



Student and Teacher Responses to the Use of Media and Teaching Tools in the STEM Boardgame

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ABSTRACT

Purpose of the study: This study aims to determine the responses of students and teachers to the use of media and teaching tools in the STEM Boardgame, an integrated learning tool that combines board games, teaching modules, and worksheets in STEM learning in elementary schools.

Methodology: The study used a quantitative descriptive survey design. The subjects consisted of 27 fifth-grade students and one teacher, selected using purposive sampling based on their direct involvement in learning. Data were collected using a Likert-scale questionnaire with 38 items for students and 39 for teachers, each covering aspects of game and teaching devices. The student instrument was tested for reliability, yielding a Cronbach's Alpha of 0.924. Data were analyzed using quantitative descriptive methods.

Main Findings: Students' responses to the game device aspect reached 83.04% (Very Good) and the teaching device aspect 80.93% (Very Good), with an overall average of 81.99% (Very Good). Teacher responses to the game device aspect reached 92.19% (Very Good) and the teaching device aspect 79.35% (Good), with an average of 85.77% (Very Good). Teachers placed greater emphasis on the board-game aspect, while students rated the teaching-device aspect higher.

Novelty/Originality of this study: This study specifically evaluates user responses to integrated STEM learning tools that encompass two aspects simultaneously-the game tool (board game) and the teaching tool from two direct user perspectives. Unlike previous studies, which generally examine only one aspect at a time, this study provides a more comprehensive empirical picture.

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1. INTRODUCTION

Education for Sustainable Development (ESD) is a crucial educational approach for addressing global challenges, equipping students with an understanding and application of sustainable lifestyles from an early age [1]. At the elementary school level, introducing sustainability issues should be done through learning that is relevant to students' lives, easy to understand, and that provides space for active involvement. This is increasingly important in the era of Society 5.0, which demands that the world of education equip students with 21st-century skills such as critical thinking, communication, collaboration, as well as creativity and innovation through a well-designed learning system, thus requiring the birth of adaptive and innovative human resources in

facing the developments of the times [2] [3]. In line with this, STEM (Science, Technology, Engineering, and Mathematics) education is considered the most appropriate approach in implementing ESD programs in schools because of its strategic role in preparing future generations to face increasingly complex global challenges [4], so that technology-based learning innovation through interactive media is an important need in building students' awareness and understanding of sustainable environmental issues [5].

STEM learning is a project-based approach that requires students to apply knowledge to solve problems [6]. The STEM approach is highly suitable for implementation because it is based on problem-solving, thus training students to solve problems related to everyday life [7]. In elementary schools, the STEM approach has great potential to foster scientific literacy and 21st-century skills from an early age because it encourages students to think analytically, design innovative solutions, and apply knowledge meaningfully [8], [9]. To achieve this potential, STEM learning needs to be supported by open media and tools that can guide students to understand problems, discuss them, try strategies, and find solutions gradually.

The successful implementation of STEM learning is influenced by teachers' readiness to utilize integrated learning media and teaching tools [10]. Teachers are required to improve their knowledge and skills to deliver quality learning [11]. STEM learning requires teacher creativity in creating innovations that increase student engagement, so that the learning process actively engages students in developing knowledge, skills, and attitudes [12]. One form of this innovation can be realized through the development and use of teaching tools that support active, meaningful learning. In the context of this research, this innovation is realized through the use of the STEM Boardgame, which combines game media, teaching modules, and Student Worksheets into a single learning tool.

Teaching tools that play a crucial role in STEM learning include Student Worksheets, teaching modules, and learning media. Student worksheets serve as a guide for understanding concepts through directed and independent learning activities, [13] and help students grasp STEM concepts in a practical, in-depth manner [14]. Learning modules contribute to more flexible learning because they are not dependent on textbooks, allowing the pace and learning strategies to be tailored to students' needs [15]. Integrating learning modules and worksheets is crucial for effective STEM learning, as learning modules provide a systematic flow of material. At the same time, worksheets supports students' investigative and problem-solving activities [16]. With both modules and worksheets, the learning process no longer relies solely on teacher explanations but also provides students with space to participate in learning activities more independently and in a directed manner.

Innovative learning media are also needed to support STEM learning optimally. One such medium is board games. Board games are an effective educational medium for training students' concentration, memory, problem-solving skills, strategic planning, and creative and critical thinking [17]. The use of board games encompasses visual and audio aspects through discussions and question-and-answer sessions, as well as affective aspects that support active student engagement [18]. The STEM Boardgame was developed by integrating teaching modules, student worksheets, and board games for urban sustainability-themed learning in elementary schools

However, the reality on the ground shows that science instruction in elementary schools remains dominated by conventional, teacher-centered approaches. Many teachers still use conventional teaching methods such as lectures, which lead to student passivity and create a less engaging learning environment [19]. This situation results in students' poor understanding of abstract science concepts and the suboptimal development of 21st-century skills. If learning remains one-way, students will have limited opportunities to discuss, express ideas, solve problems, and relate the material to real-life situations. Therefore, learning tools are needed to help teachers create more active, collaborative, and easily understood learning experiences. Therefore, this research addresses the limited empirical evidence on students' and teachers' responses to the use of integrated STEM learning tools that combine board games, learning modules, and student worksheets in elementary schools. This information is crucial for assessing the extent to which learning tools are accepted and used in practice during the learning process.

Various studies have examined the development of STEM-based learning tools and the use of board games in learning. However, most have focused on the development and effectiveness of learning in general. Studies specifically addressing students' and teachers' responses to STEM learning tools that integrate board games and teaching materials (learning modules and student worksheets) remain limited. Therefore, this study fills this gap by examining the responses of two direct users, students and teachers, to the STEM Boardgame and its teaching materials in STEM learning in elementary schools. Based on these issues, the STEM Boardgame is used as an alternative learning tool that combines game elements with structured teaching materials. The board game is used to create engaging, collaborative learning activities, while the teaching modules and worksheets guide the learning flow, student activities, and understanding of the material. Through this integration, learning is expected to be not only enjoyable but also aligned with learning objectives and student needs.

This study aims to describe student and teacher responses to the use of media and teaching materials in the STEM Boardgame. Specifically, this study aims to determine: (1) student responses to the game or board game; (2) student responses to the teaching materials in the form of teaching modules and worksheets; (3)

teacher responses to the game or board game; and (4) teacher responses to the teaching materials in the form of teaching modules and worksheets.

Based on these objectives, the research questions in this study are: (1) how do students respond to the game or board game in the STEM Boardgame? (2) how do students respond to the teaching materials in the form of teaching modules and worksheets? (3) How do teachers respond to the game device aspect of the STEM Boardgame? and (4) How do teachers respond to the teaching device aspect, including teaching modules and worksheets?. This research is expected to provide an empirical overview of students' and teachers' perceptions and responses to the use of integrated STEM-based teaching devices, such as board games. In practice, the results of this study can serve as considerations for educators in implementing more innovative, collaborative, and meaningful STEM learning in elementary schools. Theoretically, this research contributes to the development of studies on STEM education game-based learning, particularly the integration of board games, teaching modules, and worksheets in elementary school science instruction.

2. RESEARCH METHOD

This study employed a quantitative descriptive method with a descriptive survey design. A descriptive survey design was used to describe students' and teachers' responses to the use of open-ended media and devices in the STEM Boardgame. This study did not aim to compare treatments or test the effects between variables, but rather to describe the level of user response based on quantitatively analyzed questionnaire data. Quantitative descriptive research focuses on solving problems that arise during the study to describe a condition precisely, accurately, and systematically using numerical data [20].

The study was conducted at Elementary School 002 Samarinda Kota. The study subjects consisted of 27 fifth-grade students and one teacher directly involved in learning using the STEM Boardgame. The study sample was determined using purposive sampling, a sampling technique based on specific criteria, as described by [21]. The consideration for selecting the sample in this study was that students and teachers had participated in learning using board games, teaching modules, and student worksheets, and were thus deemed capable of responding to the media and teaching devices used.

The data collection technique used a student response questionnaire and a teacher response questionnaire. The student response questionnaire consisted of 38 statement items, while the teacher response questionnaire consisted of 39. The questionnaire instrument covered two main aspects, namely the game device aspect (board game) and the teaching device aspect (teaching module and worksheet). The difference in the number of items was found in the teaching device aspect, because the teacher questionnaire included one additional item on the suitability of the material to learning outcomes. The following is a grid of the student and teacher response questionnaire instruments used.

Table 1. Grid of Student and Teacher Response Questionnaire Instruments

Aspects of gaming Devices		Aspects of Teaching Tools	
Dimension	Indicator	Dimension	Indicator
Appearance and design	Assess the attractiveness of the appearance, visual design, colors, images, and layout of the board game.	Material Suitability	Assess the suitability of the module and worksheet materials to learning objectives, student needs, and learning outcomes.
Content suitability	Assess the suitability of game content to the material, learning objectives, and STEM Sustainable City themes.	Language Clarity and Readability	Assess the use of language, sentences, font size, and readability of the contents of the module and worksheet
Clarity of use	Assess the ease of understanding the rules, instructions, game flow, and how to use the board game components.	Equipment and ease of use	Assess the completeness of the module/worksheet components and the ease of use of them by students and teachers.
Collaborative activities	Assess the ability of board games to encourage cooperation, discussion, communication, and interaction between students.	Attraction	Assess the appearance, presentation, activities, and design of teaching tools in attracting students' interest in learning.
Learning success	Assess the extent to which board games help students understand the material and achieve learning objectives	Critical thinking	Assess the ability of modules and worksheet to encourage students to analyze problems, find solutions, and think reflectively.
Impact on students	Assessing the influence of board games on students' motivation,	Learning benefits	Assess the benefits of modules and worksheet in helping the

Aspects of gaming Devices	Aspects of Teaching Tools
interest, activity, and learning experience	understanding of material, learning activities, and learning effectiveness.

The indicators in the questionnaire grid are arranged with reference to the indicators used in the research Annisa et al. [7]; Santoso et al. [22]; Juwati et al. [23]; Wijayanti et al. [24]; Samhati et al. [25]; A'yun et al. [26]; Putri et al. [27]; Saragih et al. [28]; Sapitri et al. [29]. The questionnaire was structured using a 1–4 Likert scale. The four-choice scale was used to avoid neutral responses and allow respondents to provide clearer assessment tendencies. Scoring guidelines Adapted from [30], are presented in Table 2.

Table 2. Assessment Score Guidelines

Number	Score	Remarks
1	4	Strongly Agree (SS)
2	3	Agree (S)
3	2	Disagree (TS)
4	1	Strongly Disagree (STS)

Prior to use, the questionnaire instrument was tested for internal consistency using Cronbach's Alpha. According to [31] instrument is considered reliable if its Cronbach's Alpha value exceeds 0.70. Reliability testing was conducted on the student response questionnaire, which consisted of 38 items and involved 27 students. The results showed a Cronbach's Alpha value of 0.924, confirming the reliability of the student response questionnaire and its suitability for use in data collection. Meanwhile, the reliability of the teacher response questionnaire was not analyzed using Cronbach's Alpha because there was only one teacher respondent, making the internal consistency test inapplicable to this data.

Data collection was conducted after the learning activities using the STEM Boardgame were completed. Students completed the questionnaire based on their experiences using the board game, teaching modules, and worksheets. Teachers completed the questionnaire based on their experiences and observations during the implementation of the learning tools in the learning process. The data were analyzed using quantitative descriptive methods. The scores for each statement were summed and then compared to the ideal maximum score to obtain the response percentage. The percentage formula was adapted from Andriani et al. [32]

$$P = \frac{TS}{S_{max}} \times 100\% \dots (1)$$

Description:

P = percentage of questionnaire results,

TS = total score obtained,

Smax = ideal maximum score.

The percentage results are then interpreted into student and teacher response categories Adapted from [33], based on Table 3.

Table 3. Categories of Student Responses

Average Score	Category
$\leq 20\%$	Very Bad
$20\% < x \leq 40\%$	Not Good
$40\% < x \leq 60\%$	Enough
$60\% < x \leq 80\%$	Good
$80\% < x \leq 100\%$	Excellent

Because this study used a descriptive survey design, data analysis was not directed at testing inferential hypotheses. The analysis was conducted to describe the level of student and teacher response to the media and teaching tools based on total scores, maximum scores, percentages, and response categories. Therefore, the research results are presented for each indicator, each aspect, and the overall average of student and teacher responses to the use of the STEM Boardgame.

3. RESULTS AND DISCUSSION

This study aims to describe students' and teachers' responses to the use of media and teaching tools in the STEM Boardgame. This section presents the research findings to answer four research questions, namely

student responses to aspects of game tools, student responses to aspects of teaching tools, teacher responses to aspects of game tools, and teacher responses to aspects of teaching tools in the STEM Boardgame. The analysis was carried out according to the research method, namely, a quantitative descriptive analysis using total, maximum, and percentage scores, along with response categories, to describe the levels of student and teacher responses to the learning tools used.

3.1. Student Responses to Game Device Aspects

The results of student responses to aspects of the game device are presented in Table 4.

Table 4. Shows the results of student responses to the game device

Indicator	Number of Points	Total Score	Maximum Score	Percentage (%)	Category
Appearance and Design	3	274	324	84.57	Excellent
Content Suitability	3	263	324	81.17	Excellent
Clarity of Use	2	180	216	83.33	Excellent
Collaborative Activities	2	182	216	84.26	Excellent
Learning Success	3	281	324	86.73	Excellent
Impact on Students	3	255	324	78.70	Good
Subtotals of Gaming Devices	16	1435	1728	83.04	Excellent

Based on Table 4, to answer the first research question, the analysis results show that student responses to the game device aspect were 83.04%, categorized as Very Good. These results indicate that the STEM Boardgame received a very positive response from students across all measured indicators. The learning success indicator achieved the highest percentage of 86.73% (Very Good). This indicates that students experienced real success from using board games in the learning process. This success is reflected in the board game's ability to create meaningful learning experiences and encourage active student engagement throughout the learning process. This finding aligns with [16] statement that using board games as a learning medium has been shown to provide significant benefits for social and emotional development. Furthermore, the use of games in learning not only enhances learning interest but also helps develop students' problem-solving and critical thinking skills [34].

The appearance and design indicator achieved 84.57%, categorized as very good. These results indicate that the board game visuals attracted students' attention and facilitated their understanding of the learning material. The material's attractive appearance and simple presentation were shown to encourage active student engagement throughout the learning process. This finding aligns with research [35], which stated that attractive visual aspects and clear presentation of material can increase student participation. Furthermore, According [36] also emphasized that visual elements in educational board games play a crucial role in increasing the appeal and effectiveness of learning. Therefore, the use of expressive, communicative illustrations is a crucial factor in creating effective, engaging learning media.

The collaborative activity indicator scored 84.26%, categorized as very good. These results indicate that board games can create an interactive learning environment and encourage student collaboration. This is evident in the game instructions, which direct students to play in groups, thus encouraging communication, discussion, and collaborative problem-solving [37]. Furthermore, board games also have the advantage of developing collaborative and critical thinking skills, encouraging cooperation among students, and strengthening analytical thinking skills [38]. The clarity of use indicator scored 83.33%, indicating that the instructions and game mechanics were easy for students to understand, and was categorized as very good. This is important because media designed with ease of use and portability in mind can enhance learning effectiveness [38]. In this case, game rules serve as a supporting tool, outlining the rules that must be followed, helping students understand the game flow more clearly [39]. In addition, board games, which consist of components arranged and operated according to certain rules on an attractively designed board, support ease of use and enhance the attractiveness of learning [40].

The content suitability indicator achieved 81.17%, categorized as Very Good. Students found the material integrated into the game relevant to the learning theme being studied. Adapting game content to students' capacities and ability levels is crucial to ensure learning activities remain challenging without frustrating them [24]. Content relevance, duration, and appropriate presentation methods are key determinants of a learning medium's success [41]. The impact on students indicator achieved the lowest percentage, at 78.70%, but still falls into the Good category. Although lower than other indicators, board games still demonstrate a positive impact on students. Educational games that incorporate elements of challenge, reward, and direct feedback have been shown to increase students' intrinsic and extrinsic motivation [42]. Furthermore, the use of board games also significantly impacts students' knowledge and learning interest [43].

3.2. Student Responses to the Teaching Tools Aspect

The results of student responses to aspects of teaching tools are presented in the following table 5

Table 5. Student response results to teaching tools

Indicator	Number of Points	Total Score	Maximum Score	Percentage (%)	Category
Material Suitability	3	260	324	80.25	Excellent
Language Clarity and Readability	2	183	216	84.72	Excellent
Equipment and Ease of Use	3	270	324	83.33	Excellent
Attraction	6	516	648	79.63	Good
Critical Thinking	5	434	540	80.37	Excellent
Learning Benefits	3	260	324	80.25	Excellent
Subtotal of Teaching Tools (Modules And Worksheet)	22	1923	2376	80.93	Excellent

Based on Table 5, to answer the second research question, the analysis results show that students' responses to the teaching device aspect were 80.93% in the Very Good category. This result indicates that the teaching module and Worksheet used in the STEM Boardgame learning received a very positive response from students. The language clarity and readability indicators achieved the highest percentage in this aspect, at 84.72%, categorized as Very Good. These results indicate that students considered the language used in the modules and worksheets easy to understand. According [44] found that using simple, clear, and effective language makes worksheets easier to understand. Furthermore, clear and easy-to-read fonts also contribute to students' comprehension speed[45].

The completeness and ease-of-use indicators achieved a 83.33% score, categorized as Very Good. These results indicate that students found the teaching materials complete and easy to use in the learning process. Ease of use is reflected in students' ability to understand the material and language presented in the teaching materials [23]. Furthermore, the use of student worksheets prepared in accordance with didactic requirements can help students understand the material more easily, increase their enthusiasm for learning, support communication during learning, and encourage active involvement in learning activities [46]. The teaching modules provide a clear, structured learning framework, helping students understand the material while developing positive character traits [47].

The critical thinking ability indicator showed an achievement of 80.37%, categorized as very good. This achievement indicates that the teaching tools used have been effective in facilitating the development of higher-order thinking skills in students. Learning tools designed in alignment with curriculum objectives can foster logical, analytical, systematic, critical, and creative thinking patterns [22]. Furthermore, the integration of game elements into the learning process also contributes to encouraging students to think more reflectively and analytically, thus supporting the strengthening of higher-order thinking skills, a key focus of modern-day learning [48]. STEM-based worksheet has a positive impact on learning by encouraging students to think more deeply and actively through activities designed according to the STEM framework and critical thinking indicators[49].

The indicators for material suitability and learning usefulness showed the same percentage, at 80.25%, categorized as very good. This result indicates that students assessed the material presented as appropriate to their learning needs and as providing tangible benefits to the learning process. A quality teaching module ideally meets several criteria, such as being important, engaging, meaningful, challenging, relevant, and contextual to the students' lives [50]. The suitability of a teaching module is crucial because it supports the effectiveness and optimization of learning for students, teachers, and educational institutions. Furthermore, a systematic, comprehensive, and adaptive teaching module can facilitate student learning independence and help them understand concepts more deeply [51].

The attractiveness indicator achieved a percentage of 79.63%, categorized as Good. Although not yet categorized as Very Good, this achievement indicates that the developed teaching materials are capable of encouraging students' enthusiasm for learning. Samhati et al. [25] revealed that student worksheets and modules designed interactively and innovatively through the use of digital-based media, the implementation of collaborative activities, and project-based learning orientation have been proven to be able to foster student interest and enthusiasm for learning, so that the results obtained on this indicator are in line with these findings. In addition, According [38] revealed that the application of gamification elements in designing learning media plays an effective role in creating a conducive learning atmosphere, which ultimately contributes to increasing student understanding and motivation. This is further strengthened by [52], who stated that delivering material in an interactive and interesting manner can arouse students' enthusiasm for learning, sharpen their concentration, and encourage their active involvement throughout the learning process.

3.3. Teacher Responses to Game Device Aspects

The results of teachers' responses to aspects of game devices are presented in table 6.

Table 6. Shows the Results of Teacher Responses to Game Devices

Indicator	Number of Points	Total Score	Maximum Score	Percentage (%)	Category
Appearance and Design	3	12	12	100.00	Excellent
Content Suitability	3	11	12	91.67	Excellent
Clarity of Use	2	8	8	100.00	Excellent
Collaborative Activities	2	7	8	87.50	Excellent
Learning Success	3	11	12	91.67	Excellent
Impact on Students	3	10	12	83.33	Excellent
Subtotals of Gaming Devices	16	59	64	92.19	Excellent

Based on Table 6, to answer the third research question, the analysis results show that teachers' responses to the game device aspect achieved a percentage of 92.19%, categorized as Very Good. This achievement exceeded the percentage of student responses of 83.04%, indicating that teachers gave an extraordinarily positive appreciation to the board game media used in learning.

The indicators of appearance and design, as well as clarity of use, achieved a percentage of 100.00%, categorized as Very Good. These results reflect the responses of teachers who have participated in learning using the STEM Boardgame, who found the visual display very engaging and the instructions easy to understand. According [53] stated that the appropriateness of the content to learning outcomes, ease of play, and visual displays tailored to student abilities are determining factors in the quality of learning devices. Based on these findings, the design of the STEM Boardgame is deemed to meet professional and functional visual standards for students.

The content suitability and learning success indicators each achieved a percentage of 91.67%, categorized as Very Good. Teachers assessed that the game content was highly aligned with the learning objectives and provided significant benefits for students. According [54] found that using board games in environmental learning can increase student engagement while simultaneously training decision-making skills related to sustainability issues in a fun, collaborative manner. Therefore, the STEM Boardgame is considered relevant in terms of content and supports learning success.

The collaborative activity indicator achieved a percentage of 87.50%, categorized as Very Good. Teachers assessed that the developed board game significantly supported collaborative activities among students during the learning process. According [55] stated that board games, as a gamification method, have fun, challenging, and dynamic characteristics, enabling social interaction and cooperation among participants. This finding is supported by [56], who stated that this game can foster positive collaborative and competitive attitudes while simultaneously teaching the value of teamwork and encouraging students' enthusiasm in overcoming challenges.

The impact indicator on students achieved a percentage of 83.33%, categorized as Very Good. Teachers assessed that the use of board games in learning has a tangible positive impact on student development. According [57] revealed that board games serve as a means to improve students' analytical skills to a higher level, thus optimally achieving required competencies. In line with this, According [58] stated that learning outcomes do not reflect only academic achievement but also describe the development of thinking skills and the formation of attitudes that support students' readiness for the next stage of learning.

3.4. Teacher Responses to the Teaching Tools Aspect

The results of teachers' responses to aspects of teaching tools are presented in table 7 below

Table 7. Results of Teacher Responses to Teaching Materials (Modules and Worksheet)

Indicator	Number of Points	Total Score	Maximum Score	Percentage (%)	Category
Material Suitability	4	13	16	81.25	Excellent
Language Clarity and Readability	2	6	8	75.00	Good
Equipment and ease of use	3	10	12	83.33	Excellent
Attraction	6	19	24	79.17	Good
Critical thinking	5	15	20	75.00	Good
Learning benefits	3	10	12	83.33	Excellent
Subtotal of Teaching Tools (Modules and Worksheet)	23	73	92	79.35	Good

Based on Table 7, to answer the fourth research question, the analysis results show that teachers' responses to the teaching materials aspect achieved a percentage of 79.35%, categorized as Good. Although slightly below the Very Good category, this result still indicates a positive assessment from teachers of the teaching modules and worksheet used. The indicators of completeness, ease of use, and learning usefulness each achieved the highest percentages, at 83.33% (Very Good). Teachers assessed that the developed teaching materials were complete, easy to use, and provided tangible benefits in learning. This finding aligns with research by Rosmana et al. [59] that found that Student Worksheets can support effective learning and generate positive responses because they enhance student understanding and develop basic skills in line with the competency indicators that must be achieved. Worksheet also encourages active student involvement, facilitates understanding and development of concepts, and serves as a guide for teachers in designing and implementing learning [60]. A complete teaching module component is one indicator of successful learning because it can provide extensive benefits for teachers in delivering material to students and in developing the teaching module itself [61]. Thus, the combination of worksheet and teaching modules as a complete, easy-to-use teaching tool provides real benefits for teachers and students, improving understanding of the material, learning engagement, and the effectiveness of the entire learning process.

The material suitability indicator scored 81.25% (Very Good). Teachers assessed that the material in the teaching materials aligned with the established learning outcomes. Selecting appropriate teaching materials can help students understand concepts correctly, enable them to connect them to prior knowledge, and facilitate their identification of related new concepts [62]. The learning appeal indicator scored 79.17% (Good). Teachers perceived the teaching materials as engaging and motivating, although there is still room for improvement. Student worksheets should be designed with a more attractive layout to increase student enthusiasm for learning, and attention should be given to font type and size to ensure a neater, more structured, and easier-to-read appearance [63].

The language clarity and readability indicators and the critical thinking indicator each scored 75.00% (Good). These results indicate that the language used in the module and student worksheets is quite simple, easy to understand, appropriate for the students' age, and structured with effective sentences [64]. The student worksheets are designed by presenting contextual problems that encourage students to activate their prior knowledge in finding solutions. Concise instructions, accompanied by structured steps and visual illustrations, facilitate understanding and stimulate students' critical thinking skills [29]. Although categorized as good, a score of 75.00% indicates that there are still areas for improvement to optimize the clarity of the language and the structure of the problem-solving questions.

3.5. Comparison of Student Responses and Teacher Responses

To see a more comprehensive picture, the following presents a comparison of student and teacher responses to the two aspects assessed.

Table 8. Comparison of Student and Teacher Response

Aspects	Percentage of Students (%)	Category	Teacher Percentage (%)	Category
Game Devices (Game Panel)	83.04	Excellent	92.19	Excellent
Teaching Tools (Modules & Worksheet)	80.93	Excellent	79.35	Good
Average	81.99	Excellent	85.77	Excellent

Based on Table 8, a comparison of student and teacher responses to the STEM learning tool, the Boardgame, shows positive results across all assessed aspects. For the Game Tool (Board Game), student responses reached 83.04% and teacher responses reached 92.19%, both in the Very Good category. The high ratings in this aspect indicate that the board game developed was well-received by both students and educators. Board games are considered a strategic learning tool to support the achievement of 21st-century competencies, particularly in developing students who think critically and creatively, and possess strong character [65]. This success is also due to the combination of game elements, visual presentation of materials, and interactive activities between groups, which make the board game both appealing and highly educational in today's learning context [66].

For the Learning Tool (Modules & Worksheet) aspect, student responses reached 80.93% and were categorized as Very Good, while teacher responses reached 79.35% and were categorized as Good. Despite slight differences in the categories between student and teacher responses, both results remained within a reasonable range and indicated that the developed module and Student Worksheet were effective in supporting the learning process. The presence of worksheet in learning shifts the teacher's dominant role, moving the learning process toward a more focused approach to students' independent development of understanding [67].

Furthermore, well-designed worksheet has been shown to be easy for students to operate, fostering enthusiasm for learning and contributing to improved overall learning outcomes [68].

Overall, the average student response rate was 81.99%, and the average teacher response rate was 85.77%, both falling within the Very Good category. These results demonstrate that the developed STEM learning tool, the Boardgame, was well-received by all test subjects. The integration of game elements into learning activities has proven effective in capturing students' attention and fostering their enthusiasm for active participation in learning [69]. Thus, this learning tool is considered appropriate and effective for implementation in STEM learning at the elementary school level.

4. CONCLUSION

This study concluded that the STEM Boardgame received a positive response from both students and teachers. Student responses to the game hardware aspect reached 83.04% (very good) and the teaching hardware aspect 80.93% (very good), with an overall average of 81.99% (very good). Teacher responses to the game hardware aspect reached 92.19% (very good) and the teaching hardware aspect 79.35% (Good), with an average of 85.77% (very good). The differences in the teaching hardware aspects indicate that teachers assess from a more critical pedagogical perspective than students. The implications of this study indicate that the integration of board games, teaching modules, and student worksheets as complementary STEM learning tools can be well-received by direct users in elementary schools, thus potentially becoming a model for active, collaborative, and meaningful STEM learning innovation within the Education for Sustainable Development (ESD) framework. Indicators that remain in the Good category in teacher assessments serve as notes for improvement in future development.

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AUTHOR CONTRIBUTIONS

Conceptualization, Methodology, Formal Analysis, Investigation, Resources, Data Curation, Writing – Original Draft Preparation, and Visualization, N.H.; Writing – Review & Editing, N.H., E.S., T.W., and Y.S.; Supervision and Project Administration, E.S., T.W., and Y.S. All authors have read, reviewed, and provided approval for the final version of the manuscript submitted for publication.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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