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Utilization of Agricultural Technology as Contextual Media in Science Learning on Sustainability and Agricultural Economics

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Abstract: The agricultural sector faces challenges related to efficiency and sustainability, which can be explored in science learning to improve students' understanding of sustainability and economic concepts. Digitalization and modern agricultural technology offer a relevant context for science learning. This study examines the development of technology and digitalization in the agricultural sector, analyzes its potential as a contextual medium in science learning, and identifies challenges and opportunities for its implementation in education. The research method used is a systematic literature review by collecting data from various academic sources. The results of the study indicate that technologies such as the Internet of Things (IoT), automatic irrigation systems, and mobile-based applications can be used to teach science concepts such as ecosystems, energy, and environmental change in the context of agriculture. However, pedagogical strategies are needed to integrate these technologies effectively into the science curriculum. This study concludes that agricultural technology has great potential as a contextual medium in science learning, which is relevant to sustainability and agricultural economics, but requires further development in its educational approach.

Keywords: Agricultural Context; Agricultural Economics; Agricultural Technology; Learning Media; Science Learning; Sustainability.

Introduction

The agricultural sector is the backbone of the economy in many countries, but it faces various challenges that affect efficiency and sustainability. These challenges can be a relevant context for science learning, helping students understand the practical application of scientific concepts in real life. Agriculture not only provides food for daily needs, but also provides raw materials for industry, creates jobs, and makes a major contribution to the global and local economy (Elizabeth et al., 2024). Digitalization has become a global trend that has brought significant changes to various aspects of agriculture, including economic management systems.

Technologies such as modern agriculture are defined as the development of the agricultural sector based on innovation and in line with the Industrial Revolution 4.0. Modern agriculture that is developed has characteristics such as: producing products according to market demand, high economic value, has optimal productivity, and is environmentally friendly and sustainable (Sondakh et al., 2020). These concepts are relevant to science learning that emphasizes sustainability and understanding complex systems. Data analytics are essential in managing agricultural management data and are also used by the Ministry of Agriculture.

According to Tosida et al. (2017), there are 4 types of data analysis, namely descriptive analytics, diagnostic analysis, predictive analysis, and prescriptive analytics. Understanding of data analysis can be developed through agricultural case studies in science learning, which train critical thinking and problem-solving skills. In addition, the digital marketplace has an influence on developments in the agricultural industry where transactions can be made online without face-to-face. Hermansyah et al. (2020) argue that farmers, suppliers, and buyers will be directly connected, so that the trade chain becomes shorter. This allows farmers to get better

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selling prices, while buyers can enjoy more affordable purchase prices. This economic concept can be integrated into science learning through projects that connect science, technology, and society. However, the application of this technology still encounters various obstacles, especially in developing countries that have limited infrastructure and human resources that are not ready to accept digital change. This challenge emphasizes the need for digital and scientific literacy among farmers, which can be a focus in science education.

Method

This study uses a literature study method or systematic literature review (SLR) (Tranfield et al., 2002) by collecting data from various academic sources, such as scientific journals, articles, and science education publications that are relevant to the topic of technology and digitalization in agricultural economics and science learning. Data collection was carried out with the help of the Publish or Perish application, which produced around 1000 potential articles and books as reference sources. However, not all of these articles were used as supporting sources for the study. Only articles that conducted primary data-based research and studies on science learning that were relevant to the agricultural context were selected to be used as sources in the results and discussion of this study.

Results and Discussion

Research conducted by Setiawan et al. (2024) examined farmers' perceptions of agricultural technology, including cognitive, affective, and conative aspects, as well as the role of mentors in influencing technology acceptance. These findings are relevant to science learning in the context of non-formal education, where mentoring and education play an important role in improving science and technology literacy among farmers. Farmers' understanding of technology is greatly influenced by the education provided by mentors. In addition, farmers' feelings and emotions towards technology, including motivation and reduction of anxiety, are also influenced by the role of mentors. Finally, farmers' intentions and readiness to adopt technology are influenced by the evaluation and guidance provided by mentors. Thus, mentors play a key role in shaping farmers' perceptions and acceptance of agricultural technology. This emphasizes the importance of an effective pedagogical approach in transferring technological knowledge to farmers, which can be adapted in the context of formal and non-formal science learning.

Technological Developments in the Agricultural Sector

The application of modern technology in agriculture can improve efficiency, productivity, and sustainability. This provides a rich context for teaching science concepts that are relevant to global challenges. By utilizing technology, innovative solutions can be created that drive the progress of the agricultural sector. This innovation can be a case study in science learning to develop students' problem-solving and creative thinking skills.

Basmalah et al., (2023) identified supporting and inhibiting factors in the development of the agricultural sector, which can be analyzed in science learning to understand the interaction between social, economic, and environmental factors. Supporting factors include: (1) Mutual cooperation in cultivation activities; (2) Availability of local production tools and materials; (3) The existence of infrastructure facilities; (4) The existence of the Agricultural Extension Center institution; (5) The existence of BUMDes institutions; (6) Diversity of agricultural products; (7) Capital lending facilities; (8) Extensive production marketing network; (9) The existence of research institutions from universities.

Inhibiting factors in technological development include: (1) Lack of water availability; (2) There are no special training institutions or educational facilities for farmers; (3) Non-intensive cultivation activities; (4) Technological developments that have not been optimally utilized; (5) The unavailability of skilled human resources with agribusiness insight.

Analysis of these factors can be integrated into science learning through projects that focus on sustainable development and community empowerment. Maulida et al., (2023) categorize internal and external factors that influence the development of agricultural technology, which are relevant to science learning about systems and interactions. Internal Factors are knowledge and skills and community awareness and participation. External Factors are infrastructure Provision, policies that support the development of agricultural technology, and support from the Agricultural Industry.

Science learning can use this framework to analyze agricultural case studies and develop students' understanding of the complexity of socio-economic-environmental systems. Sari et al., (2024) outlines IoT Applications in Agriculture, which offers a rich context for teaching science concepts of sensors, automation, and data: (1) Smart Irrigation; (2) Humidity and Temperature Controller; (3) Soil Fertility Detection; (4) Automatic Plant Watering; (5) Monitoring Soil Moisture and Rainfall; (6) Agricultural Land Security System. Sensor Tools Used Water flow, Temperature sensor,

Rain sensor, Water level, DHT22, Ultrasonic, soil pH, and Soil moisture.

Science learning can utilize IoT technology in agriculture as a case study to teach the principles of applied physics, chemistry, and biology. For example, students can design and build a simple automated irrigation system or analyze sensor data to optimize plant growth.

Research conducted by Kholili & Hidayatulloh, (2023) found that the Application of a mobile-based agricultural product sales information system can connect farmers, collectors and consumers efficiently. This is relevant to science learning about the food chain, ecosystems, and the impact of human activities on the environment. Conventional agriculture often faces major challenges in terms of inefficient water use. Traditional irrigation systems, such as flooding or manual watering, can cause water waste through uneven evaporation and absorption by the soil. In addition, climate change and water scarcity are worsening this situation, threatening agricultural productivity and global food security. Therefore, innovation is needed in agricultural methods that can optimize water use while supporting environmental sustainability. This sustainability concept can be integrated into science learning through projects that focus on resource conservation and environmentally friendly technologies.

According to Tangkesalu et al., (2023) water use in the agricultural sector can be overcome through the application of a hydroponic system. This system reduces water waste by flowing water directly to the roots of plants, thereby avoiding evaporation and absorption by the soil which can cause significant water losses. The efficiency of resource use strengthens the sustainability aspect in agriculture, especially in the face of global challenges such as climate change and water scarcity. Hydroponic systems can be an interesting case study in science learning to teach the principles of plant growth, nutrition, and controlled environments. The adoption of technology in the agricultural sector plays a key role in increasing productivity and efficiency, but farmer acceptance of new innovations does not happen automatically.

Farmers will accept new technology or ideas if they meet the following criteria: (a) provide economic benefits or increase profits (profitability), (b) are in accordance with local values and culture (cultural compatibility), (c) are compatible with physical environmental conditions (physical compatibility), (d) provide ease of application, (e) save time and energy, and (f) do not require many resources or large costs to implement. Thus, technological development in the agricultural sector is influenced by various factors that need to be considered to achieve optimization (Maulida et al., 2023). Analysis of these factors can help students understand the complexity of technology adoption and the importance of considering the social, cultural, and economic context in innovation.

The Influence of Digitalization on Agricultural Economic Management and Its Relation to Science Learning

Digitalization, especially through the application of IoT and internet-based technologies, has great potential to improve the efficiency, productivity, and sustainability of the agricultural sector. This can be a relevant context for science learning about systems, optimization, and the impact of technology on society. However, to maximize its benefits, efforts are needed to increase awareness and adoption of technology among farmers, as well as attract the interest of the younger generation to be involved in the agricultural sector (Niken Puspitasari et al., 2023).

The development of effective educational programs is essential to achieve this goal. Digitalization can be the key to improving farmer welfare and realizing food security in Indonesia. These concepts are relevant to science learning that focuses on sustainability, food security, and economic development. Another study conducted by Putri et al. (2023) showed that the use of the Millennial Farmer Application has great potential in increasing productivity, efficiency, and sustainability of the agricultural sector. Information technology, collaboration, and online marketing help farmers optimize the use of resources, harvest yields, and reach wider markets. In addition, digitalization also encourages farmer empowerment through education and training, and improves farmer welfare through increased income and operational efficiency.

Case studies on this application can be used in science learning to teach economic concepts, technology, and social impacts. Community Service of the Makmur Cultivation group in Wonopringgo Village shows that the application of automatic irrigation technology has a significant and beneficial impact. The real impact felt by farmers is the implementation of innovative activities that contribute to increasing knowledge and application of technology in agricultural practices. Farmers feel benefited by 60%, very benefited by 33%, and not benefited by 7% (Handriatni et al., 2023). This case study can be used in science learning to teach concepts of applied technology, resource efficiency, and the social impact of technology.

Agricultural case studies involving digital technologies can help students develop skills:

- Critical thinking: Analyze data and information related to agricultural technology to make informed judgments.

- Solution to problem:Identifying challenges in agriculture and designing technology-based solutions.
- Science and technology literacy:Understand the scientific and technological concepts underlying modern agricultural practices.
- 21st century skills:Collaboration, communication, creativity and innovation in the context of agriculture.

However, the implementation of digital technology in agriculture still faces various challenges, especially in developing countries. Some of the main challenges include the lack of supporting infrastructure, limited skilled human resources (both farmers and educators), low adoption of technology among farmers, and cultural and social barriers. These challenges are also relevant in the context of science education, where science education needs to prepare young people to:

- Understanding and addressing global challenges:Such as climate change, food security, and environmental sustainability.
- Developing digital and science literacy:To be able to use and evaluate scientific and technological information effectively.
- Contributing to sustainable development:Through innovation and responsible adoption of technology.

In addition, support from the government and other related parties is still needed to ensure that technology can be accessed and utilized optimally by farmers. In the context of education, this support includes:

- Curriculum development:Integrating agricultural technology into relevant and contextual science curriculum.
- Teacher training:Preparing teachers to use agricultural technology as an effective learning medium.
- Resource provision:Provide access to technology, software, and learning materials that support implementation.
- Partnership:Building partnerships between schools, universities, agricultural industries and communities to create authentic learning opportunities.

Based on the research findings, here are some suggestions that can be considered to improve the implementation of technology and digitalization in the agricultural sector, as well as its implications for science learning:

- Infrastructure Improvement:The government and related parties need to improve supporting infrastructure, such as internet networks, electricity, and modern irrigation facilities, especially in rural and remote areas. In the context of education, access to adequate infrastructure is important to enable schools and students to access agricultural technology and integrate it into learning.
- Training and Education:Intensive training and education programs are needed to improve farmers' skills and awareness of the benefits of agricultural technology. In the context of education, teacher training is essential to prepare them to use agricultural technology as an effective learning medium. Educational programs also need to be designed to improve students' scientific and technological literacy, preparing them to participate in modern agriculture.
- Financial Support:Governments and financial institutions need to provide access to affordable capital and financing for farmers to adopt modern technologies. In the context of education, investment in educational technology and curriculum development is essential to ensure that schools and students have access to adequate resources.
- Collaboration Between Stakeholders: Collaboration between government, private sector, academics, and farming communities needs to be enhanced to create an ecosystem that supports innovation and technology adoption. In the context of education, collaboration between schools, universities, agricultural industries, and communities is essential to create relevant and meaningful learning opportunities for students. This can involve collaborative projects, field trips, and mentoring.
- User Friendly Technology Development:The technology developed must be easy to use and appropriate to local conditions, both in terms of culture and physical environment. In the context of education, educational technology needs to be designed to meet the needs of students and teachers, taking into account factors such as learning styles, ability levels, and cultural context. This also includes the development of interactive and engaging learning software and applications.
- Promotion and Socialization:Socialization and promotion of the benefits of agricultural technology need to be increased to attract the interest of the younger generation and increase community participation in the agricultural sector. In the context of education, promotion of the importance of science and technology education in agriculture is important to encourage students to pursue careers in agriculture and related fields. This can be done through extracurricular programs, science projects, and information campaigns.

By addressing these challenges and integrating agricultural technology into science learning, it is hoped that digitalization and technology can be the key to improving farmer welfare, increasing food security, increasing the sustainability of the agricultural sector in the future, preparing the younger generation to contribute to an innovative and sustainable agricultural

future, increasing students' science and technology literacy, and developing 21st century skills that are relevant to the agricultural context.

Challenges and Opportunities for Implementing Digital Technology in Science Learning in the Agricultural Context

Despite having many benefits, digitalization in agriculture still faces obstacles such as: Noviar et al., (2023) stated that the obstacles to digitalization in agriculture are: (1) Agricultural management which is still traditional; (2) Capital support from third parties in this case banking; (3) Technology support, and (4) Training support. Meanwhile, according toManurung et al., (2024), the obstacles to digitalization in agriculture are a positive social environment in providing motivation and vice versa and the use of ICT.

Integrating these challenges into science learning can create relevant, contextual, and meaningful learning experiences for students. Science learning can help students understand the complexities of modern agriculture and prepare them to contribute to a sustainable and innovative agricultural future.

Conclusion

Based on the results of the literature study conducted, it can be concluded that technology and digitalization have an important role in increasing efficiency, productivity, and sustainability of the agricultural sector. The application of technologies such as IoT, automatic irrigation systems, and mobile-based applications have helped farmers optimize resource use, increase yields, and expand market access. Digitalization also encourages farmer empowerment through education and training, and improves farmer welfare through increased income and operational efficiency.

In the context of science education, agricultural technology and digitalization offer rich opportunities to create relevant and contextual learning experiences. Agricultural technology can be used as a medium to teach science concepts related to:

- Systems and interactions:How components in the agricultural ecosystem interact with each other and are influenced by technology.
- Energy and matter:How energy and matter flow in agricultural systems, and how technology can improve the efficiency of their use.
- Environmental changes:How agricultural technology can affect soil, water and air quality, and its impact on sustainability.
- Sustainability:How agricultural technology can support sustainable agricultural practices and maintain ecosystem balance.

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