

Serious Video Games for Agricultural Learning: Scoping Review

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Abstract—Serious video games provide a immersive learning environment for agriculture by simulating real-life challenges scenarios. However, empirical evidence of their effectiveness is sparse. This scoping review follows PRISMA-ScR guidelines to summarize literature on serious video games for agricultural learning, highlighting research trends and identifying gaps. We systematically searched nine prominent research databases for papers on serious video games for agriculture learning published between January 2000 and July 2022. Two independent reviewers conducted screening, data extraction, and synthesized the collected data using a narrative approach. The initial search identified 3,297 articles, of which 0.58% ($n = 19$) were included in the review. Most reviewed games were released in the last five years, with a predominant presence in the mobile platform. They commonly employed a simulation-based approach, featuring 2-D graphics and designed for single-player experiences. These games mainly target students, focusing on crop production and sustainable agriculture. Educational theories were often unspecified in the studies. Evaluation protocols primarily consisted of pilot studies, emphasizing user experience and knowledge enhancement. Positive outcomes, such as improved user experiences, knowledge, and attitude and behavior changes, were commonly observed in these studies. This study highlights advancements in using serious video games for agricultural learning over 20 years. However, it stresses the need for deeper exploration of game elements' impact on user experience and effectiveness. Creating games for underrepresented players and specific agricultural challenges is essential, as is enhancing theoretical foundations and learning approaches. Rigorous research designs are vital for assessing game effectiveness across short, medium, and long terms.

Index Terms—Agriculture learning, educational video games, serious video games, simulations, teaching/learning strategies.

I. INTRODUCTION

A. Agriculture Learning

AGRICULTURE, as an indispensable sector, plays a vital role in providing sustenance and diverse commodities to

global populations, supporting rural communities, and driving economic growth and development [1]. Nonetheless, agriculture confronts significant challenges beyond the imperative of ensuring food security [2], [3], encompassing climate change, water scarcity, soil degradation, and biodiversity loss [4], [5]. Moreover, labor shortages arising from aging populations, urbanization, and migration exacerbate these challenges [6]. Consequently, farmers, agriculture stakeholders, and agriculture students face mounting pressure to acquire knowledge and embrace novel practices and techniques that mitigate the impacts of these challenges while enhancing food production [7], [8]. Furthermore, these challenges have amplified the necessity for urban citizens to gain knowledge and skills pertaining to food production, enabling them to address future imperatives such as achieving self-sufficiency, enhancing nutrition, and promoting environmental sustainability [9].

Contrary to popular belief, agriculture represents an intricate system characterized by interdependence among various elements, including land, water, seeds, fertilizers, pesticides, livestock, farm machinery, equipment, and markets. Collectively, these components contribute to the production of indispensable agricultural commodities, such as food and fiber, which are vital for human consumption and utilization [10]. Consequently, the acquisition of agricultural knowledge requires a comprehensive understanding of interdisciplinary subjects encompassing biology, chemistry, and economics. Moreover, the effective transmission of this knowledge necessitates the incorporation of authentic real-world examples, case studies, and hands-on activities to reinforce the learning process [11]. However, multiple obstacles impede the progression of agricultural education, including limited access to education and resources, technological advancements, changes in practices due to climate change, language barriers, and cultural disparities [12]. Therefore, the integration of educational video games emerges as a potentially viable solution for overcoming these challenges associated with agricultural education.

The application of video games for educational purposes has grown substantially, and serious video games have emerged as a recognized academic field [13]. Serious video games are designed to do more than just provide entertainment; they aim to improve users' knowledge, abilities, and experiences through interactive and engaging platforms [14]. These games offer benefits such as achievement and rewards, interactivity and feedback, motivation and competition, realism and immersion, playfulness and addictiveness, problem-based learning, collaborative learning, progression, and repetition, as well as reducing

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anxiety and other affective barriers to learning [14]. In addition, serious video games offer a hands-on experience that may be difficult, expensive, time consuming, or dangerous to replicate in real life, making them valuable tools for learning and training. Over the past years, serious video games have gained recognition as a promising medium for learning across various fields, including mathematics, engineering, history, health, language, and science [15].

B. Agriculture Simulation Video Games

Agriculture and farming practices have been incorporated into strategic video games since the early days of *Romance of the Three Kingdoms* (1985) and *Nobunaga's Ambition* (1987). However, it was not until the release of *Harvest Moon* in 1996 that agriculture and farming practices took on a prominent role in video games, establishing the genre of farming simulation games. Since then, numerous agricultural and farming video games have been developed that engage millions of players worldwide in farming practices [16].

In recent years, the popularity of farming simulation games has continued to increase. Games such as *Farming Simulator* [17] allows players to take on the role of a farmer and expand their farming business by harvesting and selling crops. Other games, such as *Stardew Valley* [18], offer players a range of activities including growing crops, raising livestock, fishing, cooking, mining, foraging, and socializing with townspeople. *FarmVille* [19], a popular agriculture-simulation social network game, involves managing farmland by plowing, planting, growing, and harvesting crops, as well as raising livestock and harvesting trees. In 2011, it was one of Facebook's most popular games with 83.76 million monthly active users and 34.5 million daily active users [20]. Some games, such as *Plant Tycoon* [21], focus on indoor plant cultivation and require players to operate a plant nursery and cultivate exotic plants while keeping their shop financially successful.

The use of agriculture and farming practices in video games provides an engaging and interactive way to educate players about these fields, with the popularity of farming simulation games indicating their potential for promoting agriculture interest and education. However, there is currently a lack of empirical evidence supporting the effectiveness of serious video games in agriculture education. Two existing reviews focus on different aspects of the field: one examines the use of games as field research methods in agriculture [22], while the other analyzes the mechanisms of farming simulation video games [23]. While both works provide valuable insights, there is a need for a comprehensive review that considers a broad range of video games and how they are designed, implemented, and evaluated for agriculture learning.

C. Objective

This study aims to conduct a scoping review of serious games used for agricultural learning to answer the following questions.

- 1) What types of serious video games support agriculture learning?

- 2) What is the learner profile and learning target of serious video games for agriculture learning?
- 3) What are the theoretical foundations and learning methods used in serious video games for agriculture learning?
- 4) What agricultural simulation components are included in serious video games for agriculture learning?
- 5) How are serious video games for agriculture learning evaluated, what outcomes are assessed, and what are the reported results?
- 6) What are the reported limitations of serious video games for agriculture learning?

Through addressing these questions, this review aims to provide valuable insights into the current design, usage, and evaluation of serious video games, as well as their potential impact and limitations as digital interventions for agricultural learning.

II. METHODS

A. Overview

We followed a scoping review methodology to synthesize research on the use of serious video games as tools and interventions designed to support agricultural learning. This protocol followed the preferred reporting items for systematic reviews and meta-analyses extension for scoping reviews (PRISMA-ScR) methodology [24] to ensure that our review was conducted systematically and was bias-free.

B. Search Strategy

1) *Information Sources*: This review encompassed research papers published in the English language between January 2000 and July 2022. The search encompassed the following nine prominent databases: IEEE Xplore, Elsevier, ACM Digital, PubMed, Springer, Wiley, JSTOR, Web of Science, and MDPI. These databases cover computer science literature and provide extensive coverage of the topic and field. In addition, we also included papers cited in the retrieved articles through manual searches to ensure a thorough search process.

2) *Search Terms*: The search queries varied across databases, but they all included the same constructs of "serious video games" and "agriculture." The query used was integrated with the following words: ("serious game" OR "video game" OR "videogame" OR "game-based" OR "edutainment" OR "gamification" OR "computer game" OR "PC game" OR "educational game" OR "game simulation" OR "gamified simulation" OR "gamified approach" OR "game") AND ("farm" OR "farming" OR "agriculture" OR "ranching" OR "gardening" OR "garden" OR "agronomy" OR "crop-raising" OR "orchard"). Searches were performed on abstracts where possible, or in some cases, on the entire text of papers when libraries did not allow abstract-based searches.

C. Eligibility Criteria

We included studies that met the following criteria:

- 1) focused on the description of serious video games;

- 2) developed with the objective of supporting agriculture learning;
- 3) presented an evaluation procedure.

In contrast, the exclusion criteria included papers that did not describe serious video games, did not use serious video games for learning agriculture, or lacked an evaluation. We applied no restrictions on the study setting, study design, study outcome, month, and country of publication. For the purpose of our study, we adopted the following definition of serious video games and agriculture to precisely outline the inclusion criteria.

1) *Serious Video Games*: We adopt the definition of a serious video game proposed by Laamarti et al. [25], which states that it is an application with three components: experience, entertainment, and multimedia. The experience component is responsible for conveying knowledge, skills, or other content to the player, while entertainment provides amusement or recreation. Multimedia combines text, graphics, animations, audio, haptic, and other elements. To ensure that we focus only on serious video games and exclude other interactive applications like agricultural simulators, apps, websites, and tutorials, that might have been inaccurately categorized as serious video games we use the inclusion criteria established in [26]. Specifically, we include only those video games that contain five components: implementing rules or gameplay, presenting a challenge, featuring user interaction, having an explicit objective for entertainment, and having an implicit goal of increasing skills, abilities, knowledge, or experience.

2) *Agriculture*: We adopt the definition of agriculture provided by Harris and Fuller [27], which encompasses the various ways in which crop plants and domestic animals sustain the human population by providing food and other products. While the term “agriculture” now encompasses a wide range of activities integral to the field, we focus on serious video games that facilitate learning about core activities directly related to crop production and livestock growth for food and other products. Therefore, we exclude video games that solely address broader agriculture-related activities, such as climate prediction, water inequity, supply chains, distribution logistics, environmental governance, and agribusiness.

D. Study Selection

A multistage screening process was implemented to select relevant articles. During the initial phase, two reviewers (IEEC and CGAC) independently evaluated articles based on titles and abstracts. The primary objective was to identify papers explicitly proposing agricultural video games, given the prevalence of articles with relevant keywords leading to unrelated topics, such as “hunting games” or “game theory applied to agriculture.” The emphasis was specifically on identifying references to video games for agriculture in the title or abstract to streamline the selection process. Ambiguous cases, where it was unclear whether the paper proposed a video game or game-based technology, and instances where the emphasis on agricultural activities was uncertain, proceeded to the subsequent screening phase. The resulting articles were consolidated into a single list, and a second screening phase involving a full-text review was independently

conducted by the same two reviewers (IEEC and CGAC) to make the final inclusion decision. In cases of disagreement between the two reviewers, a discussion was held to reach a consensus. Furthermore, when multiple papers were related to a single serious video game, the most recent paper was chosen unless there was a notable difference in the evaluation protocol, such as varying results or target populations.

E. Data Extraction and Data Synthesis

All studies that complied with the stipulated inclusion criteria were included in the review. The data extraction procedure was conducted by two independent reviewers (IEEC and CGAC), and any discordance that arose was deliberated on through discourse to attain a unanimous consensus. Data extraction was centered on addressing the research objectives delineated in the objectives subsection. Several table templates were developed and calibrated to systematically extract and summarize relevant data such as the following:

- 1) the types of video games that were used to support agricultural learning;
- 2) the learner’s profile and learning target of those games;
- 3) the theoretical foundation and learning methods that served as a basis for those serious video games;
- 4) the agricultural simulation components that those serious video games approached;
- 5) the evaluation protocols, the outcomes assessed, and the reported results;
- 6) the reported limitations of those serious video games.

Finally, a narrative approach was used to synthesize the data. The data synthesis was carried out by two independent reviewers (IEEC and CGAC), and the discordances that arose were deliberated upon through discourse to attain a unanimous consensus. We further describe the main findings that emerged across the studies in the following section.

III. RESULTS

A. Overview

The search process resulted in a total of 3 297 records, with 97.6% (3 218/3 297) retrieved from the nine digital libraries and an additional 2.3% (79/3 297) obtained through manual searching. After removing duplicates, 2 755 papers were screened for eligibility, with 96.2% (2 651/2 755) excluded based on the exclusion criteria after reviewing the titles and abstracts. A total of 104 articles were reviewed in full, with 82% (85/104) excluded after the review. As a result, 19 studies were chosen for further examination. The flow diagram of the review phases is shown in Fig. 1. The first study identified dates back to 2006 [28] and 57.9% (11/19) of the studies were conducted in the last five years (2017–2022). Most of the 19 studies were conducted in Asia ($n = 8$, 42.1%) followed by Europe ($n = 7$, 36.8%), America ($n = 3$, 15.8%), and Australia ($n = 1$, 5.3%). An overview of the results is presented in Table I. Furthermore, Table II provides a comprehensive analysis of the selected studies, while Table III

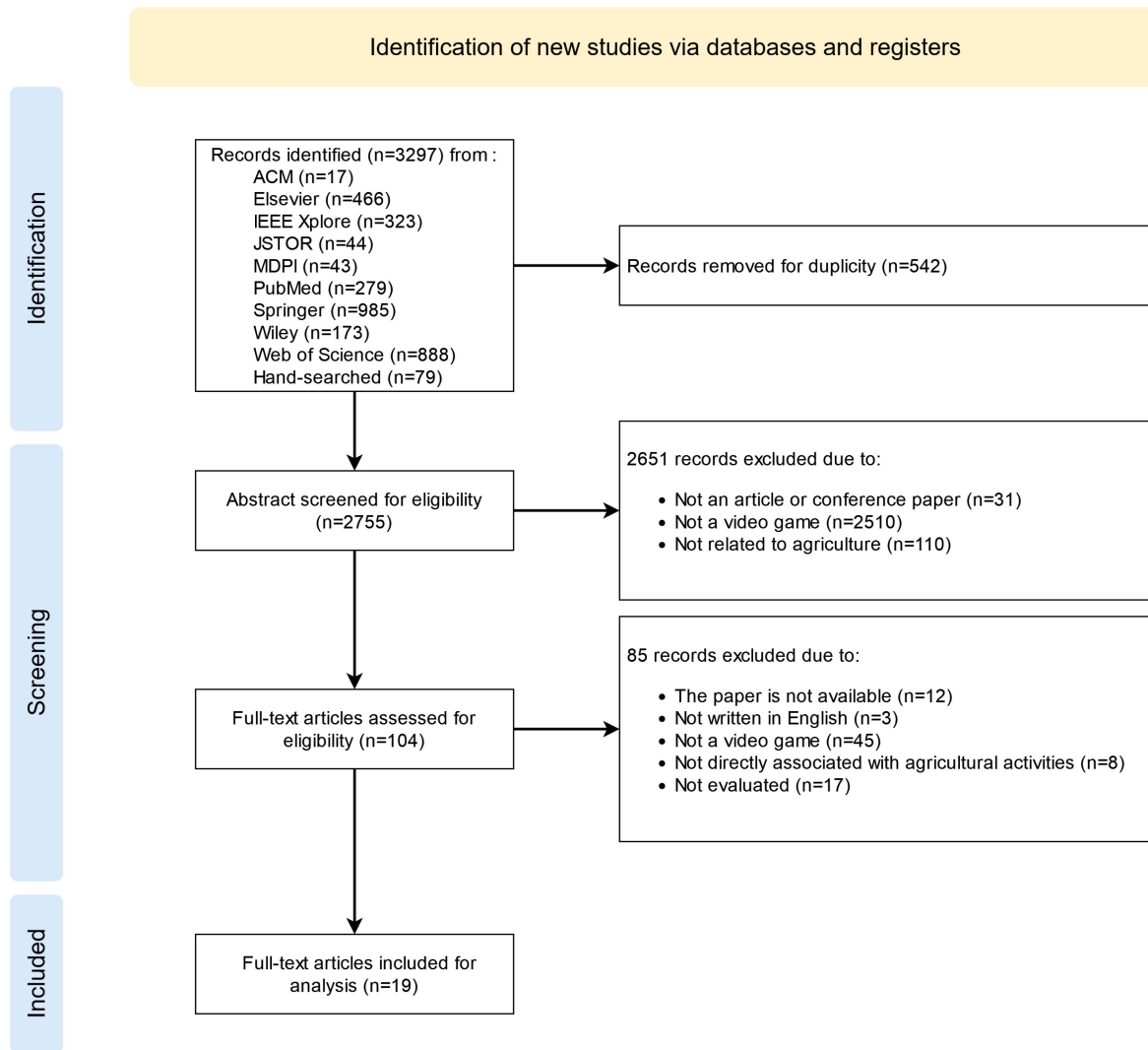


Fig. 1. Flow diagram of the study selection.

offers a detailed breakdown of the evaluation, results, and limitations. The following subsections provide detailed findings to answer the six defined questions.

B. Games Characteristics

Regarding the video game platforms, 36.8% (7/19) of the studies used mobile video games, 31.6% (6/19) used Web video games, 26.3% (5/19) used PC video games, and 5.3% (1/19) used a cross-platform video game [29]. The majority of the reviewed serious games (94.7%, 18/19) were simulation games, while only one (5.3%, 1/19) was an adventure game [30]. Out of the 19 games reviewed, 52.6% (10/19) were 2-D video games, and 47.4% (9/19) were 3-D video games. Moreover, the majority of the serious games evaluated (84.2%, 16/19) were single-player, while two (10.5%) were multiplayer [31], [32], and one (5.3%) had both single-player and multiplayer modes [33]. In terms of advanced technology, 26.3% (5/19) of the video games utilized advanced technology such as virtual interactive learning environments [31], agent-based architecture [34], location and

weather services [35], machine learning [36], and augmented reality [37]. In addition, several games employed architecture technology such as the client-server architecture [32], [34], [38] or model/view/controller architecture [39].

C. Learner Profile and Learning Objective

Regarding target audiences, most of the evaluated serious games were designed for students (elementary school, high school, or university) (9/19, 47.4%). Seven video games (36.8%) targeted the general public, while three studies (15.8%) were intended for farmers and agriculture stakeholders. In terms of the agricultural practices covered by the games, most games focused on crop production (13/19, or 68.4%), followed by games that addressed both crop and livestock production (5/19, or 26.3%), with only one game (5.3%) focusing exclusively on livestock production. Regarding the learning objectives, most games aimed to teach sustainable agriculture (5 out of 19, or 26.3%), followed by gardening (3 out of 19, or 15.8%) and general agricultural practices (3 out of 19, or 15.8%). One

TABLE I
OVERVIEW OF THE CHARACTERISTICS OF THE VIDEO GAMES ($N = 19$)

Characteristic	Studies, n (%)
Year of publication	
2018-2022	11 (57.9)
2013-2017	5 (26.3)
2008-2012	2 (10.5)
2003-2007	1 (5.3)
Platform	
Mobile	7 (36.8)
Web	6 (31.6)
PC	5 (26.3)
Cross-platform	1 (5.3)
Game genre	
Simulation	18 (94.7)
Adventure	1 (5.3)
Game environment	
2D	10 (52.6)
3D	9 (47.4)
Gameplay mode	
Single player	16 (84.2)
Multiplayer	2 (10.5)
Single and multiplayer	1 (5.3)
Advanced technology (AR, sensors, services, AI)	
No	14 (73.7)
Yes	5 (26.3)
Players profile	
Students	9 (47.4)
General public	7 (36.8)
Farmers and agricultural stakeholders	3 (15.8)
Agriculture target	
Crop production	13 (68.4)
Crop and livestock production	5 (26.3)
Livestock production	1 (5.3)
Agriculture educational goal	
Sustainable agriculture	5 (26.3)
Gardening	3 (15.8)
General agriculture practices	3 (15.8)
Agriculture maladaptation	1 (5.3)
Fertilization	1 (5.3)
Herbal medicine agriculture	1 (5.3)
Hydroponics	1 (5.3)
Pest management	1 (5.3)
Porcine farrowing management	1 (5.3)
Smart farming technology	1 (5.3)
Sufficient farming	1 (5.3)
Educational theoretical framework and methodologies	
Not specified	10 (52.6)
Specified	9 (47.4)
Evaluation protocol	
Pilot study	14 (73.7)
Proof of concept study	2 (10.5)
Comparative study	2 (10.5)
Cohort Study	1 (5.3)
Examined factors - Studies could examine several factors	
User experience, usability, or playability	15 (78.9)
Knowledge improvement	8 (42.1)
Perception of knowledge improvement	3 (15.8)
Agriculture awareness	3 (15.8)
Beliefs, attitudes, motivations, and expectations	3 (15.8)
Perception of agriculture awareness	1 (5.3)
Behaviors	1 (5.3)

video game (5.3%) was designed for each of the following learning objectives: agriculture maladaptation [40], fertilization [41], herbal medicine agriculture [38], hydroponics [30], pest management [42], porcine farrowing management [43], smart farming technology [29], and sufficient agriculture [44].

D. Education Theoretical Background and Techniques

Out of the 19 studies analyzed, nine (47.4%) explicitly mentioned their theoretical backgrounds, which were found to be varied. Two studies (2/19, 10.5%) referred to a specific

theory, namely, the interactional framing theory [40] and the flow theory [45]. Seven studies (36.8%) specified learning techniques such as active learning [28], situated and constructive learning [31], experimental learning [33], [37], indirect learning [30], [44], and tangential learning [36]. In addition, two studies specified gamification principles as the theoretical background [39], [41]. However, it is important to note that serious games and gamification are not the same, as pointed out by Dicheva et al. [46]. Although both use game elements to increase motivation and engagement, serious games are standalone games designed for a specific purpose beyond entertainment, while gamification adds game elements to an existing activity. Therefore, gamification cannot serve as the theoretical basis for serious games, which require a more comprehensive theoretical foundation to support their specific learning objectives.

E. Agriculture-Related Components

The reviewed agriculture games incorporate 15 components, including landscape, soil and water quality, crop and livestock growth, farmer practices, machinery, weather, pest management, product processing, market economics, and social factors. Among the games analyzed, SERious Game for AgroEcology learning (SEGAE) [45], had the most components, with nine, followed by Farmstasia [31], Fields of Fuel [33], and Crownking [39], each with eight components. Conversely, the games with the least components are RebEarth [30] and Uzhavan [47] with two components. Regarding the essential elements required for crop and livestock growth and yield, our analysis of video games reveals that landscape simulation is included in two video games (10.5%) [35], [45]. In addition, five video games (26.3%) include soil quality simulation, while one video game (5.3%) includes water quality simulation [33] and one video game (5.3%) features aseptic conditions simulation [43]. Regarding crop and livestock production, we found that 17 video games (89.5%) include simulation of crop health, growth, and expansion, while six video games (31.6%) feature livestock health and growth simulation. Furthermore, 17 video games (89.5%) include simulation of farming and gardening practices, such as irrigation, fertilization, watering, sowing seeds, applying pesticides, harvesting, and animal surgical intervention. Four video games (21.1%) feature farming machinery simulation [29], [30], [39], [45], and one video game (5.3%) includes farm events simulation [31]. Regarding phenomena that impact agriculture, we found that ten video games (52.6%) include weather and climate conditions and events simulation, six video games (31.6%) include pest and disease simulation, and one video game (5.3%) includes beneficial bug simulation [33]. Regarding production and economic issues, we found that 11 video games (57.9%) include business, market, and economic simulation, while six video games (31.6%) include product elaboration simulation. Finally, in relation to the impact of agriculture activities, three video games (15.8%) feature personal and social phenomena simulation, such as people's happiness, collaboration, and nutrition requirements [31], [34], [44] and two video games (10.5%) include emission and pollution simulation [33], [34].

TABLE II
CHARACTERISTICS OF THE REVIEWED VIDEO GAMES ($N = 19$)

Name	Country, year	Platform/ dimension	Video game characteristics	Learner's profile	Agricultural focus/target	Theoretical background
1. GENIX [28]	France, 2006	PC, 2D	- Simulation - Single player	University students	Crop/ Sustainable agriculture	Active learning
2. Farmtasia [31]	China, 2008	Web, 2D	- Simulation - Multiplayer	High school students	Mixed crop-livestock/ Sustainable agriculture and environment protection	Situated and constructive learning
3. Agrivillage [34]	Thailand, 2010	Web, 3D	- Simulation - Single player	General player profile	Crop/ Sustainable agriculture	Not specified
4. Agritainment [32]	Korea, 2014	PC, 3D	- Simulation - Multiplayer	K-12 Students	Mixed crop-livestock/ General agriculture	Not specified
5. Fields of Fuel [33]	USA, 2015	Web, 2D	- Simulation - Single and Multiplayer	High school students	Crop/ Sustainable agriculture	Experimental learning
6. RebEarth [30]	Bahrain, 2017	PC, 2D	- Adventure - Single player	General player profile	Crop/ Hydroponics	Indirect learning
7. Little Botany [35]	USA, 2017	Mobile, 3D	- Simulation - Single player - Location and weather services	School-aged children	Crop/ Gardening and Botany	Not specified
8. Crownking [39]	Hungary, 2017	Web, 2D	- Simulation - Single player	University students	Mixed crop-livestock/ General agriculture	Gamification principles
9. Herbopolis [38]	Singapore, 2018	Mobile, 3D	- Simulation - Single Player	General player profile	Crop/ Herbal medicine agriculture	Not specified
10. Game of Piglets [43]	Denmark, 2018	PC, 2D	- Simulation - Single Player	University students	Livestock/ Porcine farrowing management	Not specified
11. The Maladaptation Game [40]	Sweden, 2019	Web, 2D	- Simulation - Single player	Agricultural stakeholders	Crop/ Agriculture adaptation	Interactional framing theory
12. GATES [29]	Greece, 2019	Cross- platform, 3D	- Simulation - Single Player	Professionals and other stakeholders smart farming	Crop/ Smart Farming Technology	Not specified
13. V-Survival [44]	Thailand, 2020	Mobile, 3D	- Simulation - Single player	University students	Mixed crop-livestock/ Sufficient agriculture	Indirect learning
14. SEGAE [45]	France, 2020	Web, 2D	- Simulation - Single Player	University students	Mixed crop-livestock/ Sustainable agriculture	Flow theory
15. Tevi [36]	France, 2020	Mobile, 3D	- Simulation - Single Player - Machine learning techniques	Young adults	Crop/ Ecological gardening	Tangential learning and backward-reaching high road transfer
16. MahindiMaster [41]	Australia, 2021	Mobile, 3D	- Simulation - Single player	Farmers	Crop/ Fertilization	Gamification principles
17. Augmented Reality Greenhouse [37]	India, 2021	Mobile, 3D	- Simulation - Single player - Augmented reality	General player profile	Crop/ Gardening	Experimental learning
18. Spotter-Stop-It [42]	Brazil, 2022	Mobile, 2D	- Simulation - Single Player	General player profile	Crop/ Pest management	Not specified
19. Uzhavan [47]	India, 2022	PC, 2D	- Simulation - Single Player	General player profile	Crop/ General agriculture	Not specified

F. Evaluation Procedures and Reported Results

The studies analyzed in this review evaluated serious games using a variety of research designs, including 14 pilot studies (14/19, 73.7%), two proof-of-concept studies (2/19, 10.5%) [29], [40], two comparative studies (2/19, 10.5%) [28], [37], and a cohort study (1/19, 5.3%) [43]. Among the evaluated studies, 15 (78.9%) reported on the player's perception of the game, including satisfaction, experience, ease of use, usability, playability, and usefulness. [34].

Eight studies (42.1%) evaluated improvements in knowledge, while three studies (15.8%) evaluated changes in the player's perception of knowledge improvement [30], [34], [35]. Furthermore, three studies (15.8%) evaluated changes in agriculture awareness [30], [35], [36], and one study evaluated changes in perception of agriculture awareness. Finally, three studies (15.8%) evaluated changes in beliefs, attitudes, motivations, and expectations [41], [43], and one study (5.3%) even evaluated changes in real-world behaviors of players [41].

TABLE III
EVALUATION, RESULTS, AND LIMITATIONS OF THE REVIEWED VIDEO GAMES ($N = 19$)

Name	Evaluation	Measured variables	Results	Reported limitations and improvement opportunities
1. GENIX [28]	Comparative study (posttest) with university students (N =not specified). The evaluation's duration was not specified.	- Perception of the game.	- The game is effective when played as a board game. - The video game proved to be a more user-friendly and time-efficient alternative to the board game.	- Lack of user-friendliness. - The pacing of information in the game was inadequate. - The game contains unrealistic pictures. - The game's environment is unpleasant. - The game's lack of sound. - The game's pace is slow. - The game is challenging to use with a large number of players.
2. Farmtasia [31]	Pilot study (pre-post) with high school students (N =16) during 2 weeks (game-play period).	- Perception of the game. - Knowledge.	- The students' feedback on this game was generally positive. - The game facilitates valuable learning experiences.	- Not specified.
3. Agrivillage [34]	Pilot study (posttest) with university students, researchers, and professors (N =20) during 1 session (12 turns during 24 min).	- Player experience. - Perceived awareness of the environmental impact of agriculture. - Perceived improvement in knowledge.	- The game was easy to understand, had clear goals, and maintain the players' concentration. - The players' feedback indicated that the game heightened their awareness of the impact of agriculture on the environment. - The players reported that the game improved their knowledge.	- The game did not present many challenges. - The instructions are too lengthy. - The game lacks a multiplayer mode. - There are periods in the game where the player is left waiting. - The game could be made more realistic by including pests, crop diseases, and soil nutrient factors. - The lack of revision and validation of game knowledge by experts is a concern.
4. Agritainment [32]	Pilot study (not specified the type of evaluation) with a group of people with a strong interest in farming (N =not specified). The evaluation's duration was not specified.	- Knowledge.	- The game provides an engaging and non-fatiguing way for most users to acquire basic agricultural knowledge.	- Developing a domain-specific language that covers all aspects of the game would enable the game to incorporate the knowledge of domain experts and offer a more detailed simulation of activities such as cultivating, feeding, weather simulation, and insect behavior. - Create an interface between the internal simulation environment and external educational content.
5. Fields of Fuel [33]	Pilot study (posttest) involving students, educators, and researchers (N =not specified). The evaluation's duration was not specified.	- Perception of the game.	- The game was found to be enjoyable and engaging by the players. - Players reported that the game facilitated critical discussions about sustainability by providing rich and informative data.	- Not specified.
6. RebEarth [30]	Pilot study (posttest) with Web media university students (N =27) during 1 session playing all game levels.	- Perception of the game. - Awareness of the benefits of hydroponics. - Perceived improvement in knowledge.	- Half of the players were satisfied with the "fun" factor of the game. - The game proved to be an effective tool in raising awareness about hydroponics, and participants highly recommended it for achieving this purpose. - Players reported that they learned about hydroponics after playing the game.	- Add new difficulty levels.

TABLE III
CONTINUED

Name	Evaluation	Measured variables	Results	Reported limitations and improvement opportunities
7. Little Botany [35]	Pilot study (posttest) with school-aged children (N=28) during 3 weeks (At least 3 sessions per week).	- Usability and playability. - Awareness of gardening. - Perception of knowledge improvement.	- The game shows a high level of playability and usability. - Players felt they were maintaining a real garden. - The average scores of questions related to the perception of knowledge improvement and increase of interest were relatively lower compared to the other questions.	- To accurately evaluate educational effectiveness, a long-term experiment is necessary. - Include an indoor hydroponic module.
8. Crownking [39]	Pilot Study (posttest) with university students (N=30). The evaluation's duration was not specified.	- User feedback on functionality.	- The game received positive feedback regarding its overall functionality.	- A mobile version of the application. - The quiz module should reward the players. - Include a module for credit and commodities.
9. Herbopolis [38]	Pilot Study (posttest) with university students (N=19) during 1 week.	- Usability, playability, mobility, and educability. - Knowledge.	- Usability, playability, mobility, and educability were generally positive. - The game had a positive impact on players' knowledge of herbal medicines. - The game motivates players to learn about herb-related information.	- Improve robustness and performance. - Include more types of herbs and herbal products.
10. Game of Piglets [43]	Cohort Study (posttest) with university students (N=186, n=67 negative control, n=62 exposure group, n=57 positive control). The exposure group used the game during 1 session of two hours.	- Satisfaction with the game. - Knowledge. - Self-efficacy.	- Most players reported a positive experience and enjoyment while using the game. - The game had a positive impact on learning outcomes, particularly for students who were initially performing at a lower level. - The players' self-efficacy increased.	- Add more game modules to practice skills. - Difficulties related to navigation. - The lack of immediate feedback in the game.
11. The Maladaptation Game [40]	Proof of concept in 8 focus groups with agriculture stakeholders (N=37).	- Spontaneous reactions during or after individual playing. - Reflections about the most important issue that has been brought up.	- The game serves as a reference point for players to discuss their perspectives and experiences.	- Experienced incorrectness. - The game lacks context-relevant content. - The game lacks relevant actions and choices. - The game is simplistic in comparison to complex real-life situations. - The game text and symbols have been used incorrectly, resulting in confusion among players.
12. GATES [29]	Proof of concept (workshops and surveys) with smart farming technology stakeholders (N=750, n=297 students, n=253 farmers, and n=204 farm machinery specialists).	- Satisfaction with the game.	- The satisfaction level increased in comparison to previous versions of the game. - The 3D interactive module received the highest ratings from players in terms of usefulness and entertainment value. - The game provides a convenient online platform for acquiring knowledge on the latest advancements in smart farming technologies.	- Incorporate language options beyond English. - Include an avatar of an instructor/tutor to assist users in selecting the most suitable smart farming technologies for their fields.
13. V-Survival [44]	Pilot study (posttest) with university students (N=30), 15 have a game session of 10 minutes.	- Knowledge.	- The game can help students recall the key concepts of self-immunity and sufficient economy theory to some extent.	- The game should incorporate additional concepts from the sufficient economy theory.

TABLE III
CONTINUED

Name	Evaluation	Measured variables	Results	Reported limitations and improvement opportunities
14. SEGAE [45]	Pilot study (pre-post) with university students (N=52) and teachers (N=15) during 1 session. The session's duration was not specified.	- User experience. - Knowledge.	- The majority of the students enjoyed the game, as it provided a high level of interaction and feedback. - The game significantly increased the students' knowledge of agroecology, particularly among those who had little prior knowledge of crop production.	- Add more case studies. - The game's objectives were not clearly defined, leading to difficulties in concentration for players. - Include practices related to animal production, biodiversity management, and socio-economic decisions. - Include more theoretical information to help players understand the implications of practices.
15. Tevi [36]	Pilot Study (posttest) with general public participants (N=24) during 1 session. The session's duration was not specified.	- User experience. - Ecological awareness.	- Participants had a slightly positive overall impression of the game. - The short-term ecological awareness of the participants did not improve.	- Characters that represent player actions. - Expansion of property. - The presence of rewards. - The ability to use harvested fruit. - The plant photography and detection functions lacked proper contextualization within the game.
16. MahindiMaster [41]	Pilot study (pre-post) with farmers (N=200) during 1 session. The session's duration was not specified.	- Beliefs - Behaviors	- The farmers' beliefs about the benefits of fertilization were modified. - The intervention prompted changes in the farmers' use and perceptions of fertilization.	- Include more personalized, competitive, and pedagogical elements.
17. Augmented Reality Greenhouse [37]	Comparative Study (posttest) with young adults (N=12, n=6 negative control, n=6 intervention). The intervention group used the video game during 1 session of two hours.	- User experience. - Interest to learn gardening. - Knowledge.	- The game provides a more engaging, enjoyable, and stimulating learning experience. - The users of the game showed a consistent interest in learning and felt more responsible and involved in the plant's life cycle. - Players expressed a keen interest in expanding their knowledge on gardening. - The users of the video game have shown a higher level of information absorption.	- Incorporate a feature that allows users to easily share and showcase their terraria creations with others. - Add more tools and plant species. - Increase the information presentation rate. - Include professional knowledge.
18. Spotter-Stop-It [42]	Pilot study (posttest) with general public users (N=47) during 1 session. The session's duration was not specified.	- Knowledge.	- Players could recognize Suzuki flies and their impact on crops after playing. - Most of the players identified the effect in the soft-skin fruits correctly. - Most of the players demonstrated knowledge of how harvesting frequency, sanitation, and alternative host management can control pests.	- Add more levels with increasing difficulty. - Provide additional tools for pest management. - introduce changes in the farmer and non-crop alternative hosts. - Translate the game to different language versions.
19. Uzhavan [47]	Pilot Study (posttest) with general public users (N=not specified) during 1 session.	- Understandably. - Entertainment.	- Novice players can be readily captivated by the game's features and mechanics. - The game was found to be easily playable, comprehensible, and accurately represented the users' reality.	- The game has a limited scope and scale. - Enhance the graphical details for a smoother experience. - The incorporation of modern Internet of Things (IoT) technology can enhance the simulation of a smart farming environment.

The reported results from the studies were in general positive. Most of the studies that evaluated user experience (13/15 86.7%), reported positive results reflecting that players enjoyed the games, a game reported slightly positive results [36], and one game reported that half of the players were satisfied with the game [30]. All of the studies that evaluated improvement in knowledge reported positive results (8/8 100%). The improvement of knowledge is related to sustainable agriculture [31], [45], general agriculture [32], herbal medicine [38], porcine farrowing management [43], sufficient agriculture [44], gardening [37], and pest management [42]. Similarly, all of the studies that evaluated the perception of improvement of knowledge (3/3 100%), reported positive results [30], [34], [35]. Two of the three studies (2/3, 66.6%) that evaluated agriculture awareness changes reported positive results. The study that reported negative results relates to gardening [36]. In addition, the study that evaluated changes in the perception of agriculture awareness also reported positive results. All of the studies that evaluated the changes in beliefs, attitudes, motivations, and expectations (3/3 100%), reported positive results. The changes are related to porcine farrowing management [43], gardening [37], and fertilization [41]. Finally, the study that evaluated changes in the real-world behaviors of players also reported positive results in changes in fertilization use [41].

G. Reported Limitations and Improvement Opportunities

Reported limitations and opportunities for improvement can be grouped into the following four categories.

- 1) *Agricultural knowledge*: These limitations include a lack of expert validation [34], incorrectness in experience, insufficient contextually relevant content and choices, simplistic representation of real-life scenarios, and incorrect use of text and symbols [40]. Improvements could be made by including more case studies, theoretical information [45], and professional knowledge [37].
- 2) *Agricultural components*: These limitations relate to a lack of components such as pests, crop diseases, and soil nutrition [34]; limited coverage of farming activities like cultivating, feeding, weather simulation, and insect simulation [32]; and the absence of hydroponics simulation [35]. In addition, the games should include more tools and plant species [37], [42]; a wider range of herbs and herbal products [38]; incorporate changes in the farmer and noncrop alternative hosts [42], new modules such as credit and commodities [39], modules to practice skills [43], [45], and new agricultural technologies [47]. Furthermore, it is necessary to include additional agriculture-related ideas connected to the game's central idea [44].
- 3) *Game features*: These limitations relate to a lack of multi-player mode [28], [34], insufficient challenges [34], and a lack of links to external educational content [32]. In addition, the games could benefit from including more levels with increasing difficulty [30], [42], more gamification elements such as rewards [36], [39], an instructor/tutor avatar to help players [29], characters that represent player actions or property expansion, and the ability to use

harvested fruit [36]. A shared experience feature to see the progress of other players [37], more personalized, competitive, and pedagogical elements [41], and support for multiple languages [29], [42] could also enhance the gaming experience.

- 4) *User experience and usability*: The current limitations of agricultural video games include unfriendly sounds and interfaces, unrealistic graphics, an unpleasant environment, inadequate information pacing, and slow performance [28]. Players may also encounter long instructions and periods of waiting during gameplay [34]. Other issues include difficulties with navigation and the lack of immediate feedback [43], unclear game goals, and challenges with concentration [45]. In addition, some game functions may not be appropriately contextualized [36], and the presentation rate of information may need to be increased [37]. The graphics should also be improved for a smoother visual experience [47]. To enhance usability, a mobile version of the game should also be developed [39].

IV. DISCUSSION

A. Overview

As serious video games continue to gain popularity as tools for agricultural education, it is crucial to determine the essential elements that game designers must consider. To accomplish this goal, we conducted a scoping review of existing game designs and intervention outcomes and identified and summarized six key characteristics. Our review included 19 serious games released between 2000 and 2022, with the majority (11/19, 58.8%) being released in the past five years, specifically from 2018 onwards.

B. Game Characteristics

Our analysis of agriculture games revealed that mobile video games accounted for 36.8%, followed by web-based games (31.6%), PC games (26.3%), and cross-platform games (5.3%). Furthermore, we found that in the last five years, 78% of newly developed games were either mobile or web-based, indicating the increasing popularity of these platforms for educational games [48], [49]. Out of the 19 games analyzed, 52.6% were 2-D and 47.4% were 3-D. Moreover, most of the serious games evaluated were designed for single-player gameplay, with only three games having multiplayer modes. While commercial video games often prioritize popular platforms, environments, and gameplay modes for commercial and economic reasons, it is important to consider that each platform, environment, and gameplay mode has its own advantages and disadvantages in educational games. For instance, mobile games may have limitations for long-term learning compared to computer games [48]. In addition, while 3-D games provide immersive experiences and realism, with a wide range of gameplay mechanics available [50], 2-D games offer advantages due to their simplicity, ease of navigation, better visual clarity, and more straightforward understanding of the game world [51].

Single-player games offer benefits such as control, personalized learning, and flexibility, but they may lack social interaction and competitive elements, leading to limited engagement and potential isolation [48]. In contrast, multiplayer modes provide players with opportunities for collaboration, teamwork, competition, and engagement, but they may be subject to technical issues, distractions, and unequal participation. Interestingly, some studies have shown that users tend to prefer multiplayer versions of games compared to their single-player counterparts [52]. Given the aforementioned considerations, selecting the characteristics of educational games depends on several factors, including the target audience, learning objectives, simulation complexity, specialized interface, portability, accessibility, data security, game mechanics, and economic resources [49], [51]. To maximize the potential of agriculture-themed serious games for learning and user engagement, it is imperative to conduct further research to assess the advantages and disadvantages and effectiveness of different platforms, environments, and game-play modes. This will enable game designers and developers to make informed decisions about game design and mechanics, leading to better learning outcomes and higher levels of user engagement.

Furthermore, it is noteworthy that only 5 out of 19 video games (26.3%) used advanced technologies such as virtual interactive learning environments, augmented reality, intelligent systems, and machine learning. Virtual and augmented reality (VR/AR) can create immersive and interactive experiences, increase motivation and engagement, and promote constructive learning [53]. Artificial intelligence can improve game functioning and provide personalized experiences [54]. Further research is required to assess the impact of integrating emerging technologies, including VR/AR, and artificial intelligence in agriculture serious games to enhance user engagement, and learning outcomes, and create more interactive, engaging, and realistic experiences.

C. Learner Profile and Learning Objective

Serious games have been developed to educate students and the general public about agriculture, but there is a shortage of games available for farmers and agriculture stakeholders. Students and the general public often have greater access to technology and familiarity with technology-based learning. Serious games designed for students usually focus on specific agricultural topics, while those for the general public may not need to accurately represent real-world scenarios since they aim to raise awareness about agriculture's importance and impact. In contrast, limited access to technology in rural areas, language, and cultural barriers, and the need to accurately reflect real-world situations are some challenges associated with using video games for agricultural education [55], [56], [57]. In addition, farmers may prefer traditional training methods or be uncomfortable with technology-based learning [56], [58]. To address the shortage of serious games available for farmers and agriculture stakeholders, more research is needed to develop and evaluate games that target these groups. It is also important to determine whether serious games designed for university

students can be adapted for use by farmers without requiring significant modifications to the game mechanics.

The majority of serious games analyzed in the field of agriculture focus on practices related to crop production, followed by those covering mixed crop-livestock production. This emphasis on crop-based agriculture is not surprising since it constitutes the foundation of human food systems globally, providing most of our caloric intake and essential nutrients [59]. According to data from the Food and Agriculture Organization (FAO) of the United Nations for 2021, crops represent about 85% of global agricultural production, while livestock represents around 15% [60]. However, mixed crop and livestock farming offer a unique opportunity to learn about the interdependencies between crops and livestock, the significance of sustainable land management practices, and the economic realities of farming [61], [62]. Only one serious game focuses solely on livestock farming, which is surprising given the importance of livestock farming in many regions of the world. However, the complexity of this subject requires extensive research, modeling, and programming to develop effective serious games [63]. Therefore, it may be more practical to develop games that address specific aspects or issues of livestock agriculture to provide players with a deeper understanding of the complexity of livestock farming and the challenges faced by farmers. Moreover, a large proportion of the analyzed serious games aim to educate players about general and specific agricultural practices, including herbal medicine agriculture, and hydroponics. This is expected since education is one of the primary objectives of serious games. However, it is worth noting that almost half of the games concentrate on sustainable agriculture and addressing specific agricultural challenges, such as maladaptation, fertilization, pest management, and food sufficiency. These challenges have significant social, economic, and environmental impacts, and addressing them is crucial to ensure sustainable agriculture that benefits society as a whole [4]. Future research efforts are needed to develop and evaluate video games that effectively educate players about these challenges and other critical issues, such as climate change, soil degradation, water scarcity, pest and disease outbreaks, and food insecurity [4].

D. Educational Theoretical Background and Techniques

Theoretical grounding is essential for understanding the effectiveness of serious game interventions. However, a substantial portion of the reviewed studies (10/19, 52.6%) did not specify the theoretical basis for their games. Of those that do, one game uses the interactional framing theory, which explains how people use communication to create shared meanings and make sense of the world around them [64].

Another game uses the flow theory, which posits that individuals experience a deep sense of enjoyment and satisfaction when they achieve a balance between their skills and the challenges presented by an activity [65]. Seven studies (36.8%) specify learning approaches, with four using student-centered approaches to learning, including active learning, constructive learning, situated learning, and experimental learning. These approaches are instructional methods and strategies that focus on

the learner as an active participant in the learning process [66]. The other three studies use incidental learning approaches, such as indirect learning, tangential learning, and backward-reaching high-road transfer, where learning is not the primary focus of the activity but occurs as a byproduct or side effect [67]. The lack of a clear theoretical basis for serious games makes it difficult to identify which game elements and mechanics are effective for enhancing agricultural learning and the underlying principles that support these mechanics. Therefore, further research is necessary to explore how educational theories and learning approaches can be integrated into agricultural serious games to facilitate authentic and meaningful learning experiences, manage cognitive load, and foster motivation and engagement among learners [68].

E. Agriculture-Related Components

Our analysis of agriculture games revealed that the majority of them incorporate only a limited number of simulation components, typically ranging from two to nine out of a possible 15 identified from all games. Although it might seem that games with more components would offer higher fidelity and lead to better learning outcomes, the relationship between fidelity and learning is complex and nonlinear, with conflicting evidence [69]. Furthermore, the impact of fidelity on learning outcomes is influenced by various factors such as learners' backgrounds, learning conditions, and learning goals [69]. Therefore, educational game designers must carefully consider these factors when designing simulations for their games.

Our analysis also showed that the most common simulation components included in these games are related to farming and gardening practices, crop and livestock health and growth, and business, market, and economy simulations, which align with industrial agriculture's focus on intensive and often mechanized production methods to maximize yields and profits [70]. However, some important agricultural components are surprisingly absent. Although over half of the games incorporate weather and climate conditions, greater emphasis on simulations for these factors is needed to help students understand the impact of extreme weather events and adapt their farming techniques accordingly. In addition, many important components such as soil quality, water quality, pests, diseases, landscape, farm machinery, and farm events are largely absent from most games, despite the fact that understanding these elements is essential for successful crop production [71].

Incorporating simulations for these components in agriculture educational games could provide a more comprehensive and engaging learning experience for students. We found it both surprising and encouraging that some games include simulations for product elaboration, beneficial insects, emissions, and pollution, as well as personal and social phenomena such as people's happiness, collaboration, and nutritional requirements. For example, simulations on beneficial insects educate players on their importance in crop production and how to promote their populations, while product elaboration simulations allow students to understand how raw agricultural products are transformed into consumer goods and create opportunities

in the market. Emissions and pollution simulations teach the importance of reducing the environmental impact of agriculture, and human and social issue simulations educate players about the impact of farming on communities and promote socially responsible agriculture. In summary, our analysis reveals that the games exhibit varying levels of fidelity and cover a broad range of agricultural components, ranging from basic to specialized. However, further research is necessary to assess the effectiveness of different simulation components in promoting agricultural education among players. It is also crucial to explore the impact of fidelity levels on learning outcomes and whether more accurate and realistic simulations lead to better learning outcomes. Understanding these factors can inform the development of more effective educational games that better prepare learners for real-world challenges in agriculture.

F. Evaluation Procedures and Reported Results

Evaluating the effectiveness of educational agriculture games is crucial for improving agricultural education by identifying their strengths, weaknesses, and limitations, and making improvements to enhance their effectiveness. In our review, we identified several types of studies, including two proof-of-concept studies, 14 pilot studies, two comparative studies, and one cohort study. While these studies demonstrated positive impacts of agriculture games on various factors such as usability, user experience, player perception, agricultural awareness, knowledge, beliefs, attitudes, expectations, and behavior, the lack of randomized controlled trials (RCTs) suggests that the research area is still in its early stages with limited strong evidence for causal relationships between interventions and outcomes, and we need to be cautious when interpreting the findings.

In addition to the aforementioned findings, we found that the majority of reviewed papers focused on evaluating the usability and gaming experience of educational agriculture games. Specifically, six papers reported exclusively on usability and user experience, while four studies used self-reported perceptions to evaluate the subjective perceptions of players. However, these may not provide strong evidence for the intervention's effectiveness. Ten papers focused on reporting only posttest evaluations of agriculture awareness, knowledge, beliefs, attitudes, and expectations, but without a pretest measurement, it is challenging to determine whether changes are due to the intervention or other factors. Only four studies conducted prepost evaluations, which are important in evaluating the effectiveness of educational agriculture games as they allow researchers to control for factors that may affect knowledge levels and assess changes over time. Overall, the lack of prepost evaluations and RCTs could weaken the evidence and hinder the ability to form definitive conclusions regarding the efficacy of agriculture games. Thus, it is crucial to conduct more rigorous research designs to produce robust scientific evidence that can help improve the development of educational agriculture games and advance agricultural education.

G. Reported Limitations

The analysis of limitations in current agricultural educational games is vital to improving their effectiveness and design, leading to better educational tools. The analysis identified several key limitations in agricultural knowledge, agriculture components, game features, and user experience and usability that must be considered when developing an agriculture educational game. First, the game must incorporate accurate, relevant, and validated agricultural content that represents real-life scenarios to enable meaningful learning. Second, the game should incorporate educational theories and instructional design principles to ensure that it effectively teaches agricultural concepts. Third, games should include the components of agricultural simulation necessary to provide a comprehensive learning experience and to achieve the game's objectives. Fourth, it is necessary to analyze and implement game characteristics such as player mode, the balance of challenges and difficulty, increasing levels, representation of player actions, rewards, elements to provide educational content, game mechanics, language, social elements and strategies, and personalization. These elements are critical for creating an engaging and effective learning experience. Finally, ensuring good user experience and usability is essential by addressing sound, images, environment, user interface, instruction, clear goals, navigation, information pacing, functions, feedback, smoothing of graphical elements, and the robustness and performance of the game. This requires expertise in user experience and usability principles to ensure the game is accessible and enjoyable for learners. From these limitations, we can identify that developing an agriculture educational game requires a multidisciplinary team with diverse knowledge and skills in agriculture, educational theories and instructional design, game design, game development, and user experience and usability principles. By addressing the limitations identified in current agricultural educational games, we can create more effective and engaging educational tools to support agricultural education.

H. Limitations of This Review

The scoping literature review has some limitations that need to be considered when interpreting the results. First, academic repositories were the only academic sources used to identify serious games, and no other sources such as app stores were considered. Second, only studies with an evaluation process were included, excluding innovative serious games that had not been tested yet. Finally, a metaanalysis was not feasible due to heterogeneity in the research design, outcomes reported, and outcome measures. Despite these limitations, this study is still important as it provides an overview of the current state of serious games in agriculture, highlighting important characteristics and reported evaluation results, as well as limitations.

V. CONCLUSION

This scoping review highlights significant progress in the use of serious video games for agriculture learning over the past 20 years. However, most reviewed games were released in the last five years. They frequently utilized a simulation-based approach,

predominantly on the mobile platform, incorporating 2-D graphics and tailored for single-player experiences. The primary audience targeted students, with a specific emphasis on crop production and sustainable agriculture. Educational theories were often unspecified in the studies. Evaluation protocols leaned toward pilot studies, focusing on user experience, usability, playability, and knowledge improvement. Positive outcomes, such as enhanced user experiences, knowledge, and attitude/behavior changes, were observed in most studies. However, the studies also reported limitations in terms of agricultural knowledge, simulation components, game features, and user experience and usability. Building on the revealed findings, future research should explore the implementation of game characteristics (such as platforms, gameplay mode, and environment) and advanced technology (such as AR and artificial intelligence) to assess their impact on learning outcomes. There is also a need to develop video games that address underrepresented agriculture stakeholders and agricultural areas and challenges. Additional research is necessary to strengthen their theoretical foundations and learning procedures to maximize the learning, engagement, and user experience of agriculture serious video games. Furthermore, research should evaluate the impact of simulation components on promoting agricultural education and investigate the role of fidelity levels in learning outcomes. Improvements to agricultural knowledge, simulation components, game features, and user experience can enhance the engagement and effectiveness of games. Finally, rigorous research designs are needed to assess the effectiveness of video games in promoting learning and persuasion over the short, medium, and long term.

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