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Dari *Immersive* ke *Metaverse*: Kesenjangan Pembelajaran dan Teknologi dalam Penerapan di Pendidikan Bidang Pertanian

From Immersive to Metaverse: The Gap of Learning and Technology in Agriculture Education Application

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Abstrak

Teknologi imersif seperti *augmented reality, virtual reality*, media sosial, avatar virtual, dan game *online* telah mendukung pendidikan. Pertanian, sebagai salah satu proses penting untuk kesejahteraan manusia, menuntut teknologi pendidikan yang kaya interaksi dan konten untuk meningkatkan pemahaman siswa tentang lingkungan pertanian yang kompleks. Tren teknologi pendidikan saat ini mulai bergeser ke *metaverse*. Namun, ada kesenjangan antara penerapan teknologi imersif saat ini dan *metaverse* yang matang. Selain itu, penelitian sebelumnya menunjukkan kurangnya penekanan pada teori pembelajaran, konten pembelajaran, dan elemen desain untuk aplikasi imersif dalam pendidikan. Penelitian ini dilakukan untuk mengidentifikasi kesenjangan tersebut, khususnya dalam pendidikan pertanian. Kami secara sistematis menganalisis publikasi sebelumnya yang mengembangkan aplikasi mendalam untuk pendidikan pertanian di pendidikan tinggi. Kami menyimpulkan bahwa (1) sebagian besar konten pembelajaran dan elemen desain teknologi *metaverse* kurang dimanfaatkan; (2) ada banyak kesenjangan implementasi antara implementasi saat ini dengan *metaverse* yang matang; dan (3) Pendidikan metaverse yang matang adalah kompleks dan mahal, sehingga perencanaan jangka panjang yang cermat dan mengidentifikasi kasus penggunaan dianjurkan. Kesenjangan ini penting untuk penelitian selanjutnya tentang pengembangan *metaverse* untuk pendidikan, terutama di bidang pertanian. Kami berharap hasil penelitian ini akan memberi pendidik pengetahuan dasar tentang teknologi *metaverse* untuk membuat keputusan yang lebih baik dalam memanfaatkan metaverse di lembaga pendidikan.

Kata kunci: metaverse, pembelajaran, pendidikan pertanian, teknologi imersif

Abstract

Immersive technologies such as augmented reality, virtual reality, social media, virtual avatars, and online games have supported education. Agriculture, as one of the essentials process for human well-being, demands interaction-rich and content-rich educational technology to increase student understanding of the complex agriculture environment. The current trend of education technology is starting to shift to the metaverse. However, there is a gap between the current implementation of immersive technologies and the mature metaverse. Moreover, previous research indicates the lack of emphasis on learning theory, learning content, and design elements for immersive application in education. This research aims to identify those gaps, especially in agriculture education. We systematically analyze previous publications which developed an immersive application for agriculture education in higher education. We conclude that (1) most of the learning content and design element of metaverse technology is underutilized; (2) there are many implementation gaps between the current implementation with a mature metaverse; and (3) A mature metaverse education is complex and expensive, so careful long-term planning and identifying use cases is recommended. These gaps are essential for subsequent research on developing metaverse for education, especially in agriculture. We hope the results of this research will provide educators with a baseline

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knowledge of metaverse technologies to make better decisions on utilizing metaverse in educational institutions.

Keywords: agriculture education, immersive technologies, learning, metaverse

INTRODUCTION

Immersive technologies such as augmented reality (AR), virtual reality (VR), social media, virtual avatars, and online games have been utilized to support education (Kamińska *et al.* 2019; Asfarian and Ardiansyah 2012). Kavanagh *et al.* (2017) showed that most domains of VR for education are health-related (35%), general education (28%), engineering (19%), science (16%), and others (27%). A significant proportion of them (51%) are implemented in higher education. Despite those findings, researchers argue that implementing immersive technologies in agriculture will advance pedagogy and reduce fatalities and operating costs in the learning space, especially when new technologies or practices are being tested (Isafiade and Mabiletsa 2020). Its implementation in agriculture also benefits visualizing data effectively and providing a safe virtual environment for an experiment (Goka *et al.* 2022). de Oliveira and Corrêa (2020) provided research highlights on implementing immersive technologies in agriculture from 2004-2019. Half of the 20 research reviewed is about VR and AR applications for agriculture for farmers, students, and other types of learners.

Despite the infancy of the concept, the current trend of education technology is starting to shift to the metaverse, as some companies stated their interest in this area, making the technology development overgrowing and promising a potential user base (Tili *et al.* 2022). Albeit, the standard of what makes a metaverse is unclear until recent research by Park and Kim (2022) provides the taxonomy of the metaverse (by concept, component, and approach). Using the taxonomy defined in Park and Kim (2022), we could analyze the gap between the current implementation of immersive technologies and the mature metaverse. From this gap, we can define the future research path in this area.

Besides technology, another important aspect of immersive technology for education is the education itself. Previous research emphasizes the importance of learning content, learning theory, and design elements of the products Radianti *et al.* (2020). Other research (Wang *et al.* 2018) also suggests future directions for immersive education: integrations with emerging education paradigms, improvement of VR-related educational kits, VR-enhanced online education, hybrid visualization approaches for ubiquitous learning activities, and rapid as-built scene generation for virtual training. Radianti *et al.* (2020) conclude that research tends to focus on the usability (Asfarian *et al.* 2020) and technological aspect rather than emphasizing the learning theory of the products, resulting in a gap in learning.

This research aims to identify the technology and education gap in implementing immersive technologies in agriculture education. We identified the learning (Radianti *et al.* 2020) and metaverse Park and Kim (2022) elements from previous research. We gathered the previous augmented reality and virtual reality research on two computing publication indexers (ACM Digital Library and IEEE Xplore), which produced immersive artifacts for agriculture education in higher education. We hope the results of this research will provide educators with a baseline knowledge of metaverse technologies to make better decisions on utilizing metaverse in educational institutions.

METHODS

This research methodology is adopted from the systematic literature review (SLR) (Kitchenham 2004). We gathered the publication in the ACM Digital Library and IEEE

Xplore using six different queries, combining the immersive technology, education, and education subject (agriculture or veterinary). We added veterinary as a subject as it is strongly related to agriculture and showed a remarkable increase in immersive technology implementation (Cahyadi *et al*. 2022; Farrel 2020), primarily when Covid-19 disrupting higher education (Ramadhan *et al*. 2022). The query was executed within publication metadata (title, abstract, and indexing term) using a standard search engine available on the site. We choose publications that contribute to a working immersive technology and provide adequate illustrations to show how the proposed system works. We further filter the retrieved publications based on their contribution to higher education (i.e., their primary user must be university students) and subject (agriculture and veterinary). We then analyze the paper using the framework available in Table 1. We give each publication labels for each category in learning and metaverse elements (Figure 1). We adopt the labels used by Radianti *et al*. (2020) for learning elements and Park and Kim (2022 for metaverse elements. We used the labels for further analysis.

Table 1 Data analysis framework, categories, and labels used to analyze the publication. Further description of each labels
are available in Radianti *et al*. (2020), Wohlgenannt *et al*. (2019), and Park and Kim (2022).

Elements	Categories	Labels
Learning	Learning Theory	Behavioral learning; experiential learning; generative learning; operational learning; game-based learning; contextual learning; Jeffries simulation theory; and cone of learning theory.
	Learning Content	Analytical and problem-solving; communication, collaboration, soft skills; procedural–practical knowledge; declarative knowledge; learning a language; behavioral impacts; others; not specified.
	Design Elements	Realistic surroundings; passive observation; moving around; basic interaction with objects; assembling objects; interaction with other users; role management; screen sharing; user-generated content; instructions; immediate feedback; knowledge test; virtual rewards; and making meaningful choices.
Metaverse	Concept	Metaverse; avatar; extended reality;
	Component: Hardware	Head-mounted displays; hand-based input device; non-hand-based input device; motion input device; and smartphone.
	Component: Software	Scene/object recognition; scene/object generation; sound/speech recognition; sound/speech generation; and motion rendering.
	Component: Contents	Multimodal content representation; agent persona modeling; multimodal entity linking and expansion; scenario generation; scenario population; and scenario evaluation.
	Approach: User Interface	Language interaction; multimodal interaction; multi-task interaction; and embodied interaction
	Approach: Implementation	multimodal inference reinforced learning (RL)-based approaches; life-long learning; multi-agent optimization; integration; optimization; and pperation consideration.
	Approach: Application	Simulation; game; office; social; marketing; and education.

Source: Radianti *et al*. (2020), Wohlgenannt *et al.* (2019), and Park and Kim (2022).

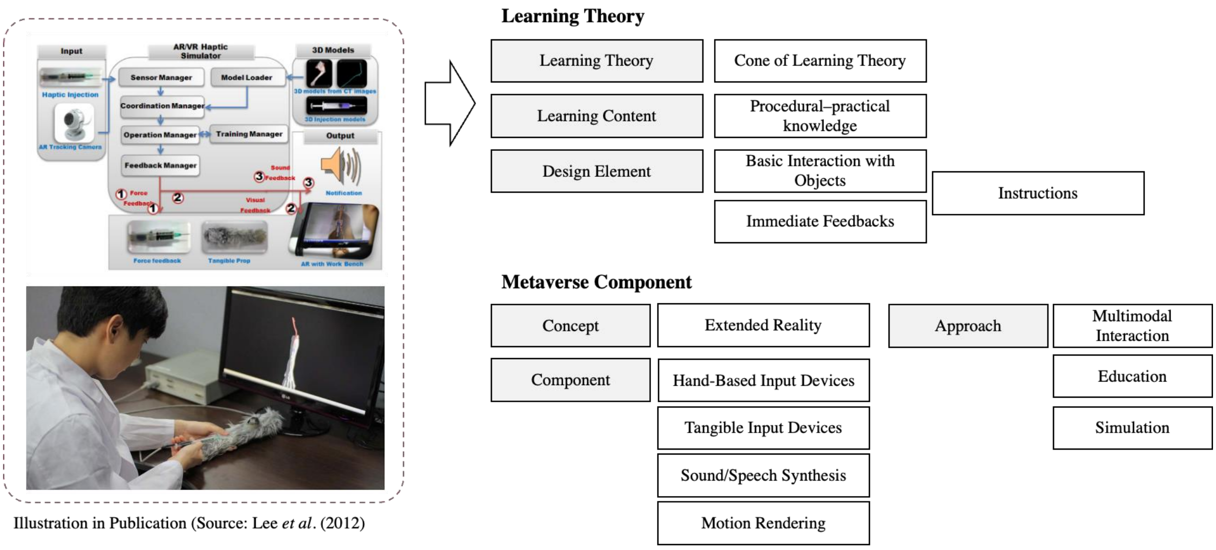

Figure 1 Illustration of the labelling process.

RESULTS AND DISCUSSION

Data Collection

Figure 2 depicts the data collection process in the research. We ran six queries provided in Table 2 and resulted in 57 publications in the IEEE Xplore and 13 in the ACM Digital Library. However, after the relevance filtering, we only get 8 publications from IEEE Xplore and 1 publication in ACM Digital Library (which overlap with the one in IEEE Xplore). The primary reason for exclusion is that the query also returns review papers, short communication without adequate illustration or description of the technology, or the immersive artifacts are not intended for higher education.

Table 3 lists all eight publications processed further in the learning and metaverse labeling analysis. The publications are spread from 2004 to 2022, with most published between 2018-2022. All the publications are conference proceedings, which are dominant in both IEEE Xplore and ACM Digital Library. As both indexers are focused on computing and engineering, most of the publications are technology-oriented, with a minimal elaboration of pedagogical or learning aspects. For further studies, we encourage researchers, given adequate access to documents is available, to include non-engineering indexers, preferably from subject domain sources such as McCaw *et al*. (2021) and Farrel (2020) approaches.

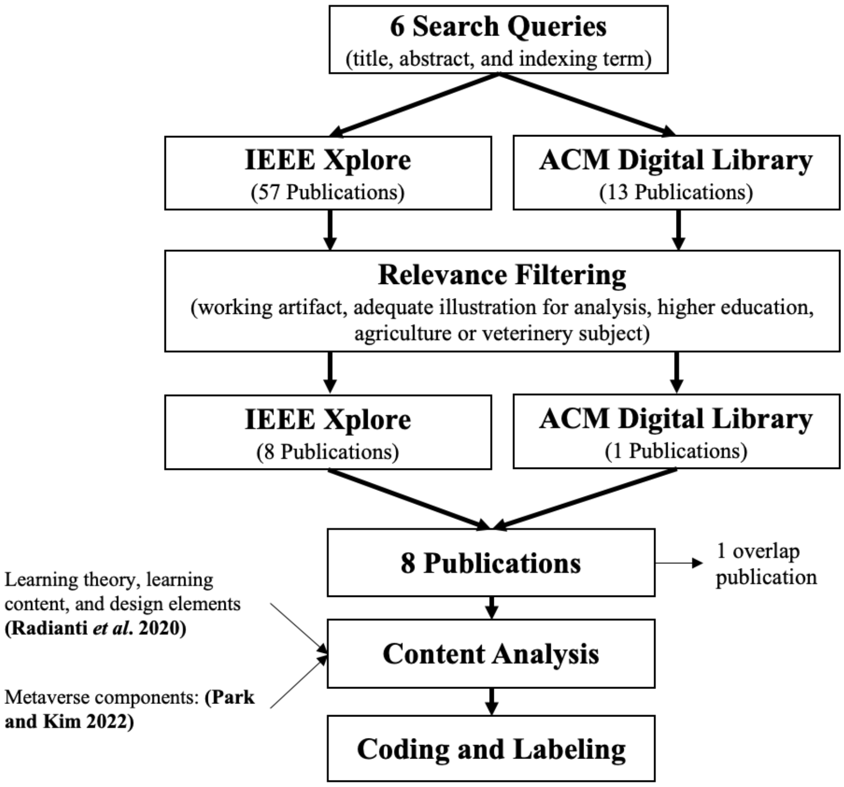

Figure 2 Data collection process.

Table 2 Results of each query used in the data collection process

Query	IEEE Xplore			ACM Digital Library		
	Results	Relevant	Selected	Results	Relevant	Selected
"metaverse" AND education AND agriculture	1	1	1	0	0	0
"virtual reality" AND education AND agriculture	32	2	2	3	0	0
"augmented reality" AND education AND agriculture	13	1	1	0	0	0
"metaverse" AND education AND veterinary	0	0	0	0	0	0
"virtual reality" AND education AND veterinary	9	3	3	2	0	0
"augmented reality" AND education AND veterinary	2	1	0	8	1	1
TOTAL	57	8	7	13	1	1

Table 3 The relevant 8 publications for learning and metaverse framework analysis

No	Year	Paper
1	2022	Khansulivong, C., Wicha, S., & Temdee, P. (2022, January). Adaptive of New Technology for Agriculture Online Learning by Metaverse: A Case Study in Faculty of Agriculture, National University of Laos. In 2022 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering (ECTI DAMT & NCON) (pp. 428-432). IEEE.
2	2020	Xu, X., Kilroy, D., Mangina, E., & Campbell, A. G. (2020, June). Work-in-progress—Adapting a virtual reality anatomy teaching tool for mobility: Pilot study. In 2020 6th International Conference of the Immersive Learning Research Network (iLRN) (pp. 328-331). IEEE.ISO 690
3	2020	Kovas, K., Grivokostopoulou, F., Perikos, I., & Hatziligeroudis, I. (2020, July). A Virtual Reality Platform for Learning Aspects of Entrepreneurship. In 2020 11th International Conference on Information, Intelligence, Systems and Applications (IISA) (pp. 1-4). IEEE.
4	2020	Garzón, J., Baldiris, S., Acevedo, J., & Pavón, J. (2020, July). Augmented Reality-based application to foster sustainable agriculture in the context of aquaponics. In 2020 IEEE 20th International Conference on Advanced Learning Technologies (ICALT) (pp. 316-318). IEEE.
5	2018	Xu, X., Mangina, E., Kilroy, D., Kumar, A., & Campbell, A. G. (2018, August). Delaying when all dogs to go to heaven: virtual reality canine anatomy education pilot study. In 2018 IEEE Games, Entertainment, Media Conference (GEM) (pp. 1-9). IEEE.
6	2017	Seo, J. H., Smith, B. M., Cook, M., Malone, E., Pine, M., Leal, S., ... & Suh, J. (2017, July). Anatomy builder VR: Applying a constructive learning method in the virtual reality canine skeletal system. In International Conference on Applied Human Factors and Ergonomics (pp. 245-252). Springer, Cham.
7	2012	Lee, J., Kim, W., Seo, A., Jun, J., Lee, S., Kim, J. I., ... & Lee, H. (2012, December). An intravenous injection simulator using augmented reality for veterinary education and its evaluation. In Proceedings of the 11th ACM SIGGRAPH International Conference on Virtual-Reality Continuum and its Applications in Industry (pp. 31-34).
8	2004	Kuo, C. C., Shiau, Y. H., Huang, C. P., Shen, C. Y., & Tsai, W. F. (2004, July). Application of virtual reality in ecological farmland navigating system. In Proceedings. Seventh International Conference on High Performance Computing and Grid in Asia Pacific Region, 2004.(pp. 285-288). IEEE.

Learning Label Analysis

The learning label frequency is depicted in Figure 3. Most of the inspected publications already implement various learning theories, with contextual learning as the most popular. However, most works focus on delivering declarative knowledge as learning content, which only uses the minimal capability of immersive technologies. Many design elements are underutilized, such as interaction with other users, assembling objects, making meaningful choices, and moving around, enabling richer interaction and learning experience. Dawley and Dede (2014) conclude that immersive technologies are effective when learners need practice with repetitive tasks, such as procedural-practical knowledge or even analytical and problem-solving. Lee *et al*. (2012) showed a use case when immersive technology is created to support veterinary students' procedural-practical knowledge of intravenous injection.

Learning Theory	Learning Content	Design Element	
Contextual (3)	Declarative Knowledge (6)	Basic Interaction with Objects (8)	Assembling Objects (2)
Jeffries Simulation Theory (2)	Analytical and Problem Solving (2)	Immediate Feedback (8)	Realistic Surrounding (2)
Cone of Learning Theory (2)	Procedural–practical knowledge (1)	Instruction (5)	Making Meaningful Choice (1)
Generative (2)	Others (1)	Knowledge Test (3)	Screen Sharing (1)
Operational (1)		Moving Around (3)	Interaction with Other Users (1)

Figure 3 Frequency of learning label (sorted by higher frequency). Label in Table 1, which does not show here, has 0 frequency.

We argue that the lack of variety in the learning content is caused by the difficulties in implementing various design elements. Making an immersive education application is not cheap and tailoring it to learning content is challenging. Although the off-the-shelf solution is readily available, such as the one used in Khansulivong et al. (2022), they are often limited to essential design elements for virtual interaction and lacking in content specific to education (such as knowledge test or simulation). On the other hand, a tailor-made solutions such as those developed in Kuo *et al*. (2004), Lee *et al.* (2012), Seo *et al*. (2017), Xu *et al*. (2018), and Xu *et al*. (2020) are expensive and difficult to build, which in the most case resulting in particular capabilities.

These problems lead to the need for authoring tools for immersive technologies, which still become a focus area of research in immersive technology (Rajaram and Nebeling 2022). Eventually, the need for authoring tools will become even more prominent in metaverse technologies, which involve richer interaction and generated content. The current solution is between using an off-the-shelf solution with limited simulation capability or developing a specific solution for a specific use case in learning. In the end, all technologies developed in the analyzed publications are never intended to replace the entire education or courses. Instead, they have a role in enriching real-world course content to increase student understanding of a learning outcome.

Metaverse Label Analysis

The metaverse label frequency is depicted in Figure 4. All inspected works used extended reality, but only two works show the user's avatar in the system, and none show the impact of avatar engagement in the real world—most of the works already used at least hand-based input devices to simulate complex hand-based movement. However, speech and object recognition are underutilized in multimodal interaction. The complex implementation of the metaverse is not yet shown, with all works implementing classical computer graphics applications. Aside from the education approach, simulation is the second most popular.

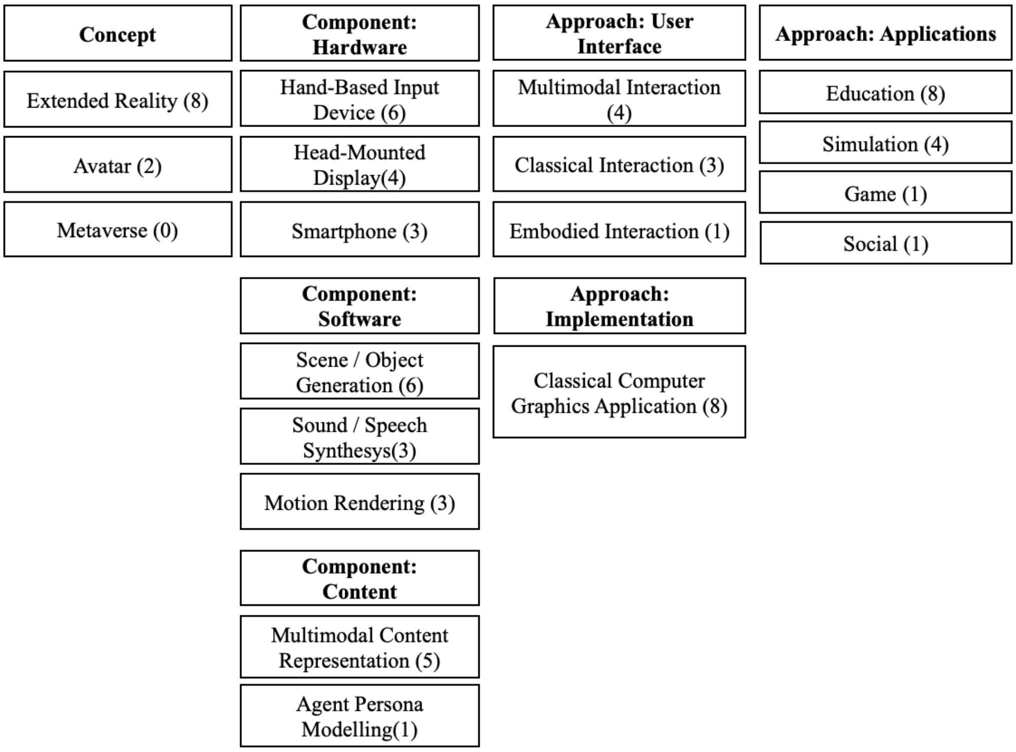

Figure 5 Frequency of metaverse label (sorted by higher frequency). Label in Table 1, which does not show here, has 0 frequency.

It must be noted that out of 8 publications, only 1 publication claimed they are using metaverse to deliver education (Khansulivong *et al*. 2022), while others are limiting their scope to either augmented or virtual reality applications. This trend also showed in Table 2, where query about metaverse only retrieved one publication. This indicates that although the metaverse topics have gained momentum in scientific publications, there is still a lack of study exploring the potential implementation in agriculture education.

The study showed a large gap between current immersive technology implementation to a mature metaverse described in Park and Kim (2022). All 8 publications showed a particular virtual environment previously programmed by the developers, while the metaverse in Park and Kim (2022) can simulate their own environment using reinforced learning and virtual agents. Another challenge of the metaverse technology is the cost of technology acquisition which are expensive, primarily if used in a large cohort of students. In the end, although there are massive gaps and technology and economic challenges, we encourage more study on the potential of metaverse for agriculture education. At this point, an insight into what use case metaverse could enrich students learning will be a potential waypoint for further study in this area.

CONCLUSION

From the review of 8 works about metaverse for agriculture education, we can conclude: (1) most of the learning content and design element of metaverse technology is underutilized; (2) there are many implementation gaps between the current implementation with a mature metaverse; and (3) a mature metaverse education is complex and expensive, so careful long-term planning and identifying use cases is recommended. For further studies, we encourage researchers, given adequate access to documents is available, to include non-engineering indexers, preferably from subject domain sources. We also encourage more study on the potential of metaverse for agriculture education.

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