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Effectiveness of sustainable palm oil education in improving knowledge of sustainable palm oil farming practices through game Sawit Palmi day series: A quasi-experiment on millennial and Zillennial generations in Jakarta

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Abstract: This study aims to analyze the influence of the knowledge levels of the Millennial and Zillennial generations in Jakarta regarding sustainable palm oil, as well as their interest in learning about the topic before and after participating in the mobile-based educational game, "Game Sawit." This study integrates Social Cognitive Theory and Gagne's Conditions of Learning Theory. The Game Sawit serves as a medium to promote positive behavioral changes related to sustainable palm oil. It employs an edutainment strategy, combining education with entertainment. The study used a quasi-experimental design involving two experimental groups and a control group. The sample consisted of 120 participants, including 60 Millennials and 60 Zillennials. Data analysis was conducted using independent samples t-tests and paired t-tests. The results indicate that the Game Sawit significantly increased participants' knowledge, especially in the experimental group that played the game, compared to the control group. This study has important implications for game-based educational campaigns aimed at improving knowledge and interest in sustainable palm oil among younger generations. The findings highlight the potential of digital edutainment in raising awareness of sustainable agricultural practices.

Keywords: *Digital media, Education, Game, Palm oil, Sustainable agriculture.*

1. Introduction

Palm oil is often considered an environmental threat because it is planted on peatlands and primary forests, contributing to climate change [1] . Negative narratives surrounding palm oil emerged on social media—particularly Facebook, YouTube, and Twitter—in 2015. Claims regarding palm oil's health hazards were widely circulated on Facebook and YouTube, while Twitter focused more on its negative impacts on the environment . In response to these negative narratives, campaigns promoting sustainable palm oil farming practices are needed to counter misinformation across various media, especially digital media. Palm oil is a strategic commodity for Indonesia, significantly contributing to the achievement of the Sustainable Development Goals (SDGs), particularly in reducing unemployment by creating job opportunities. However, the image of the palm oil industry continues to be undermined by persistent negative narratives, including environmental degradation of primary forests, loss of endangered species, greenhouse gas emissions, alleged health hazards, and adverse social impacts.

The Indonesian government has taken steps to educate both domestic and international audiences about sustainable palm oil as part of a political marketing campaign. One of its key initiatives involves disseminating updated information about palm oil via social media platforms. The campaign uses the

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hashtag #SawitBaik on Twitter, serving as an active governmental effort to educate the public, build online awareness, and foster diplomatic goodwill within the global community. Hashtags are powerful tools designed to influence others and serve as symbols for larger movements, encouraging individuals to become part of a much larger movement [2]. Twitter, as a social media platform, is widely used in the digital era for advocacy, enabling rapid and concise information dissemination [3] . In addition to government initiatives, palm oil producers are also actively using social media to advocate palm oil. They promote a positive image of palm oil by influencing public opinion. Food producers and retailers use Twitter as a marketing tool to inform consumers about their policies on palm oil, to share lists of products made with certified palm oil or those free from palm oil, and to respond to consumer inquiries, doubts, or complaints [4]. Stakeholders in the palm oil industry must collaborate to maintain a positive image of palm oil. Several media-driven stakeholder attitudes significantly influence the policy-making process, including: (1) environmental degradation such as forest and land fires; (2) the formation and dissolution of the Indonesian Palm Oil Pledge (IPOP); (3) the strengthening of ISPO certification; (4) discussion of the draft law on palm oil plantations; (5) deforestation concerns; (6) the allocation of BPDPKS fund management; (7) peatland restoration; (8) the palm oil moratorium; and (9) European Union parliamentary resolutions [5] .

This study developed a mobile-based educational game about sustainable palm oil Game Sawit Palmi Day Series for the Millennial and Zillennial generations. The widespread dissemination of negative narratives regarding palm oil both domestically and internationally particularly concerning its environmental and social impacts, has inspired researchers to engaged in palm oil campaigns through a mobile-based educational game. Palm oil continues to face criticism for its alleged role in deforestation, land burning, biodiversity loss, social conflicts, and climate change. These negative narratives are often amplified through social media platforms such as Facebook, YouTube, and Twitter [6]. To address these concerns, this study introduces a mobile-based educational game, "Game Sawit Palmi Day Series," designed using Social Cognitive Theory and Multiple Intelligence Theory.

Social Cognitive Theory, introduced by Albert Bandura, has shown success in influencing behavioral change through video games. Games designed based on this theory have been shown to produce positive outcomes [7]. Studies indicate that participants in game-based intervention group develop self-efficacy to change behavior [8]. The design of the Game Sawit in this study integrates Social Cognitive Theory with Multiple Intelligence Theory [9]. Multiple intelligence is a multifaceted learning theory that emphasizes individualized cognitive strengths, where learning is facilitated through diverse activities that align with distinct intellectual capacities. Several elements of this theory are integrated into the development of the Game Sawit developed by researchers. An edutainment (entertainment-education) approach serves as the foundation for the game's design, implementation, and messaging. This strategy intentionally combines entertainment with education to improve knowledge, foster positive attitudes, and influence social norms and behaviors [10]. While entertainment-education is not a communication theory, it functions as a communication strategy aimed at promoting both behavioral and societal change. It contributes to social transformation in two key ways: (1) by improving awareness, shaping attitudes, and modifying behaviors in alignment with socially desirable objectives, and (2) by leveraging various media formats—including radio, television, video, film, print media, and creative expressions such as crafts, textiles, and toys [11]. This study aims to develop a mobile-based educational game about palm oil that improves knowledge among the Millennial and Zennial generations regarding sustainable palm oil. Additionally, it evaluates the game's effectiveness in improving knowledge and interest in sustainable palm oil within these target demographics.

2. Methodology

This study was conducted using a quantitative method of quasi-experimental design. Quasi-experimental research involves two groups an experimental group and a control group where the samples are not selected randomly [12]. In this study, both groups were established accordingly. The research was conducted over three years, from February 2021 to February 2024, covering the

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development of the Game Sawit through to its experimental testing phase. The study was conducted in Jakarta. The experimental sample consisted of individuals from the Millennial and Zillennial generations. According to the Corciolani, et al. [13] the Zillennial generation includes individuals born between 1997 and 2012, while the Millennial generation includes those born between 1981 and 1996. The total sample for the experimental testing phase consisted of 120 participants, and all participants were involved in the experiment without any form of coercion, and their personal data were handled with strict confidentiality in compliance with ethical research guidelines.

Both experimental and control groups were involved in this study. A key similarity between the two groups is that each was given a pre-test and a post-test using a structured questionnaire. The difference lies in the intervention: the experimental group used a learning model based on the Game Sawit Palmi Day Series, whereas the control group did not receive this intervention. The research hypotheses are as follows: (1) There is a difference in scores between the control and Game groups within both the Millennial and Zillennial generations. (2) There is a difference between pre-test and post-test scores within each of the Millennial and Zillennial generations.

Table 1.
Total Number of Participants.

Group	Frequency (%)	Group	Frequency (%)
Control		Experimental	
Millennials	30 (50)	Millennials	30 (50)
Zillennial	30 (50)	Zillennial	30 (50)
Total	60 (100)	Total	60 (100)

3. Result and Discussion

Data were collected and analyzed to determine whether the mobile-based educational game significantly influenced participants' knowledge of sustainable palm oil. The Game Sawit is a positive campaign in the form of edutainment delivered through digital media, targeting the younger generation.

Digital media can be created, accessed, shared, and modified, and it can be stored on electronic devices. Using digital media as a pedagogic tool has a positive impact and tends to be more effective than conventional methods [14]. According to Aguilera and Mendiz [15] utilizing games in learning activities can have a positive impact and produce significant outcomes. In this context, games can enhance motivation, train skills, and strengthen perception. Furthermore, games can help users develop problem-solving and decision-making abilities. Games also serve as entertaining yet intelligent learning media. The Game Sawit, as a digital learning medium, presents materials and information on sustainable palm oil. This information may be conveyed explicitly through multimedia elements in the application, or implicitly through its narrative and storyline.

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Figure 1.
Game Sawit Design.

The Game Sawit educates participants on sustainable palm oil farming practices, including planting methods such as land clearing, the use of organic fertilizers, and water-saving irrigation techniques. These practices have a positive impact on the environment, for example, by reducing soil degradation and preserving biodiversity. In-game decisions related to the efficiency of environmentally friendly farming methods show how such approaches can enhance productivity and yield long-term economic benefits. This teaches players that sustainable farming practices can lead to both profitable economic outcomes and positive social and environmental impacts. The inclusion of local communities and the protection of workers' rights on plantations can generate positive social influences, such as improving the welfare of farmers and surrounding communities, as well as fostering harmonious, environmentally conscious relationships.

The difference in the effectiveness of the mobile-based educational game, Game Sawit Palmi Day Series, between the Millennial and Zillennial generations is a key focus in evaluating the success of digital learning media. These two generations exhibit distinct characteristics in how they respond to innovative learning methods, particularly interactive approaches such as games.

Table 2.
Differences in the Effectiveness of Palm Oil Games on Millennials and Zillenials.

Group	t-value	Sig. (2-tailed)	Conclusion
Overall	-8.913	0	Significant – overall improvement in knowledge
Zillennials	-6.866	0	Significant – marked improvement
Millennials	-5.721	0	Significant – clear improvement
Control	-2.077	0.042	Slightly significant – less effective than the Game
Games	-12.809	0	Highly significant – most effective method
Zillennials * Control	-2.088	0.046	Slightly significant – the Game is more suitable
Zillennials * Game	-9.541	0	Significant – best suited for Zillennials
Millennials * Control	-0.769	0.448	Not significant – method is ineffective
Millennials * Games	-8.572	0	Significant – effective for Millennials, though less so than for Zillennials

Based on the results of the t-test on the effectiveness of the Game Sawit Palmi Day Series, it can be concluded that this digital learning medium has a significant impact on improving participants' knowledge—both overall and when analyzed by generation. The overall t-test produced a value of t = -

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8.913 with a significance level of p = 0.000, confirming that the Game Sawit is statistically effective in improving knowledge of sustainable palm oil.

More specifically, the Zillennial group that received the Game Sawit intervention exhibited a highly significant result (t = -9.541; p = 0.000), indicating that the Game Sawit is well suited to the characteristics of the Zillennial generation, who are accustomed to interactive and visual media. The Millennial group also exhibited a significant result (t = -8.572; p = 0.000), though with a lower t-value than the Zillennial group. This suggests that while the method is effective for the Millennial generation, its impact is not as strong as it is for the Zillennial generation. Interestingly, the t-test results for the Millennial control group showed no statistical significance (t = -0.769; p = 0.448), indicating that conventional learning media are not effective for this generation. Meanwhile, the Zillennial control group showed a low but still significant result (t = -2.088; p = 0.046), reinforcing the notion that the Zillennial generation are more responsive to digital learning than to traditional, one-way instructional methods. Thus, the t-test results exhibit not only the overall effectiveness of the Game Sawit, but also the generational differences in its impact—showing that it is most optimally suited for the Zillennial generation.

The results of the t-test provides a strong empirical basis showing that game-based learning media such as the Game Sawit are not only innovative but also significantly more effective—particularly in conveying complex topics like sustainable palm oil to the digital-native generation. The Game Sawit Palmi Day Series offers substantial benefits in improving participants' knowledge of sustainable palm oil. As an interactive digital learning medium, the Game Sawit effectively delivers complex concepts such as environmental management, the socio-economic impacts of palm oil, and sustainability principles through engaging simulations and missions. This game not only presents information passively but also encourages participants to think critically and make decisions based on real-world scenarios, thereby strengthening their conceptual understanding and reflective thinking skills.

By adopting the principles of Gagné's learning theory and Bandura's social cognitive theory, the Game Sawit delivers systematic and adaptive learning—starting from capturing attention, presenting information, and providing feedback, to evaluating learning outcomes. Additionally, the Game Sawit serves as a tool for fostering awareness of sustainability values. Through gameplay that requires players to manage resources wisely, participants not only learn about palm oil but also internalize the importance of balancing production with conservation—an essential element in contemporary environmental education. Moreover, the gamification format of the Game Sawit significantly enhances player motivation and engagement.

The results of the t-test showed a highly significant improvement in knowledge among the group using the Game Sawit compared to the control group, with the highest gain observed in the Zillennial generation. This is in line with the study by Kusumandari [16] which indicates that educational game media are effective in enhancing motivation and learning achievement.

With a multisensory approach that combines text, visuals, audio, and interactivity, the Game Sawit also supports inclusive learning by addressing diverse learning styles. Therefore, the Game Sawit is not only an innovative learning tool but also a pedagogic strategy that is well-targeted, effective, and relevant for today's generation of learners in understanding sustainable palm oil in a comprehensive and meaningful way.

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*3.1. Paired Difference Test for Zillenial * Game Group.*

Table 3.
Paired Difference Test For Zillenial*Game Group.

No.	Hypothesis		Mean	N	Std. deviation	t	df	Sig. (2-tailed)
1	Palm oil contributes positively to the Indonesian economy.	POST	75.83	30	15.374	0.000	29	1,000
		PRETEST	75.83	30	13.901			
2	Palm oil provides environmental benefits.	POST	74.17	30	12.253	2.041	29	0.050*
		PRETEST	68.33	30	15.992			
3	Palm oil does not contribute to deforestation.	POST	60.00	30	14.081	1.861	29	0.073*
		PRETEST	53.33	30	19.402			
4	Palm oil provides benefits on human health.	POST	70.00	30	12.106	-.626	29	0.536
		PRETEST	71.67	30	15.720			
5	There is an interest in learning more about palm oil.	POST	65.83	30	19.122	-3.500	29	0.002**
		PRETEST	54.17	30	18.666			

Note: Description: **) alpha significance 5% *) significance 10%.

Based on the results of the paired sample t-test on the Zillennial group using the Game Sawit, it can be concluded that there is a significant improvement in knowledge and interest in learning across several aspects related to sustainable palm oil. Of the five statements tested, two showed statistical significance, indicating the success of the Game Sawit in shaping participants' understanding and attitudes toward palm oil issues.

First, regarding the statement "Palm oil provides environmental benefits," the average score increased from 68.33 to 74.17, with a t-value = 2.041 and p = 0.050, indicating significance at the 10% level. This suggests that after playing the Game Sawit, participants in the Zillennial group developed a more positive and balanced understanding of palm oil's contribution to environmental sustainability. Although palm oil is often associated with negative environmental impacts, the game helps broaden their perspectives by showing that proper management can yield ecological benefits. This is in line with the study by [16] which states that adventure game media can shape student participants' perceptions and learning attitudes toward topics initially perceived as difficult or controversial.

Second, regarding the statement "There is an interest in learning more about palm oil," there was a highly significant increase in the average score from 54.17 to 65.83, with a t-value = -3.500 and p = 0.002. This shows that the use of the Game Sawit not only improves knowledge but also fosters interest in further exploring the topic of palm oil—an essential component of sustained, long-term learning.

However, regarding the statement "Palm oil does not contribute to deforestation," although the average score increased from 53.33 to 60.00, the significance value was p = 0.073—indicating marginal significance at the 10% level. This suggests that the Game Sawit has begun to influence participants' perceptions of controversial environmental issues, though it has not yet resulted in a substantial shift in views. This may be due to the strong connotations associated with deforestation, which require more in-depth explanation or continued learning. Meanwhile, regarding the statement "Palm oil provides benefits on human health," the results were not significant (p = 0.536), which may indicate that the game content does not emphasize this aspect sufficiently.

Overall, the results of this test confirm that the Game Sawit is highly effective in enhancing learning interest and expanding the understanding of the participants in the Zillennial group of the topic of palm oil—particularly in relation to its benefits and sustainability approach. With an interactive approach grounded in modern learning theory, the game not only delivers information but also fosters participants' attitudes, perceptions, and motivation toward important and complex issues, as suggested in the literature on interactive, technology-based environmental education.

The results of the paired sample t-test provide strong evidence that engaging and interactive learning media—such as games—can promote active participation and greater interest in learning. Of the five hypotheses tested, two showed statistically significant changes (environmental perception and

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learning interest), one approached significance (deforestation), one showed no change (economy), and one showed a slight decline (health). This pattern suggests that game-based interventions are most effective in fostering learning interest and shifting perceptions about environmental issues—possibly due to strong visual and narrative elements in the game media. These results carry important implications for education, especially in selecting instructional media suited to the characteristics of the Zillennial generation, who are highly responsive to technology and experiential learning. Game-based learning media has proven effective in generating interest and changing certain perceptions—especially on complex topics such as sustainable palm oil farming practices, which are often shaped by unbalanced information in the public sphere.

This effectiveness can be explained through the integration of Bandura's social cognitive theory and Robert Gagné's learning theory in the design and flow of the game. According to Bandura's social cognitive theory, the learning process occurs through observation, modeling, and self-evaluation of the consequences of actions. In the Game Sawit, participants are invited to explore environmental simulations and make decisions regarding sustainable palm oil farming practices. They can directly observe the impact of their actions within the game, which fosters self-efficacy—namely, the belief that they are capable of making decisions and understanding complex systems. This process strengthens emotional and cognitive engagement in learning and helps shape a more positive perception of palm oil issues, including controversial aspects such as its environmental impact. This is in line with the study by Hasanah [17]which shows that experiential learning approaches and social interaction through educational games can significantly enhance motivation and learning outcomes.

Meanwhile, Gagné's learning theory emphasizes nine stages of effective learning, including gaining attention, presenting stimuli, providing feedback, and enhancing retention and transfer. The Game Sawit adopts this structure through various features such as appealing graphics (to gain attention), educational narratives (stimuli), a scoring and rewards system (feedback), and tiered missions (transfer of learning). This process enables participants not only to receive information but also to process, apply, and retain it in a real-world context. The study by Rahayu, et al. [18] in line with this, showing that construct-based educational games can improve problem-solving skills and learning outcomes in mathematics because they are designed based on systematic learning theory.

By combining both theories, the Game Sawit not only delivers informative content but also provides a reflective and meaningful learning experience. This is evident from the improved understanding among participants regarding the benefits of palm oil for the environment and economy, as well as their growing interest in further learning. This approach is especially suitable for the Zillennial generation, who benefit from learning media based on simulation, challenge, and active engagement.

Table 4.
Paired difference test for zillenial*control group.

No.	Hypothesis		Mean	N	Std. Deviation	t	df	Sig. (2-tailed)
1	Palm oil contributes positively to the Indonesian economy.	POST	77.50	30	13.693	-1.140	29	0.264
		PRETEST	80.00	30	12.106			
2	Palm oil provides environmental benefits.	POST	61.67	30	17.036	-1.278	29	0.211
		PRETEST	65.00	30	16.867			
3	Palm oil does not contribute to deforestation.	POST	56.67	30	14.582	.226	29	0.823
		PRETEST	55.83	30	20.430			
4	Palm oil provides benefits on human health.	POST	66.67	30	15.162	-1.140	29	0.264
		PRETEST	69.17	30	10.755			
5	There is an interest in learning more about palm oil.	POST	56.67	30	13.021	-.441	29	0.662
		PRETEST	57.50	30	13.375			

Note: Description: **) alpha significance 5% *) significance 10%.

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Palm oil contributes positively to the Indonesian economy. In this indicator, there was a decrease in the average score from 80.00 (pretest) to 77.50 (posttest), with a t-value = -1.140 and a significance level of p = 0.264. This decrease was not statistically significant, indicating no meaningful change in participants' perceptions of the economic benefits of palm oil. In fact, this downward trend suggests that the conventional media (control group) failed to maintain or improve the understanding of the participants in the Zillennial group regarding the economic value of palm oil.

Palm oil provides environmental benefits. In this indicator, there was also a decrease in the average score from 65.00 (pretest) to 61.67 (posttest), with a t-value = -1.278 and a significance level of p = 0.211. This decrease was not statistically significant. This indicates that participants in the control group experienced a decrease in positive perceptions of the environmental benefits of palm oil, meaning that instructional media lacking active approaches—such as games—are less effective in maintaining or improving participants' understanding of complex environmental issues.

Palm oil does not contribute to deforestation. In this indicator, there was a very slight increase from 55.83 (pretest) to 56.67 (posttest), with a t-value = 0.226 and p = 0.823. This increase was far from statistically significant, indicating that participants' perceptions of the relationship between palm oil and deforestation remained unchanged. This is understandable, as deforestation is a sensitive issue that requires educational strategies grounded in data and strong narratives to meaningfully shift participants' views.

Palm oil provides benefits for human health. In this indicator, the score decreased slightly from 69.17 to 66.67, with t = -1.140 and p = 0.264. Similar to the previous indicator, this decrease is not statistically significant, but it shows that participants' perceptions tend to weaken in recognizing the health benefits of palm oil. This confirms that the control method is not strong enough to maintain or improve participants' understanding of the health dimension of the palm oil issue.

Interest in learning about palm oil also showed a decrease, from 57.50 to 56.67, with t = -0.441 and p = 0.662. This result is not statistically significant and indicates that the conventional learning meadia is unable to foster interest of the participants in the Zillennial group in the topic of palm oil. In fact, this slight decrease may indicate that participants feel less interested or are not actively engaged in the learning process.

The results of the paired sample t-test on the Zillennial control group showed no significant differences in the five indicators of knowledge and interest related to palm oil. The significance value of all aspects was above the 0.05 threshold—for example, in the indicators "Palm oil contributes positively to the Indonesian economy" (p = 0.264) and "There is an interest in learning more about palm oil" (p = 0.662). This indicates that the control method was not effective in improving participants' knowledge and interest in learning. This condition is supported by quantitative data showing no significant change between the pretest and posttest scores in the group.

This phenomenon of stagnant learning outcomes can be explained theoretically through Bandura's social cognitive theory, which emphasizes that learning is effective when individuals are involved in the process of observation, modeling, and reflection through meaningful experiences. In the control group, learning did not present active stimuli or models that could be observed by participants, so it did not support the formation of self-efficacy or emotional involvement in learning. In comparison, the game-based learning media implemented in the intervention group allows for action-based learning experiences and direct feedback important elements in Bandura's theory.

Furthermore, according to Robert Gagné's learning theory, the effectiveness of learning is influenced by how stimuli are presented and organized through nine learning steps (Gagné's Nine Events). The control group did not experience stages such as gaining attention, presenting stimuli, providing feedback, and enhancing retention, which are explicitly included in the design of educational games such as the Game Sawit. Without these stages, students do not receive a systematic and meaningful learning experience, resulting in minimal information absorption. This is in line with the study by Hasanah [17] which shows that conventional learning is significantly less effective than game-based interactive models.

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Similar findings were reported by Gusmania and Dari [19] which compared conventional and video-based learning on mathematical concept comprehension. The results showed that the conventional approach significantly lagged behind in promoting student retention and cognitive engagement.

Thus, the insignificant results in the Zillennial control group are clear evidence that the conventional learning is unable to meet the needs of the digital-native generation, which requires active, visual, and responsive learning. This ineffectiveness is not only due to the passive method, but also to the inconsistency between the learning characteristics and the profile of the generation studied. In contrast, the Game Sawit, which was designed based on the principles of social cognitive theory and Gagné's instructional model, proved to be more adaptive and successful in improving participants' understanding and interest in learning.

In the Zillennial control group, none of the indicators showed statistically significant changes. In fact, four indicators experienced a decrease in average posttest scores. This indicates that conventional learning is less effective for the Zillennial generation, who tend to prefer active, visual, and technology-based learning. Conventional interventions often fail to maintain or even develop perceptions and interest in learning, and may even reduce participants' interest in strategic issues such as palm oil. When compared to the Zillennial group who received the Game Sawit intervention, the contrast is clear. The game was able to drive a significant increase in perception and interest, strengthening the conclusion that the interactive approach is much more effective for this digital-native generation.

*3.2. Paired Difference Test for Millennial * Control Group*

Table 5.
Paired Difference Test for Millennial*Control Group.

No.	Hypothesis		Mean	N	Std. Deviation	t	df	Sig. (2-tailed)
1	Palm oil contributes positively to the Indonesian economy.	POST	82.50	30	11.652	1.439	29	0.161
		PRETEST	79.17	30	9.476			
2	Palm oil provides environmental benefits.	POST	75.00	30	13.131	1.439	29	0.161
		PRETEST	71.67	30	10.854			
3	Palm oil does not contribute to deforestation.	POST	59.17	30	21.257	-0.177	29	0.861
		PRETEST	60.00	30	16.867			
4	Palm oil provides benefits on human health.	POST	74.17	30	12.253	1.140	29	0.264
		PRETEST	71.67	30	10.854			
5	There is an interest in learning more about palm oil.	POST	70.00	30	16.609	-0.297	29	0.769
		PRETEST	70.83	30	13.267			

Note: Description: **) alpha significance 5% *) significance 10%.

Here is a detailed explanation for each statement in the results of the paired sample t-test of the Millennial control group (without the Game Sawit intervention). These results help in understanding how much the participants' perceptions and interest in the palm oil issue have changed without the use of interactive media.

Palm oil contributes positively to the Indonesian economy. In this indicator, the average score increased from 79.17 (pretest) to 82.50 (posttest), with t = 1.439 and p = 0.161, which means it was not statistically significant. This means that although there is a slight increase in participants' perceptions of the economic benefits of palm oil, this change is not strong enough to be considered an influence of the intervention. This shows that the conventional learning is less able to provide a significant influence on participants' views on palm oil economic issues.

Palm oil provides environmental benefits. In this indicator, the posttest score increased from 71.67 to 75.00, but with t = 1.439 and p = 0.161, which means it was also not significant. Similar to the first statement, an increase in perception occurred, but it was not consistent across individuals to indicate a

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real influence. This indicates that the conventional learning is unable to significantly change participants' environmental perceptions, although there was a positive trend.

Palm oil does not contribute to deforestation. In this indicator, the posttest score decreased from 60.00 to 59.17, with t = -0.177 and p = 0.861. This indicates no significant change, even a slight decrease in perception, although small and not statistically significant. It can be concluded that without an active interventions such as games or interactive discussions, participants tend to maintain their initial views on sensitive issues such as deforestation.

Palm oil provides benefits on human health. In this indicator, the posttest score increased slightly from 71.67 to 74.17, but t = 1.140 and p = 0.264, which means it was not statistically significant. This small increase is most likely due to the natural effects of time or exposure to external information, rather than from the intervention in learning. This emphasizes the importance of using more engaging learning media (methods) and facilitating deeper understanding to change perceptions regarding the health aspects of palm oil.

There is an interest in learning more about palm oil. In this indicator, there was a slight decrease from 70.83 to 70.00, with t = -0.297 and p = 0.769, indicating no significance. This shows that conventional learning is not only ineffective in increasing interest, but also tends to stagnate or reduce participant enthusiasm. Without a fun and curiosity-provoking approach, learning interest does not grow well in the Millennial generation, who tend to be more interactive and visual.

The Millennial control group did not receive a learning intervention in the form of interactive media such as the Game Sawit. This is reflected in the results of the paired sample t-test, which showed that there was no significant increase in all indicators of knowledge and interest in palm oil. For example, the indicators "Palm oil contributes positively to the Indonesian economy" and "Palm oil provides environmental benefits" showed a significance value (p-value) of 0.161, while the learning interest indicator decreased, with a p-value of 0.769. These results indicate that without exploratory and interactive media intervention, learning becomes less meaningful and fails to encourage understanding or change in attitudes among the participants in the Millennial group. Theoretically, this phenomenon can be explained through Albert Bandura's social cognitive theory, which emphasizes that learning is effective when it involves observation, interaction, and active learning experiences. In conventional methods that only focus on conveying information, participants are not given the opportunity to observe behavioral models, explore through simulations, or receive feedback that encourages reflection. This condition inhibits the formation of self-efficacy and internal motivation to understand or deepen the material. In the context of a subject matter such as sustainable palm oil farming practices, which is complex and often controversial, a passive approach is inadequate to foster in-depth understanding.

*3.3. Paired Difference Test For Millennial Group*Game*

Table 6.
Paired Difference Test For Millennial Group*Game.

No.	Hypothesis		Mean	N	Std. Deviation	t	df	Sig. (2-tailed)
1	Palm oil contributes positively to the Indonesian economy.	POST	88.33	30	14.284	2.626	29	0.014**
		PRETEST	79.17	30	14.802			
2	Palm oil provides environmental benefits.	POST	79.17	30	18.666	2.091	29	0.045**
		PRETEST	68.33	30	20.692			
3	Palm oil does not contribute to deforestation.	POST	68.33	30	24.507	1.433	29	0.163
		PRETEST	59.17	30	23.196			
4	Palm oil provides benefits on human health.	POST	80.00	30	13.772	3.898	29	0.001**
		PRETEST	64.17	30	19.346			
5	There is an interest in learning more about palm oil.	POST	70.00	30	15.256	2.112	29	0.043**
		PRETEST	63.33	30	18.257			

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Palm oil contributes positively to the Indonesian economy. In this indicator, there was a statistically significant increase, from an average pretest score of 79.17 to a posttest score of 88.33, with $t = 2.626$ and $p = 0.014$ ($p < 0.05$). This shows that after being exposed to the Game Sawit, the perception of the Millennial generation regarding the economic benefits of palm oil increased significantly. Intervention through game media has been proven effective in strengthening their understanding that palm oil is a strategic commodity for the Indonesian economy, with broad impacts on exports, employment, and state revenue.

Palm oil provides environmental benefits. In this indicator, the average pretest score of 68.33 increased to 79.17 in the posttest. With $t = 2.091$ and $p = 0.045$, this increase is statistically significant. These results indicate that game media is effective in shifting the views of the Millennial generation toward a more positive perception regarding palm oil and the environment. Participants began to understand that although palm oil is often associated with environmental issues, sustainable practices such as ISPO minimize negative impacts and even provide ecological benefits if managed properly.

Palm oil does not contribute to deforestation. In this indicator, there was an increase in score from 59.17 to 68.33, but with $t = 1.433$ and $p = 0.163$, which means it is not statistically significant. Although there is a positive trend in participants' perceptions, these results indicate that the issue of deforestation remains a sensitive and complex topic for the Millennial generation. They may still maintain critical views or require more in-depth information to fully change their perceptions about the relationship between palm oil and deforestation.

Palm oil provides benefits on human health. In this indicator, a very significant increase was observed—from a pretest score of 64.17 to a posttest score of 80.00. The t value = 3.898 and $p = 0.001$, indicating a statistically strong change. The Game Sawit effectively succeeded in forming new understanding or correcting participants' misconceptions about the health benefits of palm oil products, such as vitamin E content, antioxidants, and their use in healthy foods. This reflects the success of delivering health information in an attractive and easy-to-understand format.

There is an interest in learning more about palm oil. In this indicator, the participants' interest scores also showed a significant increase, from 63.33 to 70.00, with $t = 2.112$ and $p = 0.043$ ($p < 0.05$). This indicates that the game intervention not only increased knowledge but also fostered participants' interest in learning more about palm oil. This means that the game-based learning media is able to create greater emotional involvement and curiosity toward the learning material.

The results of the paired sample t-test for the Millennial * Game group showed a significant increase in almost all aspects of knowledge and interest in sustainable palm oil. The most significant increases were reflected in indicators such as "Palm oil contributes positively to the Indonesian economy" ($p = 0.014$), "Palm oil provides environmental benefits" ($p = 0.045$), "Palm oil provides benefits on human health" ($p = 0.001$), and "There is an interest in learning more about palm oil" ($p = 0.043$). These findings strengthen the effectiveness of the Game Sawit as a learning media capable of conveying complex information in an easily digestible, interactive format.

Theoretically, this effectiveness can be explained through Bandura's social cognitive theory, which emphasizes that effective learning occurs through observation, direct experience, and the development of self-efficacy. In the Game Sawit, participants do not simply read information but actively experience simulated situations that resemble real-life conditions, allowing them to learn by observing the consequences of choices made in the game, as explained by Bandura [20].This interaction builds participants' confidence in their ability to understand and apply new information.

In addition, Robert Gagné's learning theory also reinforces these findings. The Game Sawit is designed based on Gagné's nine stages of instruction—starting from gaining attention through visuals and animations, stimulating the recall of prior learning through reflective scenarios, to enhancing retention and transfer through problem-solving in the context of palm oil. This makes the learning process more holistic and embedded in participants' long-term memory.

Similar studies that support the effectiveness of educational games in improving learning outcomes include the study by Jaya [21] who found that the Team Games Tournament (TGT) model

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significantly increased interest and motivation in learning mathematics. Likewise, Sutamtomo [22] showed a significant interaction between game-based learning models and learning interest in improving academic outcomes.

Thus, the Game Sawit has proven to be a digital learning medium that is not only engaging but also effective—even for the Millennial generation, who tend to be less responsive to conventional media. The integration of Bandura's and Gagné's theories into the game design provides strong justification that an interactive, game-based learning media can significantly improve understanding and learning motivation, especially when tailored to the characteristics of the target generation.

Overall, out of five indicators, four showed a statistically significant increase, proving that the Game Sawit is highly effective for the Millennial generation—especially in improving perceptions related to economic, environmental, health, and interest in learning. One aspect—Palm oil does not contribute to deforestation—did not show significant changes, indicating the need for a more in-depth approach to address controversial issues. However, in general, these results confirm that the educational game is a relevant and successful learning medium for the Millennial generation, particularly in the context of science-based campaigns, education, and social issues.

4. Conclusion and Limitations Research

The results of the analysis of the Game Sawit experimental test on the Millennial generation showed that the pretest results in both groups the control group (without game intervention) and the game intervention group did not show significant differences in knowledge about to palm oil. However, knowledge about palm oil increased significantly after the game intervention was implemented. The posttest results showed that the Zillennial generation group who received the Game Sawit intervention experienced a greater increase compared to the control group, and this result was statistically significant. Based on the average scores, it is evident that the posttest average of participants who used the game was higher than that of control participants. In the experimental test for the Millennial generation, the posttest results were also higher than the pretest, indicating that the Game Sawit had an influence on improving the knowledge of both the Millennial and Zillennial generations regarding the benefits of sustainable palm oil across economic, environmental, health, and social aspects. In accordance with the edutainment communication strategy, which aims to influence cognitive and behavioral changes, the Game Sawit is expected to serve as an alternative learning medium for sustainable palm oil. It is designed to increase knowledge amidst the many negative narratives related to palm oil, ensuring that the Millennial and Zillennial generations are not easily influenced by misinformation spread through various media platforms. With the presence of the Game Sawit *Palmi Day Series*, the younger generation can gain a better understanding of sustainable and environmentally friendly palm oil farming practices. The Game Sawit acts as a fun and informative educational tool, raising awareness of the importance of sustainability in the palm oil industry. Through game elements, players can learn about agricultural techniques that support efficient natural resource management and reduce negative environmental impacts.

This study has several limitations that should be considered when interpreting the results. First, the research was conducted only among millennial and zillennial generations in the Jakarta area, so the findings cannot be fully generalized to young people in other regions with different socio-cultural characteristics. Second, the quasi-experimental approach used was not completely random because the group allocation was done purposively, which may introduce potential bias in the selection of respondents. Third, the variables measured were limited to knowledge and learning interest related to sustainable palm oil practices, without further exploring actual behavioral changes in daily life. In addition, the exposure duration of the intervention media (*Game Sawit: Palmi Day Series*) was relatively short, around 30 minutes, which may not be sufficient to measure long-term effects on attitude changes. Finally, this study did not compare the digital intervention media with other alternative educational media, so the relative effectiveness across different media has not been fully mapped.

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Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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