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Systematic Review

A Scoping Review on the Impact of Educational Technology in Agricultural Education

Zhihong Xu [1,*], Anjorin Ezekiel Adeyemi [1], Rafael Landaverde [1], Ashlynn Kogut [2] and Matt Baker [1]

[1] Department of Agricultural Leadership, Education and Communications, Texas A&M University, College Station, TX 77843, USA; anjy2@tamu.edu (A.E.A.); rafael.q@tamu.edu (R.L.); mathew.baker@ag.tamu.edu (M.B.)
[2] Department of Teaching, Learning and Culture, Texas A&M University, College Station, TX 77843, USA; awkogut@tamu.edu
* Correspondence: xuzhihong@tamu.edu

Abstract: As the global demand for agricultural systems increases, agricultural education programs are implementing educational technologies to train industry professionals to meet 21st-century agricultural demands. No reviews have focused exclusively on the use of educational technologies in agricultural education. This scoping review presents a summary of 83 journal articles and conference papers published between 2000 and 2022 aimed at examining the impact of the use of educational technologies in agricultural education programs. Our results indicate: (1) most studies on this topic have been conducted in the United States in the context of agricultural sciences; (2) most of the studies implemented quantitative designs using researcher-designed instruments; (3) online/distance education technologies were the most widely used; and (4) there was a statistically significant increase in the use of simulation/digital games between 2000 and 2010 and 2011 and 2022. Based on our analysis, we discuss the methodological and reporting limitations that should be considered in future research, the pedagogical contributions of educational technologies in agricultural education, and the current and future research trends, highlighting gaps in the literature.

Keywords: educational technology; agricultural education; scoping review; learning outcomes; impact

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1. Introduction

Agricultural education is a fundamental part of the competitiveness of farming systems worldwide. To maintain this competitiveness, agricultural education must integrate educational technologies into curriculum development and delivery [1]. Therefore, the use of educational technologies to bring interactiveness and produce better outcomes in teaching and learning has attracted a lot of research interest over the years, both in favor of and against the topic [2–6]. Moreso, the increase in available educational technologies [7] and the recent rise in their use due to the COVID-19 pandemic have highlighted the impacts that educational technologies could have in dire circumstances [8].

This scoping review examined educational technologies' impact on agricultural education programs. Following the JBI Scoping Review Framework [9], our study attempted to summarize and communicate research findings, find research gaps in the existing body of literature, and assess the scope and character of the research activity. While researchers still debate the specific roles educational technologies have in agricultural education, it is essential to assess the contribution of educational technologies to agricultural teaching and learning. Educational technologies are more than a contingency plan, and it is crucial to fully understand, develop, and deploy the most effective educational technologies in the appropriate learning environments for the best results. Agricultural educators have implemented educational technologies in areas such as supplementing in-service education [10], individual and group instructional purposes, and administrative purposes [11],

and have found these integrations increase students' interests and retention [12] and enhance students' critical thinking [13]. However, research has not yet summarized existing research findings and highlighted potential priorities for future research and action in agricultural education.

2. Literature Review

2.1. The Development of Agricultural Education

Agricultural education has gone through a series of transitions in tandem with agricultural development processes. Anderson [14] produced a broad list of definitions by different experts, giving insight into various perspectives and dimensions of agricultural education, such as: quality instruction in all agricultural subject areas [15]; adult education to farmers both in agriculture and other subject areas [16]; and everything planned, methodical, and instructive that takes place outside of the formal system [17]. Many other authors [18–21] also made significant contributions to the topic at earlier stages. Williams [22] summarily states that the relationship between agriculture and teaching is agricultural education.

Agricultural education, as conceived by the National Council for Agricultural Education (NCAE), is a comprehensive educational curriculum that is provided to students who want to learn about the environment, natural resource management, and the science, commerce, and technology of producing plants and animals. The National Association of Agricultural Educators (NAAE) also stated that agricultural education instructs students on food production, agriculture, and natural resources. These two definitions provide a more holistic definition, especially within the context of a student-centered environment as opposed to the farmer-centered definitions earlier given. The definitions can also be linked to the interconnected delivery components of agricultural education, referred to as the three-circle model of agricultural education, which are classroom or laboratory instruction, experiential learning, and leadership education.

For this study, we adopted NCAE's definition of agricultural education as any systematic program of instruction available to students desiring to learn about the science, business, and technology of plant and animal production and about the environmental and natural resource systems [23]. More specifically, this study focused on students within the context of the three-circle model of agricultural education (classroom and laboratory instruction, leadership, and experiential learning). This includes students who are enrolled in formal education from secondary to higher education, in professional development and certification programs (e.g., certificate programs or distance education programs), or in some educational programs carried out by agricultural students under supervision in the field.

2.2. Educational Technology in Agricultural Education

Educational technology plays a vital role in agricultural education. Similar to agricultural education, there are as many definitions of the term "educational technology" as are conceptualized by various authors, organizations, and professional bodies in the field of education over time. While there has not been a dearth in the body of literature on the topic, unifying the similarities, differences, and context of each definition for the purpose of each study can be daunting. The evolution of the definitions over time is rather representative of the field's progress, and the rapid pace of advancements in technological science serves as a catalyst for this evolution [4].

Prior to 1963, the general perception of educational technology was as an instructional medium—a tangible tool used to deliver teaching to students [24]. From 1963 onwards, however, studies with different perspectives began to emanate that defined educational technology differently, such as the methodical application of scientific information regarding teaching-learning environments to increase the effectiveness of training and instruction [25–27] and the application of the newest scientific and technological advancements and contemporary abilities and methods [26,27]. In differentiating between instructional technology and educational technology, Alston et al. [28] contended that while instructional

technology was seen as a division of knowledge known as "educational technology" by Cleary et al. [29], they proposed the latter as the general approach and tools used in putting educational principles into practice.

Ibrahim [30] divided the evolution of the definitions into six distinct phases based on years: before 1963 to 1963; 1970; 1972; 1977; 1994; and 2008. The inadequacy of each definition has always dictated the need for a revision or total withdrawal in favor of a more comprehensive one. For instance, the 1963 definition coined it as a subfield of educational philosophy and practice [31], while the 1970 revision separately developed by the Commission on Instructional Technology (CIT) termed it instructional technology that can be used in conjunction with the teacher, textbook, and blackboard or a methodical approach to designing, carrying out, and evaluating total learning and teaching processes [32].

With each revision came a better and broader scope, but this did not translate into automatic adoption by all. The role of the Association of Educational Communication and Technology (AECT) has been very significant in the development and revision of these definitions from 1963 up until 2008, when the AECT committee submitted a new definition that defined educational technology as the investigation and ethical practice of facilitating learning and improving performance through the development, application, and management of appropriate technological processes and resources [33]. The replacement of instructional technology with educational technology, as well as the introduction of the concept of technological processes and resources, makes the definition more encompassing.

For this study, we adopted a working definition of educational technology as defined by the Association of Educational Communication and Technology (AECT) [33] and modified by Januszewski and Molenda [34]: the practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources, including computers, video projectors, the internet, and other technology that are placed in the classroom for the purpose of enhancing teaching and learning. Specifically, this study posits that educational technology encompasses both a process (e-learning, virtual simulations, internet observations, etc.) as well as the instructional technology/devices (projectors, iPads, smartphones, computers, mobile devices, videos, etc.) used in the process.

2.3. Importance of Educational Technology in Agricultural Education

At the center of the introduction of educational technology in agricultural education is the desire for both educational reforms and classroom innovation [35]. These innovations are particularly important in agricultural education systems, where learning is more experiential [36] and where students are challenged to apply concepts across a wide and diverse set of skills in the context of learning by doing [37]. The need for students to be autonomous thinkers, investigate challenging issues, and apply knowledge in practical settings, especially in a fast-paced, technologically driven society, shifted the paradigm from the traditional teacher-centered style of teaching and learning to technology-enhanced learning environments [38].

The place of educational technology in agricultural education has changed over time. Originally, educational technology was primarily used for creating and delivering instructional materials in military and university education contexts. In the 1980s and 1990s, the emergence of microcomputers and the internet led to the expansion and a drastic shift to a variety of digital formats such as video, audio recordings, and interactive multimedia [28,39]. The evolution and expansion of educational technology continued with the development of additional tools and approaches, including learning systems, virtual classrooms, video conferencing, educational software, and contextual educational mobile apps. The overarching goal of these tools has been to improve the outcomes of student learning through technology enhancement [28,40–42].

A few studies have attempted to quantify the impact of educational technology on students' learning outcomes in agricultural education. For example, Haynes et al. [43] found that internet-based pre-visit field trips had a positive effect and facilitated a more lasting learning experience than traditional pre-visit field trips. In a study of the flipped classroom

by Busato et al. [44], the agricultural engineering students in the flipped classroom group scored significantly higher than the conventional classroom group.

The results from studies conducted on online/web-based/distance education and virtual learning have found mixed results, ranging from positive [45–47] to negative [48–50] and even to no significantly different outcomes between the intervention and the control groups [51–54]. These results are indicative of the fact that there are several intervening variables that act as determining factors in the success of the educational technology deployed. Other studies have assessed the impact of the use of smartphones [55], teleconferencing [56], educational software like MyGuru [57], BLACKBOARD COURSEINFO® [58], Electronic Audience Response System (EARS) [59], e-exams [45], GPS/GIS [60], and Digital Game-Based Simulation/Virtual reality environments [61].

Prior research has demonstrated that smartphones and teleconferencing can be useful tools for agricultural education, allowing students to access information and communicate with their classmates and teachers remotely. Educational software, like MyGuru and BLACKBOARD COURSEINFO®, can provide an interactive platform for students to access course materials and complete assignments. The Electronic Audience Response System (EARS) can be used in classrooms to facilitate student participation and assessment. E-exams allow students to take exams electronically, potentially making the process more convenient and efficient. GPS/GIS (geographic information systems) technology can be used to support education in fields such as geography, allowing students to visualize and analyze spatial data. Many educational immersive learning experiences can be created through digital game-based simulations and virtual reality, thereby allowing students to engage with complex concepts.

In the last twenty years, online and distance education have become increasingly widespread due to improvements in technology that have made the remote delivery of classes more accessible to students. The benefits of this mode of education include flexibility, the ability to cover a wider range of audiences, and the ability to customize, to an extent, each student's experience. This is particularly noticeable in agricultural science education.

2.4. Previous Reviews

In a comprehensive review of 1777 articles on educational technology published in the British Journal of Educational Technology (BJET) from 1970 to 2018, Bond et al. [62] found that learning was the most commonly mentioned topic, followed by students, technology, research, school, training, and time. The studies focused on schools (K-12), higher education (university), and training (professional development) and were judged based on their rigor, influence, and prestige over a five-year period citation index. England was identified as the top region for studies, followed by the United States. The authors, however, stated that due to including all the authors in the country ranking, the country analysis may be biased. The importance of these variables cannot be overemphasized. For example, the very low records of studies focusing on educational technology from Africa and the Middle East, as they found in their study, may be indicative of either the absence of studies with such a focus or the inability of authors from those two regions to meet the journal criteria, such as publication fees, the rigor of the research design, or many other extenuating factors. Unfortunately, the study failed to cover the field of agricultural education.

Cheung and Slavin [63] have thoroughly dealt with the importance of taking into consideration some methodological features of included studies so as to sufficiently make sense of the effect sizes. In their study that synthesized 645 studies from 12 reviews, they found that the type of data collection instrument (researcher-made vs. independent measures), sample size (small vs. large), and research design (randomized vs. quasi-experiments) all contributed significantly to the overall effect size. Burback et al. [64] also corroborated this by stressing the importance of some methodological features (two of which included sample size and duration) to differentiate between statistical significance and clinical significance in the results of clinical trials. Mueller et al. [65] in their scoping review on methods to systematically review and analyze observational studies also noted

the importance of study designs and statistical analysis in making valid recommendations from the 93 articles included in their study.

Prior reviews have touched on aspects of educational technology in agricultural education. These include how Second Life has been used in agricultural education [66], how agricultural technology (AgTech) has been implemented into secondary agricultural education classrooms [67], and a narrative review of educational technology in The Agricultural Education Magazine [68]. Only one prior review [69] examined studies focused on the application of educational technologies in agricultural sciences education at the undergraduate and graduate levels. Vickery et al. [69] applied the technological, pedagogical, and content knowledge (TPACK) framework to analyze how educational technologies were studied in prior literature. Over half of the included studies used a module or multimedia resource as the educational technology. Additionally, in the majority of their included studies, both pedagogical and content needs were factors in choosing the educational technology intervention. Only 57% of the studies included in the analysis provided learning outcomes data to illustrate the impact of the use of educational technology interventions on student learning. Our study therefore extends their work in multiple ways. First, our review includes studies from both secondary and post-secondary agricultural education. Second, this review will include technologies developed over the last four years (2018–2022) as well as studies conducted during the COVID pandemic, when all instruction shifted to a virtual format. Finally, this review focuses on the learning outcomes that resulted from implementing a specific educational technology, an area that their study identifies as a future research area.

This scoping review aims to fill the gap in the literature regarding the impact of educational technology on learning outcomes in agricultural education. As educational technologies continue to be implemented, it is important to empirically determine if educational technology has a significant effect on student learning in agricultural education. Understanding the impact of educational technology on students' learning outcomes will also lay the foundation for its systematic incorporation into the educational process. The agricultural education students that are being prepared for prospective careers in agriculture and other related industries will benefit from a robust preparation that aligns with global job market demands.

3. Research Questions

The present review focuses on empirical studies about the effect of educational technology on agricultural education. We aim to examine the following aspects of the existing literature on this topic: (1) substantive features; (2) methodological features; (3) characteristics of educational technology within the context of agricultural education. The current study is guided by the following research questions:

- What are the substantive features of the included studies, such as publication information, country/region information, and instructional context?
- What are the methodological features of the included studies, such as the study type, research methods employed, data collection approaches, and sample size?
- Which are the characteristics of the educational technology used in the context of agricultural education, such as the type of educational technology and the learning skills targeted using educational technology?
- What is the impact of educational technology on students' learning outcomes in agricultural education?

4. Method

Our research questions focused on describing empirical studies about the impact of educational technology in agricultural education. The scoping review is the most appropriate evidence synthesis method to answer our research questions because our research questions aimed "to identify the types of evidence available", "examine how research is conducted" on the impact of educational technology, and "to identify key

characteristics" about educational technology [9]. Components of a scoping review include developing a comprehensive search strategy to find studies, including studies that use different research methods, and reporting the findings using descriptive statistics [9].

We conducted this scoping review using the JBI Scoping Review Framework [9]. First, we defined and aligned the review objective and research questions. Second, we developed the inclusion criteria to support the research questions. Third, we discussed the plan for finding, selecting, coding, and presenting the evidence. Fourth, we searched the most appropriate databases, conference proceedings, and journals. Fifth, we selected studies based on the inclusion criteria. Sixth, we extracted the relevant information from the included studies. Seventh, we analyzed the data extracted. Eighth, we descriptively presented the results. Finally, we discussed the implications of the results and provided future research directions. We used the PRISMA-ScR checklist [70] to guide the reporting of this scoping review.

4.1. Search Strategies

We searched five databases covering the disciplines of agriculture and education: CAB Abstracts (Ovid), AGRICOLA (EBSCO), ERIC (EBSCO), Education Source (EBSCO), and Web of Science Core Collection (Web of Science). The first two authors and the fourth author, a research librarian, developed the search strategy in CAB Abstracts (Ovid), and the fourth author modified the search for each of the other four databases. The date range limiter of January 2000 to September 2022 was added to each database search. The searches were run on 20 September 2022.

Based on the research questions, two core concepts were identified: educational technology and agricultural education. Synonyms as well as subject terms, which are unique to each database, were identified for the two concepts. The synonyms and subject terms for each concept were joined with "or" to create a concept cluster, and the two concept clusters were joined with "and." See Appendix A for the full search strategy for CAB Abstracts. The results from the database searches were uploaded into Covidence for duplicate removal and screening. From the five database searches, 3737 studies were imported into Covidence for screening. After 643 duplicates were removed, 3094 references from databases were screened for eligibility.

We also searched the most recent online issues of the NACTA (North American Colleges and Teachers of Agriculture) Journal and the Journal of International Agricultural and Extension Education on 26 September 2022, as these were not indexed in the databases on the date of the search. Eight references were added to the title/abstract screening in Covidence from the individual journal searches. Additionally, we searched the most recent five years of conference proceedings (2022–2018) from the following conferences: Association for International Agricultural and Extension Education, American Association for Agricultural Education (AAAE) National Conference, AAAE North Central Region Conference, AAAE Western Region Conference, and AAAE Southern Region Conference. We added 172 references (169 of which were unique) for full text screening in Covidence after searching the conference proceedings.

4.2. Inclusion and Exclusion Criteria

The included studies met the following five criteria:

1. The included studies examined the effect of educational technology on agricultural education. Articles were excluded if they were not about educational technology, if they were not within the agricultural education context, or if they did not examine the effect of educational technology on agricultural education.
2. The included studies had to be published in a journal as a conference proceeding or as a dissertation from 1 January 2000 to 20 September 2022 and be available in English. We chose this time frame because we aimed to include the most recent studies, and educational technology has witnessed rapid development since 2000 [71–73] in

agricultural education. Secondary data analysis, literature reviews, book reviews, book chapters, and reports were excluded.

3. The included studies had to report the assessment of educational technology's impact/effect on agricultural education. Articles were excluded if they were reports about a course or workshop about educational technology. Articles that generally discussed the trends or the importance of educational technology in agricultural education were excluded.
4. Included studies needed to report detailed information on the effect of educational technology on learning outcomes in agricultural education, which included the sample size, experimental design, and detailed results (either quantitative or qualitative). Conference abstracts on this topic were excluded.
5. Included studies were conducted in agricultural education, which includes formal education from secondary to higher education, professional development, certification programs, and some educational programs carried out by agricultural students under supervision in the field. Articles were excluded if they conducted studies in agricultural extension or in agricultural industries.

4.3. Data Collection and Data Analysis

The search and screening process to identify eligible studies is shown in Figure 1. After deduplication, 3271 unique references were screened for eligibility. First, the first two authors screened the article titles and abstracts using the inclusion/exclusion criteria. After the first round of screening, more than 77% of the articles were excluded. Second, the first two authors independently screened the full text of the remaining 731 articles. After the full text screening, 93 articles were eligible for inclusion in our review. In the coding process, another 10 articles were excluded for various reasons (e.g., no effect examined; no detailed information about the study design). Therefore, 83 articles were included in the final coding stage.

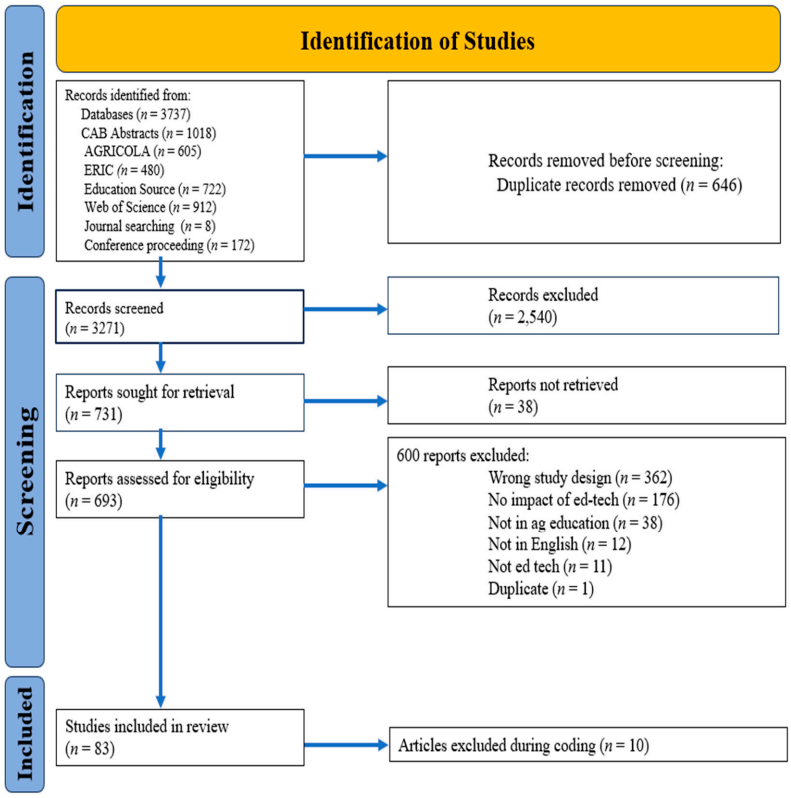


Figure 1. PRISMA flow diagram.

The first two authors independently coded the first 10 articles and developed the coding scheme for the current scoping review. Next, the first four authors used the developed coding scheme to code the articles in Microsoft Excel. The initial coding of the 83 articles was done independently in order to calibrate the coding. For the initial round of coding, we achieved an inter-rater reliability of 85.39%. When the authors had a dispute, the first author was reached to resolve the disagreement. Eventually, 100% agreement about the coding was reached. We conducted descriptive statistical analyses to answer our research questions.

4.4. Coding Scheme

We designed a detailed and comprehensive coding scheme to organize study information and facilitate data extraction. We covered the included studies' substantive and methodological features through the systematic coding form. Since the focus of the study was the impact of educational technology on learning outcomes on agricultural education, we categorized the characteristics of the educational technology.

4.4.1. Substantive Features of the Studies

Substantive features of the studies included article type, publication information, country/region of the study, course subject, and educational level. By coding the journal/conference title and publication year, we aimed to identify the major journals contributing to the field and analyze the publication trends. For the country/region where the study was conducted, we attempted to examine if the trends of educational technology in agricultural education differed across countries/regions.

We also coded the specific subjects that utilize educational technology in agricultural education. We coded the subjects as agricultural science, including agribotany, agronomy, soil science, horticulture, and agriculture and life sciences; agricultural engineering, including agricultural mechanics; agricultural leadership, education, and communication (ALEC); and agricultural economics and finance. Table 1 presents the subjects classified as agricultural sciences, agricultural engineering, ALEC, and agricultural economics and finance in the included studies.

Table 1. Breakdown of Identified Subject Areas.

Subject	Subject Content
▪ Agricultural Science	Agribotany, Equine/animal science, Plant/soil science, Agronomy, Crop production, Land resource management, Horticulture, Crop physiology, Agroecology, Forestry, Biology, Weed sciences, Reproductive management, Agriscience applications, Organic farming, Terrace gardening, Reproductive management
▪ Agricultural Engineering	Food chain logistics engineering, Biotechnology, Agricultural civil engineering, Agricultural basic technology, Agricultural mechanics, Gas metal arc welding
▪ Agricultural Leadership, Education, and Communications (ALEC)	Agricultural science teacher education program, Agricultural education program, FFA, Agricultural leadership, Teaching methods in agricultural education, Advanced methods of distance education, Health education (nutrition), Agricultural adult education, Youth leadership, Career teacher education, Agricultural communications
▪ Agricultural Economics and Finance	Agricultural economics, Agribusiness, Agricultural intermediate microeconomics, Agricultural finance/business

The education levels included in the studies were divided by secondary (7–12), undergraduate, graduate, professional education (professional and certificate agricultural education programs), and faculty and staff. If there were more than two educational levels, it was coded as mixed. If it was conducted in higher education but did not specify whether it was undergraduate or graduate, we coded it as higher education not specified.

4.4.2. Methodological Features of the Studies

Methodological features of the studies included research methods, sample size, data collection approaches, and type of instrument.

Research methods were categorized in three ways: quantitative, qualitative, or mixed methods. Quantitative studies included the use of descriptive statistics such as frequencies, percentages, means, and standard deviations [74–76]. Studies using statistical analysis, such as a *t*-test [43,77,78] or an ANOVA [58,79–82], were also coded as quantitative. We used Denzin and Lincoln's [83] definition of qualitative research: "a set of complex interpretive practices" used by different disciplines without a set approach (p. 6). Mixed-methods studies utilized both qualitative and quantitative methods. We documented whether the included studies had a control group. We also documented the sample size within the selected studies.

Data collection approaches included survey/questionnaire, interview, test/assessment which included homework assignments, GPAs of the participants, examination scores, focus groups, digital/audiovisual/photo recordings, and student evaluation. If the study applied more than one approach, it was coded as mixed data collection. For the studies employing a survey/questionnaire and a test/assessment, we documented whether the researchers designed the original instrument, adapted an existing instrument(s), or used a standardized instrument(s). Furthermore, we also documented the information on the sample size.

4.4.3. Characteristics of Educational Technology in Agricultural Education

We categorized the characteristics of educational technology utilized in agricultural education. Types of technologies were coded with the following categories: online/distance education, simulation/digital games, multimedia and traditional technologies such as utilization of LCDs, PowerPoints, video, flipped charts, and projectors, mobile technology including cellphones and tablets, social media (blogging), flipped classroom, GPS/GIS, and virtual learning. If the study employed more than one type of technology, we coded it as mixed.

Our criteria for intensity were based on Cheung and Slavin [84] and Xu et al. [85], with a cutoff of 75 min per week. Strong intensity occurred when the technology was used for more than 75 min per week. All other intensities were categorized as weak. In addition, we believe that the amount of time an educational technology is used during the semester or year may play a vital role in its effects on learning outcomes in agricultural education. Therefore, we also coded the duration of an intervention. A duration of three months was the cutoff [86] because the typical K-12 school year is 180 days, and three months represents at least half of the year. If an educational technology program was used for more than three months, it was coded as long. Durations less than three months were coded as short.

We also coded whether the studies had positive or negative effects on learning outcomes in agricultural education. If no effects were found, we coded it as nonsignificant. For studies with mixed effects, we coded them as mixed.

5. Results and Discussion

5.1. Substantive Features of the Studies

The analysis of the publication year shows an upward trend in research publications (Figure 2) focused on educational technology in agricultural education since the year 2000. Among the 83 included articles, 33 (39.76%) were published between 2000 and 2010 (11 years), while 50 (60.24%) were published between 2011 and 2022 (12 years).

Among the 83 articles identified, the majority of articles (n = 72, 86.75%) were from 22 peer-reviewed journals, while the remaining 11 articles (13.25%) were from six conferences such as the American Association for Agricultural Education (AAAE) regional (Western, North Central, and Southern) and national conferences, the International Symposium on the Taxonomy of Cultivated Plants, and the International Scientific Conference on eLearning and Software for Education. The majority of the identified journals (n = 14/22,

63.64%) appeared only once, while the other eight journals (n = 8/22, 35.36%) appeared at least twice. The number of articles per journal/conference is listed in Table 2.

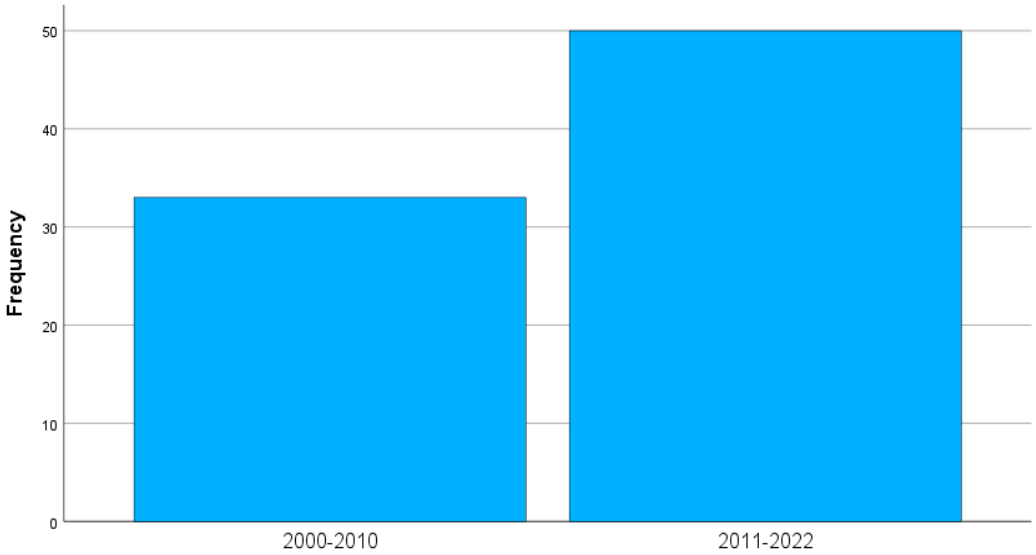


Figure 2. Distribution of Publications According to the Year.

Table 2. Journals and Conferences of Included Articles.

Journal	**Number of Articles Included in the Review**
NACTA	23
Journal of Agricultural Education (JAE)	18
Natural Sciences Education	4
Journal of Natural Resources and Life Sciences Education	4
Journal of International Agricultural and Extension Education (JIAEE)	3
Review of Agricultural Economics (Applied Economic Perspectives and Policy)	2
Journal of Applied Communications	2
HortTechnology	2
Other journals (e.g., International e-Journal of Advances in Education, Applied Engineering in Agriculture, and The American Journal of Distance Education)	14 *
Conferences	**Number of articles included in the review**
AAAE National Conference	4
AAAE Western Region	3
AAAE North Central Region	1
AAAE Southern Region	1
Int. Symp. Taxonomy of Cultivated Plants	1
International Scientific Conference on eLearning and Software for Education	1

Note: * other articles only appear once but in separate journals.

The majority of studies in the identified articles as shown in Figure 3 were conducted in the U.S. (n = 69, 83.13%), while the only other country that appeared more than once was Italy (n = 2, 2.41%). The other 10 articles (12.05%), which were studies conducted in Malaysia, Ireland, Nigeria, South Korea, India, Ethiopia, Romania, South Africa, France, and Denmark, only appeared once. Two articles (2.41%) were conducted or examined in the context of more than one country and/or region. It is not surprising that most

of the publications were conducted in the U.S., and it is also noticeable that none of the included studies were conducted in Australia. However, agricultural education is extremely important and necessary for countries' economies, especially in developing countries [87,88]. Considering the impact of educational technology on agricultural education [89], more studies on this topic should be encouraged in developing countries, especially in Asia and Africa.

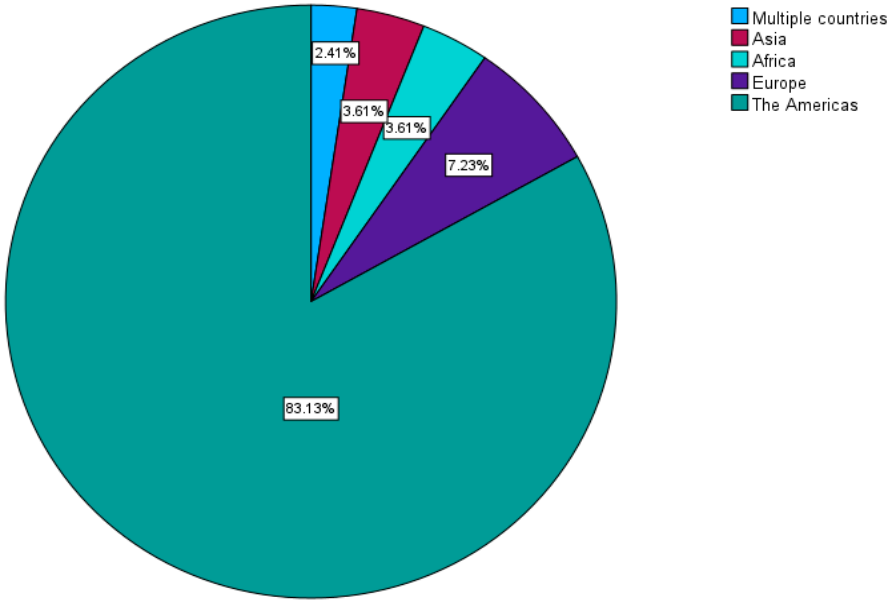


Figure 3. Distribution of Included Articles by Areas of the Study.

With regards to the subjects or fields of agricultural education (Figure 4) where various educational technologies have been deployed in the identified studies, 39 articles (46.99%) were in agricultural science subjects, while 21 articles (25.30%) covered ALEC subjects. Another 10 articles (12.05%) covered agricultural engineering subjects, and the other 11 articles (13.25%) covered agricultural economics and finance subjects. Lastly, two articles (2.41%) covered mixed subject areas in agricultural education as identified by the studies. The majority of the publications on the topic of educational technology in agricultural education were conducted in STEM subjects (agricultural science and engineering, 59.04%), while we also witnessed a large number of articles conducted in social science (ALEC and agricultural economics, n = 32, 38.55%) in the context of agricultural education. These findings indicated that educational technology had been widely employed in the field of agricultural education. However, only 2.41% of the publications covered mixed subjects. Since multidisciplinary approaches have become dominant and necessary in agricultural sciences and education, we expect to see more studies in the future covering mixed subjects to investigate the impact of educational technology in agricultural education [85,90]. When examining studies in the sub-discipline of agriculture, it becomes apparent how educational technologies are being used and in which specific areas. Haynes et al. [43] conducted a study within the ALEC sub-discipline, comparing two treatment groups and one control group of students for pre-visits to public gardens. The treatment groups, which involved traditional (lecture-based) and internet-based pre-visits, showed that the internet-based group had an equal or superior experience compared to the traditional groups. This is particularly interesting for the agrotourism industry. Agribotany is another sub-discipline within the agricultural sciences where educational technology is gaining attention. In our studies, we found that sub-disciplines involving experimentation or laboratory work, such as agricultural science and engineering, mostly use simulation and digital games as educational technologies of interest. Conversely, sub-disciplines such as ALEC and agricultural economics and finance are mostly focused on online/internet-based learning forms

of educational technology. Studies like Teolis et al. [91] and Abdullah [57] compared student performances in live versus web-based instruction in herbaceous plant identification, highlighting some noticeable trends.

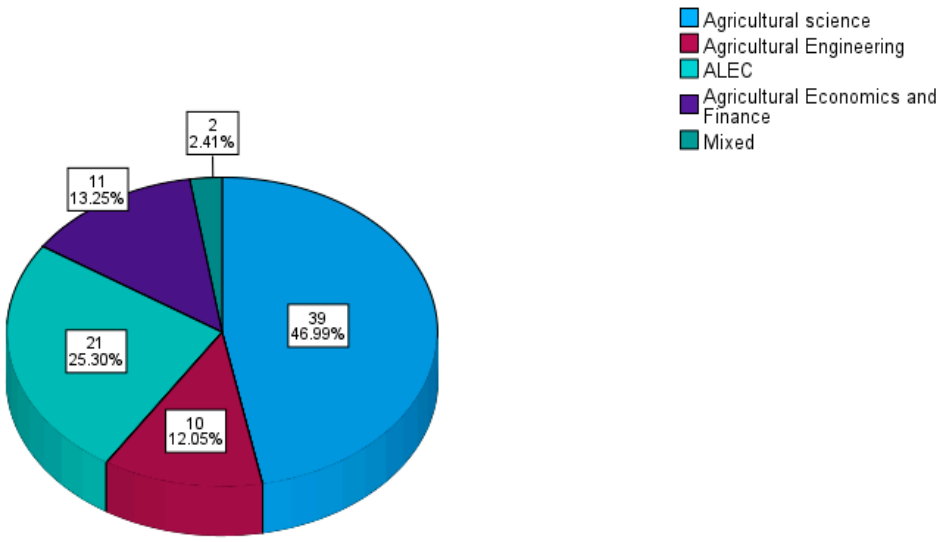


Figure 4. Distribution of Included Studies by Subject Areas/Disciplines.

The majority of the articles identified were carried out at the undergraduate level (n = 50, 60.24%). Other educational levels included graduate (n = 8, 9.64%), secondary education (n = 8, 9.64%), faculty and staff (n = 2, 2.41%), and professional/certificate/adult learners (n = 1, 1.20%). Two articles (2.41%) did not specify the higher education level, while the remaining 12 articles (14.46%) covered mixed educational levels.

5.2. Methodological Features of the Studies

The majority (n = 61, 73.49%) of the included studies adopted a quantitative method in their research design. Another 12 articles (14.46%) utilized a mixed-methods approach, while nine articles (10.85%) used a qualitative approach. For one of the articles (1.20%), it was difficult to identify clearly what method was used for the study. The prevalence of quantitative studies is consistent with the other review studies on the effect of educational technology [92]. It is not surprising that more and more studies are adopting quantitative or mixed methods to measure the effectiveness of educational technology, as mixed-methods study designs have increased in popularity [93]. Both quantitative and qualitative methods can provide insights into research findings [94], [95]. Future studies can employ more mixed-methods study designs to investigate the effect of educational technology from multiple epistemological perspectives.

We coded whether the authors used statistical analysis in their studies. The results revealed that 59 articles (71.08%) employed statistical analysis, while 24 articles (28.92%) did not. Out of the 73 articles that used either quantitative or mixed methods in the research design, 38 (52.05%) had a control/comparison group, while the remaining 35 articles (47.95%) did not. The design and development of intervention studies is a vital aspect of evidence-based research. Literature suggests that rigorous intervention studies containing a control/comparison group can help best assess the effectiveness of the intervention [96], so we recommend that future studies have control/comparison groups in their study design if possible.

According to the literature, studies with a smaller sample tend to detect larger effect sizes [97]; therefore, reporting sample size is important to prevent potential bias. Simultaneously, sample size is often dependent on the nature of the analyses being run [98,99], and the employed research methods (qualitative or quantitative). For example, qualitative researchers usually recruit fewer participants than quantitative ones [100].

Since our review focused on the impact of educational technology on agricultural education and its learning outcomes and the majority of studies employed a quantitative/mixed methodology (n = 73, 87.95%), we adhered to the recommended quantitative research guidelines: a large sample size is more than 250 participants, a medium sample size is between 100 and 250, and a small sample contains less than 100 participants [86,92,97,101]. In accordance with these sample size indicators, 44 articles (53.01%) had small sample sizes, 22 articles (26.51%) had medium sample sizes, and only 11 (13.25%) had large sample sizes. In addition, six articles (7.23%) either did not explicitly state their sample sizes or it was difficult to deduce the sample sizes from their research designs and hence were not categorized (Figure 5). This indicates that researchers in agricultural education should state information about their sample size in research reports and attempt to recruit more participants to obtain a larger sample size in order to examine the effect of educational technology.

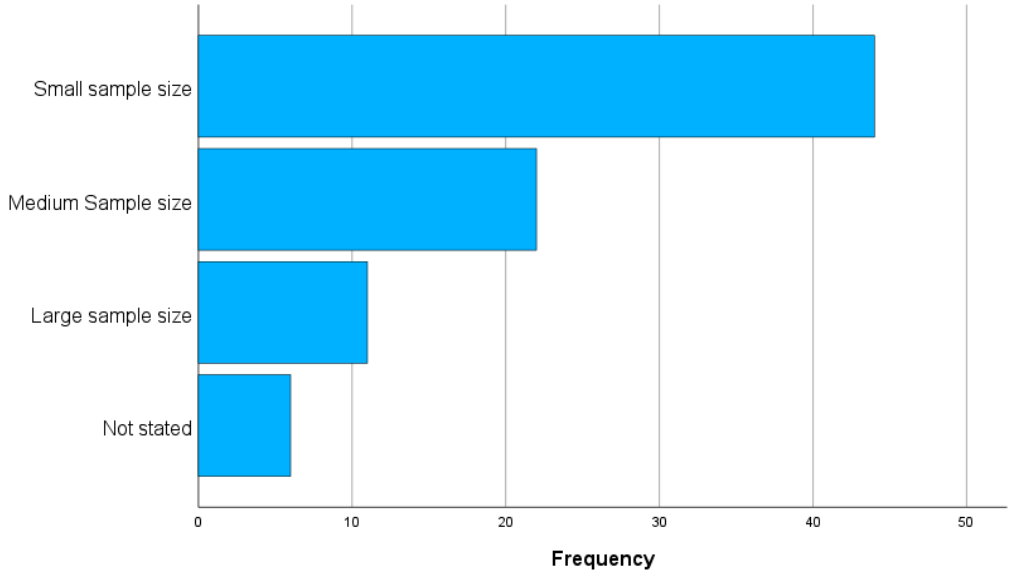


Figure 5. Distribution of Included Articles According to the Sample Size.

The data collection approach was also identified as shown in Figure 6. Among the 83 included articles, 31 (37.35%) utilized tests, assessments, examinations, homework assignments, and GPA as the method of data collection. Another 27 articles (32.53%) used mixed methods of data collection, while 20 articles (24.11%) used surveys/questionnaires. Other data collection methods included digital/audiovisual/photo recordings (n = 2, 2.41%), focus groups (n = 1, 1.20%), interviews (n = 1, 1.20%), and student evaluation (n = 1, 1.20%). It is understandable that the number one data collection approach is assessment since we limited our scope to the effect of educational technology in agricultural education. We also found that surveys and questionnaires are a very popular data collection method for agricultural education researchers.

We further coded the studies that employed assessments or surveys/questionnaires to identify whether the instruments the researchers used were standardized or researcher-designed. Among the 74 articles that used assessments and surveys/questionnaires, the majority of the articles (n = 64/74, 86.49%) utilized researcher-designed instruments, eight articles (10.81%) used standardized instruments, and two articles (2.70%) utilized a combination of both. Although we acknowledge the need for researchers to design their own instruments to measure the specific learning outcome, we caution against the reported effectiveness of researcher-designed assessments compared to standardized assessments [92,102]. Future researchers can put more effort into constructing standardized instruments to measure the effectiveness of educational technology in agricultural education.

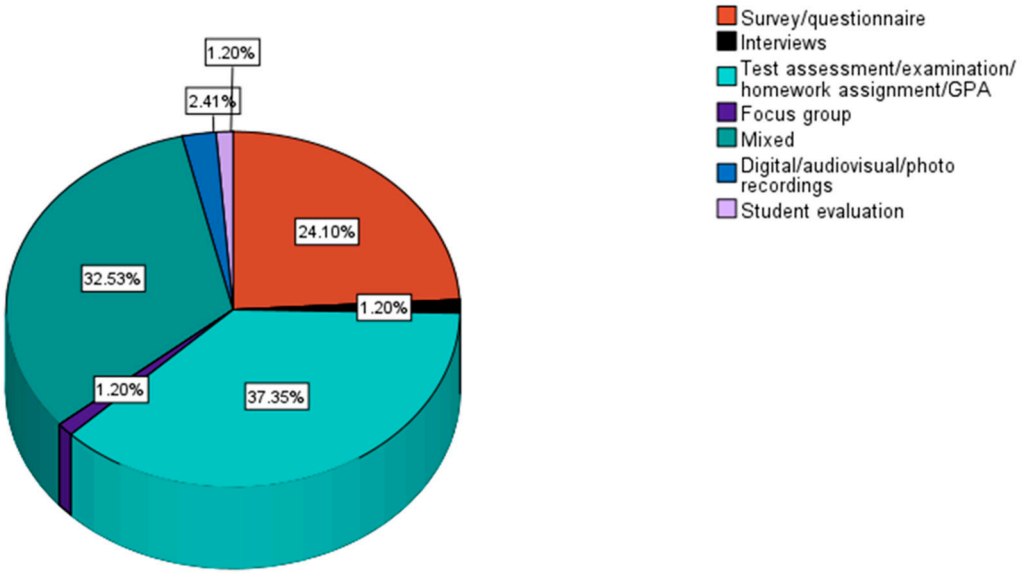


Figure 6. Distribution of Articles by Data Collection Methods.

5.3. Characteristics of Educational Technology in Agricultural Education

A number of educational technologies were identified from the 83 included articles (Figure 7). The most used educational technology in agricultural education was online/distance education (n = 34, 40.96%), followed by simulation and digital games (n = 18, 21.69%) and then multimedia and traditional technology (n = 15, 18.08%). Also, four articles (4.82%) used flipped classrooms, another four articles (4.82%) used virtual learning, three articles (3.61%) used mobile technology, two articles (2.41%) used social media, and only one article (1.20%) used GPS/GIS. Two articles (2.41%) used a combination of more than one educational technology. To gain a further understanding of the context of the usage of these educational technologies, we noted some peculiarities of the kinds of technology used. For example, Wingenbach [45] used educational technology in an examination environment to test if there was a statistical relationship between academic achievement and exam delivery method for students enrolled in a course at Mississippi State University, comparing the academic performance of students who took the exam in the traditional pencil-and-paper format as against those who took theirs in an electronic version. Miller and Pilcher [48] in their own study were interested in whether the same level of quality of education exists when students take off-campus or on-campus courses. Dooley et al. [52] focused on educational competencies when courses are delivered synchronously and asynchronously. Bazen and Clark [103], in their own study, wanted to promote interactive learning with an electronic student response system. These and many more offer some insights into the fact that the use of educational technology in agricultural education can have multi-faceted applications and that various forms of learning outcomes across different learning domains may be targeted through these technologies.

We followed Cheung and Slavin's [84] and Xu et al.'s [85] criteria for an educational technology program's intensity, with a cutoff of 75 min per week. When the technology program was used for more than 75 min per week, we coded it as strong (n = 14, 16.87%). Otherwise, it was categorized as weak (n = 7, 8.43%). There were 62 articles (74.70%) that did not provide information about the program intensity (indicated by missing). When the program lasted longer than three months, we categorized it as long duration (n = 44, 53.01%). Otherwise, we categorize it as short duration (n = 21, 25.30%). Eighteen studies (21.69%) included in the current scoping review did not provide relevant information on duration. Previous studies indicated that the educational technology program's intensity and duration have a fundamental impact on the effect of the programs [86,101]. We highly recommend that future studies provide relevant information regarding intensity

and duration in order to measure the effectiveness of educational technology in agricultural education.

In the current scoping review, 47 articles (56.63%) recorded positive learning outcomes from the use of educational technology [102,104]. Another 19 articles (22.89%) recorded a non-significant result. For instance, Batte et al. [47] found no significant difference in student performance or acceptance of the distance course compared with a conventional course in agricultural economics. Fourteen articles (16.87%) had mixed results in their learning outcomes. For instance, Schoeffling and Rice [105] found that during the COVID-19 pandemic, online/distance education was effective in preparing Arizona preservice agricultural teachers for classroom teaching experience. However, negative outcomes were reported with experimentation and problem solving in teaching and with relationship building with students and professionals. Also, only three articles (3.61%) recorded negative learning outcomes from their studies [91].

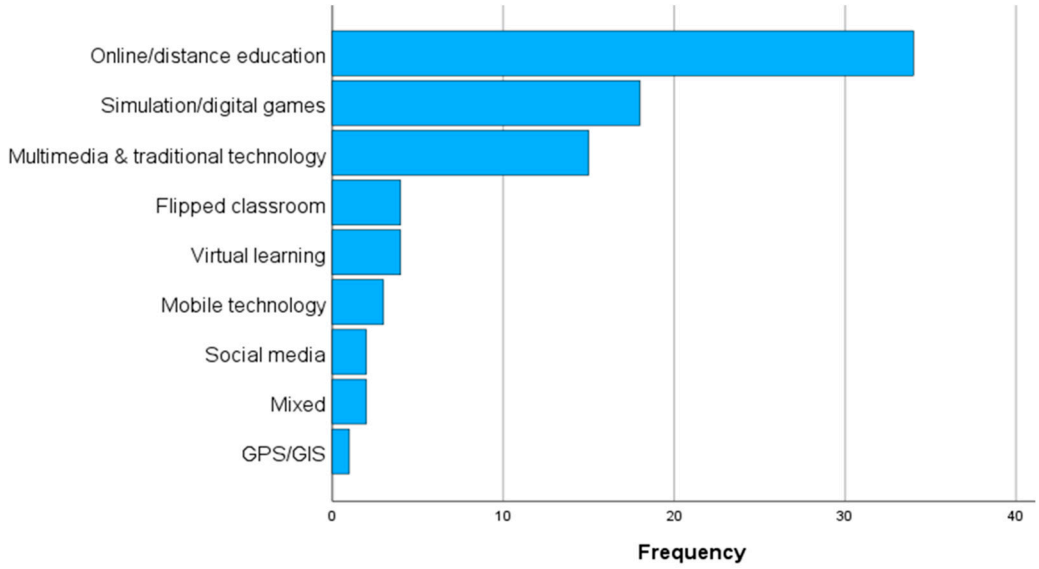


Figure 7. Distribution of Articles by Educational Technology Used.

A cross-tabulation analysis and a Chi-square test were performed to assess the relationship between the year of publication of the identified articles and the educational technology type (Table 3). There was a significant relationship between the two variables, $X^2(8, n = 83) = 21.59$, $p = 0.006$, indicating that educational technology types are statistically different between years of publication. Though online/distance education has been dominant through the years, the proportion of this type of educational technology has become less prominent as educational technology types diversify (from 22 in 2000–2010 to 12 in 2011–2022).

From the results of the cross-tabulation analysis, we witnessed an increase in simulation/digital games between the years (from four in 2000–2010 to 14 in 2011–2022) and also more diversified educational technology types in the years between 2011 and 2022, including mobile technology, social media, flipped classrooms, and virtual learning. For instance, Basche et al. [106] studied the farm simulation platform's effects on students' crop management and natural resource learning and found an increase in students' knowledge and confidence in the use of agricultural software and data-driven-decision-making capacity in crop management. Animal science [107,108] and agricultural engineering [109] are the academic/disciplinary areas in which simulations and digital games have increased over the last ten years. Our findings are congruent with those of Leggette et al. [66], who suggested that simulation technologies could improve teaching and research in agricultural subjects without leaving the classroom. At the time, they reported limited information on simulation uses in agricultural education, highlighting the need to conduct more research in

some of the academic/disciplinary areas such as welding/agricultural engineering, travel abroad programs, digital storytelling, and so on that this scoping review has identified in recent publications.

Table 3. Cross Tabulation of Year of Publication and Educational Technology.

	Year of Publication		
Educational Technology	**2000–2010**	**2011–2022**	χ^2
Online/distance education	22	12	21.587 **
Simulation/digital games	4	14	
Multimedia & traditional technology	5	10	
Mobile technology	0	3	
Social media	0	2	
Flipped Classroom	0	4	
GPS/GIS	1	0	
Virtual learning	0	4	
Mixed	1	1	

Note: χ^2 (8, n = 83) = 21.587, ** p = 0.006.

While simulation and digital game articles published between 2000 and 2010 focused on different agricultural subjects, including human nutrition [79], bovine reproduction [110], and crop physiology [111,112], all evaluated the impact of these educational technologies by assessing changes in the level of knowledge of students. This is a positive change within the field of agricultural education, as Vickery et al. [69] indicated in their analysis that only 57% of the studies included in their analysis investigated the impact of educational technology on students' learning.

A cross-tabulation analysis and a Chi-square test were performed to assess the relationship between the subjects and educational technology type (Table 4). The results indicated that there was no significant relationship between the two variables. χ^2 (32, n = 83) = 32.74, p = 0.431. Though we did not find statistical significance between these two variables, we witnessed some differences between the types of educational technology and subjects.

Table 4. Cross Tabulation of Subjects and Educational Technology Type.

	Type of Educational Technology									
Subjects	**Online/distance education**	**Simulation/Digital Games**	**Multimedia & Traditional Technology**	**Mobile Technology**	**Social Media**	**Flipped Classroom**	**GPS/GIS**	**Virtual Learning**	**Mixed**	χ^2
Agricultural Science	19	9	6	1	1	1	1	1	0	32.74
ALEC	7	2	5	1	0	2	0	3	1	
Agricultural Economics and Finance	6	1	2	0	1	0	0	0	1	
Agricultural Engineering	1	6	1	1	0	1	0	0	0	
Mixed	1	0	1	0	0	0	0	0	0	

Note: χ^2 (32, n = 83) = 32.74, p = 0.431.

One trend in the application of educational technology in different subjects is that there are more applications of simulation/digital games in agricultural science and engineering subjects (n = 15) than in the agricultural social sciences fields (n = 3). Among the agricultural science articles, five focused on animal sciences [110,113] and four on plant and soil sciences (e.g., [106,114]). All agricultural engineering articles were implemented in agricultural mechanics focused on welding systems (e.g., [109]). The simulation studies/digital games on welding systems highlighted the recent emergence of this educational technology. These results are consistent with the findings of Pulley [115], who reported an increase in the use of simulation technologies in agricultural mechanics courses due to cost reductions since

their inception in 1960. Lastly, applications of simulation/digital games in social sciences were identified in agricultural economics [61], crisis communication [116], and nutrition and physical activity [79].

6. Conclusions

Agricultural education prepares professionals who help ensure the supply of food, energy, and fiber worldwide. Historically, educational technologies have been integrated into agricultural education programs and are vital for student development at all academic levels [117]. This paper presents the results of a scoping review on the impact of educational technologies on agricultural education between 2000 and 2022. The 83 journal articles and conference papers spanned multiple geographic areas, academic/disciplinary areas, and educational levels. Although most of the research on educational technologies in agricultural education has been conducted in the United States, the results showed, although in considerably less quantity, existing studies in other regions of the world.

The results of this scoping review demonstrated variability when looking at transparency and rigor in investigator-reported methods. For the most part, the investigators reported the type of design, data, and instruments used in the studies. Self-developed instruments predominated over standardized ones, possibly due to the need for researchers to adapt to the conditions of their educational environments and cost considerations [118]. Methodological aspects in which the rigor and transparency of reporting were lower among the studies analyzed included the intensity and duration of the interventions, potentially limiting the interpretation and future uses of the results of the studies on the efficiency of educational technologies in agricultural education [76].

Some trends in the results of this scoping review correspond to recent changes or events that have modified agricultural education systems. For example, both the predominance of online/distance education over other educational technologies and the increase in research on educational technologies in recent years could be explained by the growing interest in diversifying academic offerings through virtual platforms and by the dependence of educational systems on online/distance education generated by the COVID-19 pandemic [8,119,120].

7. Future Directions

This study aims to support educators, researchers, and the agricultural education sector in identifying research priorities and more effectively implementing educational technologies in agricultural education programs. To achieve this, we recommend promoting educational technology research in regions with limited data, primarily low- and middle-income countries where educational technologies have historically been less effectively implemented [121]. Future education research, particularly educational technologies in agricultural education, should acknowledge the developing world's limitations, including overpopulated educational systems [122], limited technological infrastructure [123], and a lack of financial resources to innovate educational systems [123]. The latest opens several venues for future researchers to not only implement new educational technologies in agricultural education and evaluate the impacts on student learning but also conduct feasibility studies and needs assessments to identify adequate technologies and disseminate insights for educational innovation and improvement intended for practitioners, policymakers, and governments.

While governmental and public interest remain for agricultural education at any academic level [124], research must acknowledge instructional, student learning, and development priorities pursued at each academic level [117]. Therefore, we also recommend investigating the effectiveness of differentiated educational technologies across educational levels. In primary and secondary education, agricultural education is usually intended to enhance the learning of biology, chemistry, and other knowledge domains such as environmental awareness, food security, and nutrition [124]. At the college level, researchers should propose innovative approaches to integrating educational technologies to increase

students' knowledge and soft and hard skills [125]. Additionally, since the results demonstrated more research on the impacts of educational technologies in agricultural sciences and engineering subjects than in agricultural social sciences subjects, future research should emphasize evaluating educational technologies in the latter subjects. Researchers should integrate educational technologies when teaching about extension education, agricultural communication, and community development, to mention some of the social disciplines firmly rooted in agriculture. When including educational technologies in teaching about the social dimensions of agricultural research, researchers and educators can explore other disciplines' successful experiences using educational technologies, such as finances [126], personnel management [127], and emergency management [128].

In addition, future research should contribute to the need identified in this scoping review and supported by Xu et al. [76] for developing and testing standardized instruments that facilitate the evaluation of educational technologies' impacts on students' academic development. Even though agricultural instruction is a well-established and historical discipline that integrates pedagogical and andragogical theoretical lenses to serve as the foundations of new research discoveries [124], it deals with teaching and instructing a growing, ever-changing field facing diverse, interconnected challenges. For that reason, teachers and researchers should follow agricultural and educational innovation tendencies to effectively integrate them into their instruction and curriculum.

Finally, recent changes in agricultural educational systems call for more research on the demographics of instructors and student populations who prefer one educational technology over another [129]. Those demographic and descriptive studies should inform new research efforts to incorporate educational technologies in the conventional academic setting, but even more so in the growing online education market. For students in online agricultural education, research should emphasize the effective integration of farm technologies under a self-paced and directed learning style. Lastly, most of the literature consulted and studies included in this review focused on student learning; our results highlighted the need to investigate and address teachers' and instructors' needs for training and support. A recent study with high school agricultural teachers raised some of their relevant concerns when implementing an educational technology, including time investment, resources, and a self-perceived lack of training and institutional capacity [115].

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Appendix A. CAB Abstracts (OVID) Search Strategy

1.	educational technology/
2.	digital technology/
3.	information technology/
4.	exp computer software/
5.	internet/
6.	exp multimedia instruction/
7.	audiovisual aids/
8.	computers/
9.	exp videos/
10.	exp distance teaching/
11.	social media/
12.	((education* or instruct*) adj1 technolog*).ab,ti.
13.	((webbased or "web based" or online) adj2 (instruct* or educat*)).ab,ti.
14.	"mobile app*".ab,ti.
15.	(computer adj2 (educat* or instruct*)).ab,ti.
16.	"Intelligent Tutor*".ab,ti.
17.	"etutor*".ab,ti.
18.	((intelligent or computer* or computer assisted or artificial or webbased or web-based or online) adj1 tutor*).ab,ti.
19.	"video*".ab,ti.
20.	internet.ab,ti.
21.	computer.ab,ti.
22.	tablet.ab,ti.
23.	ipad.ab,ti.
24.	"elearn*".ab,ti.
25.	"electronic tech*".ab,ti.
26.	"distance learn*".ab,ti.
27.	"distance teach*".ab,ti.
28.	"distance educat*".ab,ti.
29.	"wiki*".ab,ti.
30.	virtual reality.ab,ti.
31.	(VR adj2 tech*).ab,ti.
32.	"mobile tech*".ab,ti.
33.	flipped classroom.ab,ti.
34.	"tech* use".ab,ti.
35.	"tech* usage".ab,ti.
36.	"digital game*".ab,ti.
37.	"game based learn*".ab,ti.
38.	"blog*".ab,ti.
39.	social media.ab,ti.
40.	twitter.ab,ti.
41.	facebook.ab,ti.
42.	instagram.ab,ti.
43.	snapchat.ab,ti.
44.	tiktok.ab,ti.
45.	whatsapp.ab,ti.
46.	"smartphone*".ab,ti.
47.	iphone.ab,ti.
48.	"mobile learn*".ab,ti.
49.	technology.ab,ti.
50.	ed-tech.ab,ti.
51.	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50
52.	exp agricultural education/
53.	exp youth programmes/
54.	(agricultur* adj1 educat*).ab,ti.
55.	(agricultur* adj1 experience*).ab,ti.
56.	(agricultur* adj1 (class* or lab* or course*)).ab,ti.
57.	"school based agricultur* educat*".ab,ti.
58.	"school-based agricultur* educat*".ab,ti.
59.	teacher training/
60.	preservice.ab,ti.
61.	inservice.ab,ti.
62.	(agricultur* adj3 teacher*).ab,ti.
63.	(agricultur* adj3 instructor*).ab,ti.
64.	(agricultur* adj3 educator*).ab,ti.
65.	"future farmers of america".ab,ti.
66.	state ffa.ab,ti.
67.	national ffa.ab,ti.
68.	"ffa organ*".ab,ti.
69.	52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68
70.	51 and 69
71.	51 and 69
72.	limit 71 to yr="2000 -Current"

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