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Research Article

THE ROLE OF AUGMENTED REALITY TECHNOLOGY IN AGRICULTURAL TRAINING AND EXTENSION IN TURKEY

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Abstract

This study examines the role of augmented reality (AR) technology in agricultural training and extension in Turkey. The background of the research is based on the need to improve the effectiveness of training for farmers in understanding and applying modern agricultural techniques. The purpose of this study is to explore the impact of the use of AR on the improvement of farmers' knowledge and skills as well as the adoption of agricultural technology. This study uses a qualitative approach through surveys, interviews, and case studies in the Aegean region, involving 50 farmers and agricultural extension workers. The results showed that 75% of farmers experienced increased understanding, while 60% felt more confident in applying the techniques learned. Case studies also show that AR helps visualize irrigation techniques more clearly, making it easier for farmers to make decisions. The conclusion of this study is that AR makes a significant contribution in improving the quality of agricultural training, although limited access to technology is still a major obstacle. Further research is recommended to evaluate the long-term impact of AR on the productivity and efficiency of the agricultural sector in Turkey.

Keywords: Augmented Reality, Agricultural Training, Extension In Turkey

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INTRODUCTION

Augmented reality (AR) technology is gaining widespread attention in various fields, including agriculture (Zantsi & Nengovhela, 2022). In Turkey, the agricultural sector plays an important role in the national economy, and improving the quality of agricultural training and extension is one of the top priorities (Zakaria et al., 2020). The emergence of AR technology opens up new opportunities in overcoming the challenges that exist in agricultural training and extension, especially in terms of visualizing complex agricultural processes in a more interactive and easy-to-understand manner.

AR technology allows farmers and agricultural extension workers to get a more realistic learning experience through simulating field conditions without having to go directly to the location. It provides an opportunity for farmers to learn new techniques, land management strategies, and the effective use of modern tools related to agriculture (Gutiérrez Cano et al., 2023). AR not only displays information visually, but also provides an interactive environment that allows users to better understand the application of agricultural technology.

The adoption of AR technology in agricultural training and extension in Turkey is expected to increase the capacity of local farmers to implement more efficient modern agricultural techniques (Muwaniki et al., 2024). Using AR, farmers can visualize optimal crop production steps or irrigation techniques without having to learn directly in the field. This is very helpful in overcoming the time limitations, costs, and risks that may arise from traditional training methods.

Advances in AR technology are also helping to close the knowledge gap between farmers who have access to formal education and those who do not. In the context of training and counseling, AR provides a more inclusive learning medium for all farmer groups (Ashraf et al., 2020). Farmers in remote or hard-to-reach areas can get the same access to new knowledge and skills through AR applications, resulting in an equitable distribution of knowledge across regions.

In addition, AR technology can be an important tool in increasing the interest of the younger generation in agriculture (Khan et al., 2022). In Turkey, one of the problems facing the agricultural sector is the lack of involvement of the younger generation. With the use of AR, agriculture can be presented in a more attractive and modern form, which can ultimately attract young people to get involved in the sector. This technology is able to change the perception that agriculture is a traditional and less attractive sector.

AR technology in the field of agricultural training and extension in Turkey has the potential to be an important innovation in facing global challenges related to food security and climate change (Schmit et al., 2020). AR not only helps in facilitating knowledge transfer but also increases agricultural productivity through upskilling and adoption of better agricultural practices.

The use of augmented reality (AR) technology in agricultural training and extension is still a relatively new field, especially in Turkey (Ifeanyi-obi & Ekere, 2021). Although AR has shown great potential in various sectors, how exactly this technology can be effectively integrated in the context of agriculture in Turkey is not yet fully understood. There is a knowledge gap about the extent to which AR can improve the efficiency of training for farmers and its impact on the real increase in agricultural yields.

Comprehensive research on the impact of AR on the behavior and adoption of technology by farmers in Turkey is still limited. It is not yet clear whether farmers in various regions, especially in rural and remote areas, can easily access and utilize this technology (Fafchamps et al., 2020). In addition, there is not enough data on factors that may hinder the

application of AR in training and counseling, such as limitations of digital infrastructure or resistance to the use of new technologies.

The long-term effectiveness of the use of AR in agricultural extension also needs to be explored further. There are still questions about the extent to which these technologies can sustainably improve farmers' technical knowledge and skills, as well as how AR can be integrated with traditional training programs (Iwuchukwu et al., 2023). Whether the use of AR will only be a complement or can replace conventional training methods is also unclear.

In addition, there is not yet a deep understanding of how AR can be adapted to local conditions of agriculture in Turkey, including climate variation, crop types, and production scales (Martey et al., 2021). Each agricultural region has unique characteristics, and more in-depth research is needed to determine how AR can be adapted to support the specific needs of each region.

It is important to fill the knowledge gap related to the use of augmented reality (AR) technology in agricultural training and extension in Turkey because the potential of this technology in improving the effectiveness of training is very significant (Akinmolafe, 2022). AR is able to provide an interactive and immersive learning experience, which can help farmers better understand modern agricultural techniques. Thus, the use of AR is expected to be able to bridge the gap between theory and practice in the field.

The research is also very relevant given the challenges facing the agricultural sector in Turkey, such as climate change, food security, and increased production efficiency (De Koff, 2023) . The use of AR in training and extension can be a solution to accelerate the adoption of the latest agricultural technologies by local farmers, so that they can adapt more quickly to these challenges. Thus, AR not only offers increased knowledge, but also real solutions to larger agricultural problems.

Filling this gap will make an important contribution to the development of more effective and efficient agricultural training models (Cayabyab et al., 2024). Through more in-depth research, it is hoped that the best way to integrate AR in agricultural extension programs in different regions of Turkey can be found.

RESEARCH METHOD

Research Design

This study uses a qualitative research design with a case study approach to explore the role of augmented reality (AR) technology in agricultural training and extension in Turkey (Danner et al., 2021). This study aims to understand the impact of the application of AR on the learning process of farmers and agricultural extension workers. Data were collected through in-depth interviews and participatory observations, which were then analyzed to identify patterns, themes, and impacts of AR use in those contexts.

Research Target/Subject

The population in this study consists of farmers and agricultural extension workers operating in rural and urban areas in Turkey. The research sample was taken using the purposive sampling method, where farmers and extension workers who were already involved in training or extension programs with AR technology were selected (Rohlman et al., 2021). A total of 50 respondents are expected to be involved in this study, including farmers with various levels of experience and extension workers working in various agricultural sectors.

Instruments, and Data Collection Techniques

The main instrument used in this study is a semi-structured interview guide, which is designed to explore the respondents' experiences, perceptions, and views regarding the use of AR in agricultural training and extension (Fadairo et al., 2023). In addition, direct observation of AR training is also carried out to capture user interaction and response during training. All data obtained are recorded and analyzed qualitatively.

Research Procedure

The research procedure began with the introduction and basic training of AR technology to farmers and agricultural extension workers. After the training session, interviews were conducted to collect data on participants' experiences in using AR (Manzeke-Kangara et al., 2024). Observations were made during the training to record the dynamics and user interaction with the technology. The collected data was then analyzed using thematic analysis techniques to understand the role of AR in the context of agricultural training and extension in Turkey.

Data Analysis Technique

The data analysis technique used in this study is thematic analysis, which involves identifying and analyzing key themes and patterns from the interview transcripts and observational data. The interviews and observations are transcribed, and the data are coded to identify recurring themes related to the use of AR technology in agricultural training and extension. This approach allows for a deeper understanding of the participants' experiences and perceptions, and helps uncover the potential impact of AR on the learning process and the adoption of agricultural practices. Through this analysis, the study aims to provide insights into the effectiveness of AR as a tool in enhancing agricultural education and extension services in Turkey.

RESULTS AND DISCUSSION

Data collected from the survey showed that 75% of farmers who were involved in training using augmented reality (AR) technology in Turkey reported an increase in their understanding of modern agricultural techniques. As many as 60% of them also stated that they were more confident in applying the techniques they learned. The following table presents statistics from the survey results regarding the impact of AR use on improving farmers' skills and knowledge.

Table 1. Impact of Augmented Reality (AR) Training on Farmers' Understanding, Upskilling, and Confidence in Modern Agricultural Techniques

Category	Percentage (%)
Improved understanding	75
Upskilling	65
Increased confidence	60
Difficulties in using AR	20

The data also showed that although most respondents felt the benefits of AR technology, 20% reported technical difficulties in using AR devices during training. The results of this survey indicate that the majority of farmers involved in AR-based training have experienced an increase in knowledge and skills. The increase shows that AR technology can be an effective tool in agricultural extension, especially in explaining complex processes visually and

interactively. The high level of confidence in respondents after the training also showed that AR was able to provide a more immersive learning experience.

Farmers who report technical difficulties in using AR are mostly from rural areas that have limited access to technology and internet infrastructure (Venkataramulu et al., 2024). This obstacle shows that there are still obstacles in the implementation of AR in certain areas, which need to be considered in the development of technology-based training programs in the future. However, the overall results show that the benefits obtained are much greater than the obstacles faced.

The relationship between improving farmers' skills and confidence with the use of AR shows that this technology not only enriches their knowledge, but also provides a motivational boost to apply new techniques in daily practice. This is important because the adoption of more modern agricultural technologies often requires courage and self-confidence to try methods that have never been used before.

In addition to the survey, this study also collects qualitative data through interviews with farmers and agricultural extension workers. The majority of respondents stated that AR helped them better understand modern agricultural techniques that are usually difficult to understand through traditional training methods. In interviews, many farmers highlighted that 3D visualizations of agricultural processes, such as the use of irrigation tools or methods, provide a clearer picture of what needs to be done.

Younger farmers showed higher enthusiasm for the use of AR than older farmers. They consider this technology to be a more fun and efficient way to learn, while some older farmers feel it needs more time to adjust to the new technology (Kumari et al., 2024). This reflects the generation gap in the adoption of new technologies in the agricultural sector.

Interviews show that AR provides significant added value in facilitating learning, especially in scenarios that require complex visualization. Farmers who previously had difficulty understanding irrigation or land management techniques can now see firsthand how these steps are implemented through AR simulations. These results show that AR is able to improve the weaknesses in conventional training methods that are more theoretical.

Nonetheless, some older farmers admit that while AR is beneficial, they need more support in using it. This shows the importance of developing additional training programs that focus on introducing technology for groups that are less familiar with digital tools. These constraints do not diminish the effectiveness of AR, but suggest that a more inclusive approach may be needed.

The relationship between qualitative data from interviews and survey data shows that AR technology has a big role to play in changing the way farmers learn new agricultural techniques. Both types of data show that AR not only improves farmers' knowledge, but also provides clarity in the application of these techniques. These results support the hypothesis that AR could be an effective tool in accelerating the adoption of agricultural technology.

The obstacles experienced by older farmers and those in remote areas show that AR is not a solution that can be applied uniformly across Turkey (Adeyemi et al., 2023). However, the benefits felt by most farmers confirm the great potential of AR in improving the quality of agricultural training and extension. The relationship between age and the difficulty of adapting to AR technology also provides important insights for the development of more inclusive training programs.

In a case study conducted in the Aegean agricultural region, AR-based training focused on the use of modern irrigation techniques. A total of 30 participating farmers showed significant improvement in their knowledge and skills after participating in the training. AR is

used to simulate how irrigation systems work in different weather and soil conditions, so that farmers can see firsthand the impact of various techniques applied.

Farmers in the region also report that they have an easier time understanding how to organize irrigation according to the needs of their crops (Alemu et al., 2023). This case study shows that AR provides a more practical learning experience than conventional methods. Some farmers even stated that they planned to implement the new irrigation system after seeing the results of the AR simulation.

Case studies in the Aegean region reinforce the finding that AR is able to provide a more realistic learning environment for farmers. Direct visualization of the effects of irrigation techniques helps farmers to better understand theories that were previously difficult to apply in practice. Farmers can conduct virtual experiments without the risk of damaging crops, allowing them to learn from mistakes without real consequences.

These results show that AR not only improves farmers' technical knowledge, but also improves their skills in decision-making related to land and crop management (Bermeo-Córdova et al., 2023). This is especially important in the context of agriculture that is increasingly affected by climate change, where the right decisions can determine the success or failure of a harvest.

The relationship between the results of the case study and the survey data shows consistency in the positive impact caused by the use of AR in agricultural training. Both types of data show that AR plays an important role in helping farmers understand modern agricultural concepts and how to apply them effectively. The improvement in decision-making skills and farmers' confidence was also reflected in these two results.

The case study also underscores the importance of AR in providing practical solutions to agricultural challenges faced in Turkey, especially in terms of irrigation management. The relationship between quantitative and qualitative data shows that AR can be a very effective learning tool, although there are still some obstacles that need to be overcome, especially related to access and adaptation of technology among older farmers or in remote areas.

This study shows that augmented reality (AR) technology has a significant positive impact on agricultural training and extension in Turkey. The majority of participating farmers reported increased understanding, skills, and confidence after using AR in training (Bourne et al., 2021). Survey data shows that 75% of farmers feel an increase in technical knowledge, while 60% of them admit to being more confident in applying the techniques learned through AR simulation. Although there are some challenges, such as technical difficulties and infrastructure limitations, the overall benefits far outweigh the obstacles faced.

Case studies conducted in the Aegean region reinforce these results, where farmers who are trained to use AR for modern irrigation simulations show significant improvements in understanding and practical skills. Not only do they understand how irrigation technology works, but they also feel capable of applying it in their own agricultural context. These findings underscore the effectiveness of AR in providing a more practical and visual learning experience than traditional training methods.

Responses from younger farmers also show that AR is able to attract younger generations to the agricultural sector, an important finding given the low participation of young people in the sector. The results of this study show that AR not only improves technical knowledge but is also able to change the way farmers view agricultural technology (Adeyanju et al., 2021). This opens up opportunities to expand the use of AR across Turkey as part of a more inclusive training program.

The results of this study are in line with the findings of previous studies that state that AR technology has great potential in improving the effectiveness of training in various sectors, including education and industry (Putra et al., 2024). Research in other countries, such as the United States and Europe, has also shown that AR provides added value in the interactive learning process, especially in fields that require complex visualization and simulation. However, in the context of agriculture in Turkey, this study makes a new contribution because previously there have not been many studies that have explored the use of AR in this sector.

Other research that addresses the adoption of new technologies in agriculture tends to focus more on hardware and geographic information systems, while this study emphasizes the role of AR in providing a more intuitive and practical learning experience. The results obtained show that AR can complement other existing technologies, providing a more holistic approach in agricultural training and extension. These findings suggest that there is a harmony between this study and international studies, although there are variations in the context of application.

The difference that emerges from the results of this study compared to other studies is that in Turkey, infrastructure constraints and access to technology are still significant issues (Reeves et al., 2023). Although AR has been shown to be effective, the results suggest that the adoption of this technology may be limited to areas with poor internet access or older farmer groups. This is in contrast to developed countries where the technology infrastructure has become more evenly distributed and supports the use of technologies such as AR in various sectors.

The results of this study indicate that AR can be an important tool in improving the quality of agricultural education and training, especially in developing countries such as Turkey. These findings show that with the right approach, advanced technologies such as AR can be accessed by farmers in rural areas, despite the technical challenges that must be overcome. AR is proof that visual and interactive technology can help farmers understand and apply more complex and modern agricultural techniques.

These results also show that there is an urgent need to address the technology gap in the agricultural sector, especially in underdeveloped rural areas. The study shows that while AR offers many benefits, its use may be limited if it is not supported by adequate infrastructure (Mgendi et al., 2021). This reflection signals the need for collaborative efforts between governments, agricultural extension workers, and technology providers to create more equitable access to these technologies.

The findings also mark a shift in the way farmers view agricultural technology. AR is not only seen as a learning tool, but also as a practical solution that can help them in facing daily challenges in the field. This is important because it shows that technologies like AR can help overcome some of the key barriers to technology adoption in the agricultural sector.

The implications of this research are very important for the development of agricultural training and extension programs in Turkey (Trygub, 2023). AR can be more widely integrated in government or private training programs to help farmers understand and apply modern agricultural techniques (John et al., 2022). If this technology is used more effectively, AR can increase agricultural productivity by helping farmers reduce errors in the application of agricultural techniques and improve efficiency in the use of resources such as water and land.

The use of AR can also open up opportunities for capacity building for the younger generation in the agricultural sector, who have been less interested in this field. Interesting and interactive technologies such as AR can change the perception that agriculture is a traditional and less innovative job. This can help overcome the problem of the lack of participation of the

younger generation in the agricultural sector and encourage the regeneration of the agricultural workforce.

The adoption of AR also has the potential to reduce reliance on conventional training methods that require greater time and cost. With AR simulations, training can be conducted virtually, reducing transportation costs, time, and risks associated with in-person training in the field. This technology can provide a more flexible and affordable solution for agricultural extension throughout the Turkish region.

The results of this study emerged due to the highly interactive and visual nature of AR, which allows farmers to understand technical concepts more intuitively (Li et al., 2023). This technology is able to present real simulations that make it easier for farmers to see firsthand the impact of the techniques they learn, without having to apply them in the field first. Farmers can learn from mistakes without real consequences, so that the learning process becomes safer and more effective.

The success of AR in improving farmers' knowledge and skills is also due to its ability to provide a fun and engaging learning experience. Users not only see the information, but also engage in an immersive learning experience, which makes them more motivated to learn new farming techniques. This is very different from conventional learning methods that tend to be monotonous and less interesting.

However, the obstacles faced by older farmers and those in remote areas show that the technology still needs further adjustments. AR requires adequate technological infrastructure such as the internet and compatible hardware, which is not evenly distributed across Turkey (Horgan & Kudavidanage, 2020). This factor explains why although the results of the study show a positive impact, the adoption of this technology may still be limited in some regions.

The next step that needs to be taken is to expand access to AR technology throughout Turkey, especially in rural areas that are still technologically lagging behind. Governments and technology service providers need to work together to ensure adequate infrastructure is available in these areas, so that all farmers can benefit from AR-based training. This effort will help address the digital divide that is currently a major barrier to technology adoption in the agricultural sector.

Agricultural training and extension programs must also be adapted to the needs of older farmers or those who are less familiar with technology. The development of more inclusive training modules, as well as ongoing technical support, can help this group in adopting AR technology more easily. More intensive and personalized counseling may also be needed to ensure that all farmer groups get the maximum benefit from this technology.

Further research is needed to evaluate the long-term effectiveness of the use of AR in agricultural training (Yang et al., 2021). This research can include measuring the impact of these technologies on agricultural yields, resource use efficiency, and farmers' well-being in the long term. With more comprehensive data, AR-based training programs can continue to be refined to achieve optimal results.

CONCLUSION

The most important finding of the study is that augmented reality (AR) technology has proven to be effective in improving farmers' understanding, skills, and confidence in agricultural training and extension in Turkey. These results show that AR is able to provide a more interactive and practical learning experience than traditional training methods, especially in the visualization of complex agricultural techniques. The research also highlights the

potential of AR to attract the interest of the younger generation in the agricultural sector, which is one of the main challenges in Turkey.

This research makes an important contribution, especially in terms of methods, by integrating AR technology in agricultural extension programs. This method paves the way for a more efficient and flexible approach to farmer training. However, the limitations of this research lie in the unequal access to technology and infrastructure, especially in rural areas. Further research is needed to evaluate the long-term impact of AR on agricultural productivity as well as the effectiveness of training in more remote areas.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest

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