands as a potential solution for urban areas seeking sustainable agriculture throughout the year. However, the current energy-intensive nature of CEA infrastructure poses a significant challenge, especially in the context of a low-carbon economy.

The research aims to train the next generation of practitioners through gamified online learning modules tailored for high school students and new entrepreneurs. It strives to make complex concepts accessible and captivating for learners in the demanding field of CEA. The incorporation of AR, VR, and AI technologies facilitates enhancing real-world understanding, immersive learning journeys, and personalized and adaptive learning. It will also employ the DSGP concept and gamification techniques.

While the research endeavors to explore the potential of AR and VR technology in agricultural education, several limitations exist. Technical challenges, such as hardware compatibility issues and software bugs, pose significant hurdles in development. In addition, crafting educational content that balances accuracy and interactivity is complex and requires meticulous attention. Equitable access to AR and VR technology is another concern, as not all students may have the necessary resources. Addressing these challenges demands proactive measures, including educator training and support, to ensure widespread adoption and maximize learning outcomes.

The integration of AR, VR and Extended Reality (XR) technologies in agricultural practices necessitates a comprehensive consideration of user experience factors, including privacy, safety, and security concerns [20]. Additionally, leveraging insights from existing works related to lighting design simulations can optimize crop growth conditions [21]. Consequently, learning from these simulations can enhance educational experiences for students, providing them with a deeper understanding of agricultural concepts and practices.

Furthermore, prior research has illustrated that integrating chatbots into education can significantly enrich the learning journey for students by providing immediate assistance, swift access to information, and customized learning materials tailored to their requirements [22]. The utilization of chatbots has been evidenced to enhance students' engagement, elevate learning outcomes, and streamline administrative processes within educational institutions [23]. The transformative potential of chatbots in educational settings underscores the value of integrating this technology to benefit students. Our future endeavors will focus on harnessing chatbot technology to enhance student engagement and improve learning outcomes. We plan to collaborate with educators and students to codesign chatbot functionalities that cater to diverse learning preferences and support interactive and collaborative learning activities.

In anticipation, the integration of these state-of-the-art technologies holds the promise of transforming the educational landscape. Since AR and VR continue to advance, their capacity to bridge theoretical knowledge with practical application in agricultural learning becomes increasingly evident.

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