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Research Article

Development and Use of Game-Based Instructional Materials for Teaching Science, Technology, and Society to College Students

Allan Gregy Villanueva Balic[1]*, Rommel Selda De Gracia[2]

[1]Department of Entrepreneurship, Bayambang Polytechnic College, Bayambang Pangasinan, 2423, Philippines
[2]Senior Education Program Specialist, Department of Education, Bayombong, Nueva Vizcaya, 3700, Philippines

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**Corresponding author:*
E-mail:
allangregybalic.official@gmail.com

ABSTRACT

This study developed and evaluated game-based instructional materials to enhance learning in the college-level subject, Science, Technology, and Society (STS). Using an action research approach, the study addressed the limitations of traditional teaching methods by introducing the "ALLAN Star Card," inspired by Bingo, and the "Amazing Challenge," modeled after the game show Who Wants to Be a Millionaire. These tools were designed to promote student engagement, critical thinking, and active participation. The research included 30 first-year BS Agribusiness students from Bayambang Polytechnic College, selected through purposive sampling. Pre- and post-tests were administered to assess the effectiveness of the materials, alongside evaluations using the LRMDS Non-Print Instructional Materials Tool. The instructional materials received a "Very Satisfactory" rating, with an average content quality score of 3.81 (SD = 0.13). However, areas such as technical quality and user control required further improvement, particularly in minimizing technical issues and enhancing user interaction.

Results from the pre-test (M=6.9, SD=2.81) and post-test (M=10.47, SD=3.31) revealed a significant improvement in student performance, confirming the efficacy of game-based methods in boosting academic achievement. These findings align with prior research on the advantages of gamification in education. Recommendations for improvement include addressing grammatical errors, reducing lifeline usage, and implementing time constraints for activities. The study concludes that game-based instructional materials effectively enhance learner engagement and academic performance in higher education.

Keywords*: Gamified materials, Game-based learning, Game activities for college learners*

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Introduction

Instructional materials are tools that teachers use to deliver instruction, playing a crucial role in the teaching and learning process. In science education, utilizing real objects can capture students' interest in a topic by allowing them to see, touch, smell, and, when appropriate, even taste the objects. For example, using real corn and mango leaves can illustrate the differences between monocot and dicot leaves. According to Eduedify (2022), when instructional materials are effectively employed, they enhance student achievement by supporting and enriching lesson content, facilitating the learning of new concepts, and providing opportunities for practice.

Tuimur and Chemwei (2015) highlighted that instructional materials should be diverse and not limited to textbooks and atlases, as outlined by the Ministry of Education, Science, and Technology (MOEST). They argued that primary schools should also be equipped with modern tools, such as televisions, computers, and radios, to enable teachers to address emerging issues in the current curriculum.

This study employed game-based instructional strategies as a tool for assessment purposes. Games such as "Bingo" and "Who Wants to Be a Millionaire" were incorporated during and after lessons. These materials are designed to enhance student engagement by encouraging active participation and promoting understanding of content in an enjoyable way. Arcagok (2021) observed that game-based teaching improves students' academic achievement. The study further indicated that game-based practices significantly boost academic performance across various curricula compared to traditional methods. Game-based teaching yielded higher academic achievement among preschool and primary school students than secondary school students. This difference may be attributed to younger students' higher levels of motivation, interest, and curiosity (Sung & Hwang, 2013; Weiss, Kramarski, & Talis, 2006) and their perception of games as educational tools (Al-Tarawneh, 2016).

While prior studies highlight the success of game-based learning among younger students, the researcher posits that such instructional materials could also be highly effective in higher education. College students, despite their differing interests, multiple intelligences, and learning styles, often face challenges with traditional lecture methods, especially those with poor study habits. Incorporating game-based instructional strategies in higher education has the potential to foster improvements in academic performance. By using game-based materials, students are likely to feel more motivated, participate more actively, and engage meaningfully in class discussions.

Objectives of the Study

This study aimed to develop game-based instructional materials, specifically "Inspired Bingo" and "Who Wants to Be a Millionaire," for teaching Science, Technology, and Society (STS) to college students. The specific objectives were to:

1. Design instructional materials tailored for science-related subjects at the college level.
2. Evaluate the instructional materials based on non-print components.
3. Assess the effectiveness of the instructional materials using pre- and post-test results.
4. Improve the instructional materials based on evaluation feedback and effectiveness data.

Methods

This study utilized an action research approach, incorporating both quantitative and qualitative methodologies to address a specific, real-world educational problem. Action research was chosen as it offers a systematic process for educators to examine their instructional environment, teaching methods, and student learning outcomes. Pre- and post-tests served as the primary tools for measuring student improvement in specific knowledge areas.

The development and implementation of the game-based instructional materials took place at Bayambang Polytechnic College, an institution accredited by the Commission on Higher Education (CHED). Founded by Dr. Cezar T. Quiambao, the college offers BS Agribusiness and Entrepreneurship programs alongside TESDA-certified technical and vocational training courses.

The participants in this research were first-year BS Agribusiness students enrolled in the

second semester of the academic year 2022–2023 at Bayambang Polytechnic College. The class comprised 34 students (18 female and 16 male), but only 30 participated in the pre- and post-tests due to absences for personal reasons. Participants were selected through purposive sampling, a non-probability technique that involves selecting individuals based on specific characteristics necessary for the study (Nikolopoulou, 2022).

The study employed the LRMDS Assessment Tool for Non-Print Instructional Materials to evaluate the developed materials. Additionally, pre- and post-tests were administered to determine the effectiveness of the instructional tools. The statistical range used for analyzing the LRMDS tool evaluation results is presented below.

Table 1. Scoring and Quantification data

Range	Qualitative Interpretation
3.50-4.00	Very Satisfactory (VS)
2.50-3.49	Satisfactory (S)
1.50-2.49	Poor (P)
1.00-1.49	Not Satisfactory (NS)

Following the creation of the game-based educational materials, which were inspired by the Bingo game and the TV show Who Wants to Be a Millionaire, two biological science teachers and one physical science teacher were tasked with evaluating the materials using standardized assessment tools for non-print instructional resources. This evaluation served as the foundation for refining and improving the instructional materials.

Bingo, a game where players use cards with numbered grids, was adapted for educational use. Players mark numbers as they are called out, and the first to complete a specific pattern shouts "Bingo" to win (Collins, n.d). In educational settings, Bingo has proven to be an effective whole-class activity, often used for revision or engagement purposes. Each student uses their card and listens carefully to prompts provided by the teacher. Matching prompts with their card's squares fosters attentiveness and participation (Twinkl, n.d).

Who Wants to Be a Millionaire, known for its challenging multiple-choice questions, requires players to demonstrate concentration, strategic thinking, and emotional resilience as they compete for increasing rewards. Its structure, featuring progressively difficult questions and lifelines like 50:50 or Ask the Audience, was adapted to create a stimulating classroom activity (Sony Pictures, n.d).

Before implementing these materials, the researcher conducted a pre-test for the Science, Technology, and Society course at Bayambang Polytechnic College. Each topic from Unit III was subsequently taught using the game-based instructional tools. A post-test was administered to measure knowledge retention and learning improvements. The intervention spanned two weeks during the final term of the 2022–2023 academic year.

The collected data were sorted, compared, and analyzed to determine the impact of the materials. The percentages of the scores were calculated, and the results were organized in tabular format. A descriptive analysis was employed to provide a comprehensive overview of the findings and identify patterns in the data. Descriptive analysis is a technique for summarizing data in meaningful ways, making it easier to identify trends and relationships (Villegas, n.d).

The following statistical tools were used to address the study's objectives:

1. Descriptive Analysis: Used to outline and summarize key elements in the development of game-based instructional materials.
2. Mean and Standard Deviation: Applied to evaluate feedback from science teachers on the quality of the materials.
3. Paired T-Test: Conducted to assess the significant differences in students'

performance between pre-test and post-test results after the use of game-based instructional materials.

4. Descriptive Analysis for Enhancement: Employed to propose improvements based on the evaluation feedback and the effectiveness results.

Result and Discussion

Game-Based Instructional Material for Science, Technology and Society

Traditional lectures are often passive and among the most commonly used teaching methods in education. However, passive learners tend to quickly forget newly acquired knowledge, as their attention typically fades after fifteen to twenty-five minutes. College students are no different from elementary and high school students in this regard; their attention during lectures also tends to wane, leaving them prone to distractions. Recognizing this challenge, this study aimed to develop game-based instructional materials specifically designed for college learners in the subject of Science, Technology, and Society.

The ALLAN Card Game, inspired by Bingo, and the Amazing Challenge, modeled after the game show Who Wants to Be a Millionaire, were employed as instructional tools. These games introduced objectives, interaction, feedback, problem-solving, competition, narrative, and an engaging learning environment—key elements that enhanced student engagement and sustained motivation (University of Waterloo, n.d.).

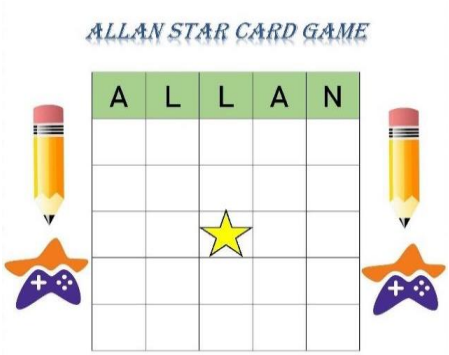

Figure 1. Sample ALLAN CARD inspire from BINGO game

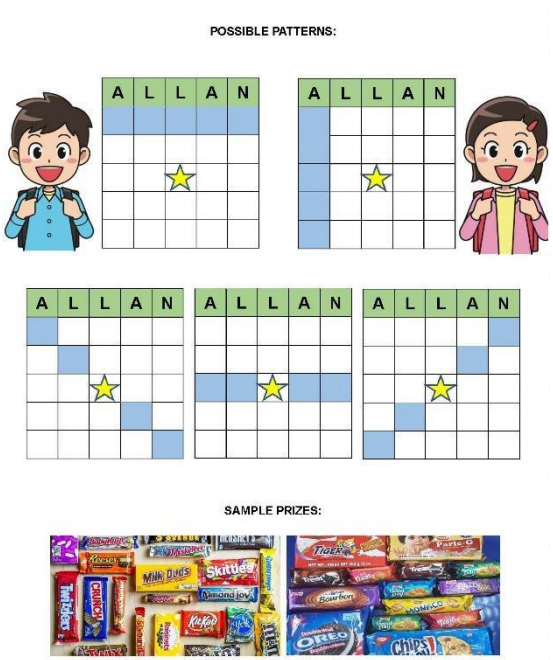

Figure 2. Possible patterns and Prizes on ALLAN Card Game

In the Science, Technology, and Society subject, students were each given an ALLAN card with corresponding numbers. Each topic was structured to align with the mechanics of the ALLAN Star Game. Students were required to complete specific patterns on their cards to receive rewards. Correct answers earned students a star for their patterns. For example, students were encouraged to share their insights, which the teacher would then elaborate upon, fostering collaborative learning.

Following effective questioning techniques, questions were presented to students before eliciting answers. If no one volunteered, the teacher would randomly draw a number, requiring the student associated with that number to share their ideas. The teacher would then expand upon these contributions, making the lesson an active learning experience. For instance, during a discussion on Genetic Engineering, the teacher might initiate by asking, "During your high school days, you encountered the term 'cell.' Can anyone share their ideas on what a cell is?" The questioning would continue, gradually leading to a discussion on the definition, importance, and applications of genetic engineering.

Upon completing a topic, rather than relying on traditional question-and-answer sessions for summarization and evaluation, the Amazing Challenge Game was introduced. This activity, inspired by the mechanics of Who Wants to Be a Millionaire, featured three levels of difficulty (easy, medium, and hard), each containing questions from the previous topic. Groups of students competed with one another, and in certain cases, only one member from a group was allowed to answer a specific question. Lifelines were made available for students who encountered difficulties. After each question, students and teachers engaged in discussions to clarify why an answer was correct or incorrect. For example, if a group answered "DNA" to the question, "What structures are responsible for producing specific proteins critical to bodily function?", the class would discuss why the correct answer is "chromosomes." This approach deepened learners' understanding while maintaining an enjoyable atmosphere.

Incorporating games into the classroom has proven to be a powerful tool in educational programs. The benefits include increased engagement among students and innovative ways to address diverse learning styles. Activities like these also promote critical thinking and provide opportunities for social-emotional learning. Although games are not the sole solution for improving education, they add a valuable dimension to teaching strategies that prepare students for success both inside and outside the classroom (Hugoboom, 2021).

Research supports the efficacy of game-based learning. Yazıcıoğlu and Güngören (2021) found that games contribute to students' cognitive, affective, and psychomotor development. Students reported learning complex concepts like specular and diffuse reflection, light, and sound more effectively while enjoying the process. Piu et al. (2016) demonstrated that using simulation games to introduce concepts such as angles facilitated the teaching process. Similar findings were reported by Boyraz and Serin (2015), who concluded that game-based activities improved students' comprehension of science concepts like force and motion more effectively than traditional methods.

Further studies have corroborated these findings. For instance, Wang and Lieberoth (2016) investigated the effects of points and audio on concentration, engagement, enjoyment, learning, motivation, and classroom dynamics using the game-based platform Kahoot!. Their study revealed that incorporating game elements significantly enhanced student engagement and motivation. Similarly, Hasselmann and Lurkin (2023) conducted a study involving an AI board game tournament to stimulate student engagement. Their findings indicated that gamified learning experiences fostered higher levels of student participation and interest.

Moreover, Gkogkidis and Dacre (2021) explored the co-creation of educational project management board games to enhance student engagement. Their research highlighted the positive impact of involving students in the game design process, leading to increased

engagement and deeper learning. A study by Jaques (2019) examined the impact of gamification on students' learning, engagement, and satisfaction, finding that gamified educational activities can enhance student engagement and learning outcomes.

Evaluation of Instructional Materials in terms of non-prints

Table 2.1 Content Quality

ITEM	MEAN	SD	QUALITATIVE DESCRIPTION
1. Concepts developed contribute to enrichment, reinforcement, or mastery of the identified learning objectives.	3.67	0.51	Very Satisfactory
2. Content is accurate.	4.00	0.00	Very Satisfactory
3. Content is up-to-date.	3.33	0.19	Satisfactory
4. Content is logically developed and organized.	3.33	0.51	Satisfactory
5. Content is free from cultural, gender, racial, orethnic bias.	4.00	0.00	Very Satisfactory
6. Content stimulates and promotes critical thinking.	4.00	0.00	Very Satisfactory
7. Content is relevant to real-life situations.	4.00	0.00	Very Satisfactory
8. Language (including vocabulary) is appropriate to the target user level.	4.00	0.00	Very Satisfactory
9. Content promotes positive values that support formative growth.	4.00	0.00	Very Satisfactory
AVERAGE	**3.81**	**0.13**	**Very Satisfactory**

Legend: 3.50-4.00-Very Satisfactory; 2.50-3.49-Satisfactory; 1.50-2.49-Poor;1.00-1.49-Not Satisfactory

The overall average mean score for Content Quality is 3.81, with a standard deviation of 0.13, placing it in the "Very Satisfactory" range. This result indicates that the educational materials are of high quality and effectively meet the content requirements of the target user level. However, there remains room for improvement, particularly in ensuring the content is up-to-date, logically developed, and well-organized.

Table 2.2 Instructional Quality

ITEM	MEAN	SD	QUALITATIVE DESCRIPTION
1. Purpose of the material is well defined	4.00	0.00	Very Satisfactory
2. Material achieves its defined purpose.	4.00	0.00	Very Satisfactory
3. Learning objectives are clearly stated and measurable.	3.67	0.51	Very Satisfactory
4. Level of difficulty is appropriate for the intended target user.	3.67	0.51	Very Satisfactory
5. Graphics / colors / sounds are used for appropriate instructional reasons.	3.33	0.19	Satisfactory
6. Material is enjoyable, stimulating, challenging, and engaging.	3.67	0.19	Very Satisfactory
7. Material effectively stimulates creativity of target user	3.67	0.19	Very Satisfactory
8. Feedback on target user's responses is effectively employed.	3.67	0.19	Very Satisfactory

ITEM	MEAN	SD	QUALITATIVE DESCRIPTION
9. Target user can control the rate and sequenceof presentation and review.	3.33	0.51	Satisfactory
10. Instruction is integrated with target user's previous experience.	4.00	0.00	Very Satisfactory
AVERAGE	**3.70**	**0.23**	**Very Satisfactory**

Legend: 3.50-4.00-Very Satisfactory; 2.50-3.49-Satisfactory; 1.50-2.49-Poor;1.00-1.49-Not Satisfactory

The developed instructional materials received an average score of 3.70, with a standard deviation of 0.23, and were classified as "Very Satisfactory" according to the accompanying legend. This demonstrates the high quality of the game-based learning tools in education. Areas such as "Graphics, colors, and sounds are used for appropriate instructional reasons" and "Target user can control the rate and sequence of presentation and review" received the lowest mean score of 3.33 (SD = 0.51). This suggests that the game-based instructional materials may require adjustments to better enable learners to control the rate and sequence of presentation and review.

Table 2.3. Technical Quality

ITEM	MEAN	SD	QUALITATIVE DESCRIPTION
1. Screen displays (text) are uncluttered, easy to read, and aesthetically pleasing.	3.67	0.51	Very Satisfactory
2. Visual presentations (non-text) are clear andeasy to interpret.	3.33	0.51	Satisfactory
3. Visuals sustain interest and do not distract user's attention.	3.67	0.51	Very Satisfactory
4. Visuals provide accurate representation of theconcept discussed.	3.50	0.50	Very Satisfactory
5. The design allows the target user to navigate freely through the material.	4.00	0.00	Very Satisfactory
6. The material can easily and independently beused.	4.00	0.00	Very Satisfactory
7. The material will run using minimum system requirements.	4.00	0.00	Very Satisfactory
8. The program is free from technical problems.	3.00	0.00	Satisfactory
AVERAGE	**3.65**	**0.25**	Very Satisfactory

Legend: 3.50-4.00-Very Satisfactory; 2.50-3.49-Satisfactory; 1.50-2.49-Poor;1.00-1.49-Not Satisfactory

The results show an average mean score of 3.65 with a standard deviation of 0.25, placing the game-based instructional materials in the "Very Satisfactory" range. This indicates that the technical quality of the game-based instructional materials is highly satisfactory. The area "The program is free from technical problems," which evaluates whether the program is free of any technical issues, received the lowest mean score of 3.00 (SD = 0.00), falling into the "Satisfactory" category. This suggests that technical problems, such as power interruptions, may occur during instruction.

Table 2.4. Other Findings

ITEM	MEAN	SD	QUALITATIVE DESCRIPTION
1. Conceptual errors.	4.00	0.00	Very Satisfactory
2. Factual errors.	4.00	0.00	Very Satisfactory
3. Grammatical and / or typographical errors	3.67	0.51	Very Satisfactory
4. Other errors (i.e., computational errors, obsolete information, errors in the visuals, etc.).	4.00	0.00	Very Satisfactory
AVERAGE	**3.92**	**0.13**	**Very Satisfactory**

Legend: 3.50-4.00-Very Satisfactory; 2.50-3.49-Satisfactory; 1.50-2.49-Poor;1.00-1.49-Not Satisfactory

The mean score for the item addressing grammatical and/or typographical errors was 3.67 (SD = 0.51), receiving a "Very Satisfactory" rating. This suggests that the game-based instructional materials are generally "Very Satisfactory," but could still benefit from improvements in grammar and typographical accuracy.

The effectiveness of Game-Based Instructional Materials using Pre-test and Post-testresults
Table 3. The statistical results of Pre-test and Post-test using Paired t-test

	n	Mean(M)	Standard Deviation (SD)	t	Two-Tailed (df=29, α=0.05)	
					Critical Value (CV)	p-value
Pre-test	30	6.9	2.81	-6.43	+/-2.05	0.00
Post-test	30	10.47	3.13			

The pre-test (M = 6.9, SD = 2.81) and post-test (M = 10.47, SD = 3.31) scores indicate a significant improvement following the intervention program, suggesting that game-based instructional materials effectively enhance student performance in Science, Technology, and Society. This finding aligns with Ahmed et al. (2022), who reported that students exposed to game-based learning outperformed those receiving traditional instruction. The experimental group exhibited increased motivation and reduced anxiety levels post-intervention.

These results are consistent with existing literature on the benefits of game-based learning. For instance, Hamari et al. (2016) conducted a meta-analysis revealing that gamification positively impacts learning outcomes and engagement. Similarly, Subhash and Cudney (2018) found that game-based learning enhances student motivation and academic performance.

Table 4. The statistical results per content of Pre-test and Post-test using Paired t-test

	Pre-test			Post-test		
	Genetic Engineering	Nanotechnology	StemCell	Genetic Engineering	Nanotechnology	StemCell
Mean	1.7	2.97	2.27	3.93	4.07	2.5
SD	1.15	1.83	1.39	1.46	2.07	1.43
t	-8.85	-2.44	-0.78	-8.85	-2.44	-0.78
CV	+/-2.06	+/-2.05	+/-2.05	+/-2.06	+/-2.05	+/-2.05
p-value	0.00	0.00	0.00	0.00	0.00	0.00

In terms of individual content or topics, the pre-test score for Genetic Engineering was (M = 1.7, SD = 1.15), and the post-test score was (M = 3.93, SD = 1.46). For Nanotechnology, the pre-test score was (M = 2.97, SD = 1.83), and the post-test score was (M = 4.07, SD = 2.07). Lastly, for Stem Cells, the pre-test score was (M = 2.27, SD = 1.39), and the post-test score was

(M = 2.5, SD = 1.43). These results indicate that after the intervention program, there was an increase in scores for items under Genetic Engineering, Nanotechnology, and Stem Cells.

Enhance the instructional materials based on the evaluation end effectiveness results

The developed game-based instructional material, categorized as non-print, still requires improvements. Based on the evaluators' suggestions, grammatical and typographical errors need to be corrected, the number of uses per lifeline should be reduced, and a time limit for answering the questions must be established. To address these suggestions and recommendations, an action plan was formulated.

Table 5. Action Plan

Area(s) and Project Title	Objectives	Person(s) Responsible	Activities	Expected Output
Checking Grammar and Typography	To correct grammatical and typographical errors	English Teacher/Language Editor	Communicate with English teachers available in the school to perform proofreading or editing. Hire a competent proofreader or grammarian.	Grammatical and typographical error-free materials
Number of Lifelines	To reduce the number of uses per lifeline in the Amazing Game Challenge	Researcher	Limit the uses of "Call a Friend" and "X2" lifelines.	Number of uses per lifeline set to two (2)
Time Limits per Question (Amazing Game Challenge)	To set a time limit for each question in the Amazing Game Challenge	Researcher	Establish a fixed time for all questions regardless of difficulty level.	Time limit for all levels set to one (1) minute per question.

To address the recommendations from evaluators, the game-based instructional materials were reviewed and improved. First, they were revised by an English teacher from the faculty. Second, all lifelines in the Amazing Game Challenge were limited to a maximum of two uses (e.g., two uses for 50:50, Call a Friend, Ask the Audience, and x2 or Switch). Lastly, students were given one minute to answer each question in the Amazing Game Challenge, which was inspired by the *Who Wants to Be a Millionaire* game show.

Conclusion

The developed instructional materials, namely the ALLAN Star Card and the Amazing Game Challenge, are game-based tools inspired by *BINGO* and *Who Wants to Be a Millionaire*. These materials create an enjoyable learning environment for learners and promote active engagement in the learning process.

The evaluation of the developed game-based instructional materials in terms of Content Quality, Instructional Quality, Technical Quality, and other relevant factors was rated as "Very Satisfactory" and met the standard requirements. Certain areas, such as language errors, require improvement, and technical issues need to be minimized. Despite these findings, the materials are suitable for use in teaching science-related subjects.

There was a notable improvement in the students' pre-test and post-test scores in the subject of Science, Technology, and Society, indicating that the intervention was effective.

To further enhance their effectiveness, the game-based educational materials will be updated and adjusted to address grammatical and

typographical errors based on the evaluation results. These updates will ensure the materials better meet the requirements and capabilities of learners while continuing to enhance students' academic performance.

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