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Needs Analysis of STEAM-Based Digital Teaching Materials with a Gamification Approach for Higher Education Students

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ABSTRACT

The integration of Science, Technology, Engineering, Arts, and Mathematics (STEAM) with gamification offers opportunities to develop interactive and contextual digital mathematics learning materials. However, the learning needs and instructional requirements for integrating these approaches into sequences and series remain underexplored. This study aimed to analyze lecturer perspectives, student characteristics, and learning-material needs as a basis for developing STEAM-gamification-based digital teaching materials. A descriptive mixed-methods design involved three lecturers and 225 first-semester students in the Elementary School Teacher Education Program at Samudra University. Data were collected through lecturer interviews, a 30-item visual, auditory, and kinesthetic (VAK) questionnaire, and a student needs questionnaire. Qualitative data were analyzed thematically, while quantitative data were examined using descriptive statistics. Both datasets were integrated by comparing related themes and identifying convergent and complementary findings. The results indicated a need for interactive, contextual, and engaging learning resources incorporating STEAM activities, multimodal representations, progressive tasks, and gamification features. Students also reported difficulties with sequences and series and expressed interest in additional digital materials. This study contributes empirically grounded design priorities for developing STEAM-gamification-based digital teaching materials. The findings provide a foundation for prototype development and subsequent validation and evaluation but do not establish instructional effectiveness.

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1. INTRODUCTION

The development of digital technology and the demands of 21st-century competencies encourage higher education institutions to prepare learning environments that are contextual, interactive, and student-centered. For elementary school teacher

education programs, this becomes a significant challenge because prospective teachers must master fundamental mathematical concepts and procedures and be able to explain mathematical concepts and facilitate problem-solving processes for elementary school students, not merely know how to solve mathematical problems [1], [2]. Digital technology has generated various innovations in the field of education. This encourages students to develop critical, creative, collaborative, and adaptive skills [3]. The integration of technology through various platforms and applications in learning provides opportunities for educators to design learning experiences, such as the use of digital-based teaching materials for prospective teachers at the higher education level [4], [5], [6]. Consequently, digital teaching materials in mathematics education need to provide more than access to information; they should also facilitate conceptual understanding, active participation, exploration, and meaningful connections between mathematical knowledge and real-world contexts.

One approach that has the potential to support the achievement of these objectives is STEAM, which integrates the components of science, technology, engineering, arts, and mathematics in meaningful contexts [7], [8]. The STEAM approach enables students to generate science- and technology-based ideas through thinking and exploration activities in solving problems [9], [10], [11], [12]. In mathematics learning, STEAM integration provides opportunities for students to connect abstract mathematical concepts with practical applications through investigation, design, creativity, and problem-solving activities. The integration of these disciplines is particularly relevant in preparing prospective elementary school teachers to develop learning experiences that are not restricted to procedural calculations but also emphasize reasoning, pattern recognition, and the application of mathematical concepts. Several studies in Indonesia have reported that STEAM-based digital modules and STEAM-oriented project-based learning contribute to improving students' abilities, particularly in the field of mathematics [13], [14], [15]. These studies indicate the potential of STEAM-oriented learning resources; however, the development of such resources also requires preliminary information about students' characteristics, lecturers' instructional needs, and the specific mathematical content that should be addressed.

Another emerging approach is gamification, which refers to the application of game design elements within a non-game framework [16]. Several meta-analyses and systematic reviews have found that gamification has positive impacts on learning outcomes, motivation, and student engagement [17], [18], [19], [20], including in STEM-related learning contexts [21], [22]. From another perspective, the implementation of gamification is highly dependent on its context and design, as competitive elements may lead to decreased student motivation and satisfaction [23], [24], [25], [26]. Therefore, gamification needs to be designed based on user needs and theoretical foundations [27], [28] and combined with digital media designed in accordance with multimedia learning principles [29], [30]. In the context of mathematics education, gamification can complement STEAM by providing structured challenges, progressive learning activities, feedback, and opportunities for active participation. While STEAM provides an interdisciplinary framework for exploring and applying mathematical concepts, gamification can organize

these activities into engaging learning experiences through appropriately selected game elements. Thus, the integration of STEAM and gamification offers a complementary instructional design approach rather than two independent strategies. Nevertheless, its potential implementation requires careful consideration of students' learning characteristics and the instructional objectives to avoid emphasizing competition or entertainment at the expense of mathematical understanding.

The context of this study is the Basic Concepts of Elementary Mathematics course in the Elementary School Teacher Education Study Program at Samudra University, with a focus on sequences and series. This topic requires students to identify and generalize patterns, which are considered sources of difficulty [31], as well as to understand the concepts underlying the solution processes [2]. Sequences and series were selected because understanding these topics involves recognizing numerical patterns, identifying relationships between terms, formulating general rules, and applying mathematical procedures to determine particular or subsequent terms. These requirements make the topic relevant to the integration of STEAM activities, particularly through pattern exploration, logical reasoning, creative problem-solving, and the representation of mathematical relationships. Furthermore, the topic provides opportunities to incorporate gamification through progressive challenges and problem-solving tasks that require students to demonstrate conceptual understanding rather than simply complete calculations. An initial interview study revealed that lecturers experienced limitations in teaching materials to support varied learning approaches. Interactive and contextual teaching materials that facilitate independent learning among students are also still limited. These conditions indicate a discrepancy between the potential of technology-supported, interdisciplinary, and engaging learning approaches and the availability of teaching materials that respond to actual instructional requirements.

Although previous studies have examined STEAM-based digital modules, STEAM-oriented project-based learning, and the implementation of gamification in educational settings, their primary emphasis has generally been on learning outcomes, motivation, engagement, and the implementation of instructional interventions [13], [14], [15], [17], [18], [19], [20], [21], [22]. Other studies have highlighted the importance of contextual design, user needs, and multimedia principles in developing gamified learning environments [23], [24], [25], [26], [27], [28], [29], [30]. However, these research directions do not fully address the preliminary conditions required to develop integrated STEAM-based and gamified digital teaching materials for a specific mathematics topic in higher education. In particular, a needs analysis that simultaneously examines lecturers' perspectives on existing instructional limitations, students' learning characteristics, and students' perceptions of the teaching materials and support they require remains insufficiently addressed in the context of sequences and series within elementary school teacher education programs. This gap is important because the development of digital teaching materials based solely on the potential of an instructional approach may overlook the actual characteristics and requirements of their intended users.

The development of effective teaching materials requires a needs analysis at the initial stage to ensure that the resulting product aligns with users’ conditions and

requirements. In this process, learning style questionnaires can provide descriptive information about students' preferred ways of accessing information, engaging with learning activities, and responding to instructional materials. Such information is useful for identifying variations in students' learning preferences and informing the presentation of content, learning activities, and multimedia components. In this study, learning style information is treated as one component of a broader needs analysis rather than as a fixed classification of students or a basis for assuming that instruction must be matched to a single learning style. This study aims to analyze the needs for developing STEAM-based digital teaching materials with a gamification approach for higher education students through the triangulation of three data sources, namely: (i) the conditions and limitations of teaching materials according to lecturers; (ii) students' learning style characteristics; and (iii) students' perceptions, needs, and support. The novelty of this study lies in the integration of these three complementary perspectives within a specific mathematical topic, namely sequences and series, to establish an empirical basis for designing STEAM-based digital teaching materials supported by gamification. Rather than evaluating the effectiveness of an existing intervention, this study translates the identified needs into instructional and design considerations for subsequent product development.

Based on this rationale, the study addresses the following research questions:

1. What are the existing conditions and limitations of mathematics teaching materials, particularly from the lecturers' perspectives, in teaching sequences and series?
2. What are the learning style characteristics of students in the Elementary School Teacher Education Study Program that need to be considered in developing digital teaching materials?
3. What are students' perceptions, needs, and expectations regarding STEAM-based digital teaching materials with a gamification approach for learning sequences and series?
4. What instructional and design considerations can be derived from the integration of lecturers' perspectives, students' learning characteristics, and students' perceptions to inform the development of STEAM-based digital teaching materials with a gamification approach?

The findings are expected to contribute to the preliminary design of digital mathematics teaching materials in higher education by providing an evidence-based understanding of user needs. Practically, the results can serve as a reference for lecturers and instructional material developers in designing contextual, interactive, and student-oriented learning resources.

2. METHOD

2.1. Research Design

This study employed a descriptive mixed-methods research design, combining qualitative and quantitative approaches, to identify the requirements for developing STEAM-based digital teaching materials with a gamification approach on the topic of sequences and series [32]. The qualitative component was used to explore lecturers' experiences, instructional challenges, and perspectives regarding existing teaching

materials, whereas the quantitative component was used to describe students' learning style characteristics, perceptions, needs, and preferences. The integration of these two approaches provided a broader understanding of the instructional conditions and requirements that should inform the development of the proposed teaching materials.

This needs analysis represents the initial stage of a series of developments of STEAM-gamification-based digital teaching materials on the topic of sequences and series. The study focused on identifying user needs rather than evaluating the effectiveness of a developed instructional product. The validity of the findings was strengthened through source and instrument triangulation, namely by comparing findings from lecturers and students, as well as from three different instruments [33]. The qualitative and quantitative findings were subsequently compared and integrated to identify convergent findings, complementary information, and specific instructional requirements for the proposed teaching materials.

2.2. Research Participants

The study involved three lecturers who taught the Basic Concepts of Elementary Mathematics course and 225 first-semester students of the Elementary School Teacher Education (PGSD) Study Program at Samudra University. The lecturer participants provided information regarding the instructional process, existing teaching materials, and challenges in teaching sequences and series. Meanwhile, the student participants provided information about their learning characteristics, experiences, preferences, and expectations regarding the proposed digital teaching materials.

The lecturers were involved as participants in the needs analysis interviews, while the first-semester students participated in the learning style and teaching material needs questionnaires. The three lecturers were selected based on their involvement in teaching the relevant mathematics course. The student data were obtained from 225 respondents enrolled in the first semester of the PGSD Study Program.

2.3. Data Sources and Research Instruments

Data were collected using three instruments administered through Google Forms, as summarized in Table 1. Primary data were obtained directly from lecturer interviews and student questionnaire responses. The three instruments were designed to examine complementary aspects of the needs analysis, including instructional conditions, student learning characteristics, and students' perceptions and requirements concerning digital teaching materials.

The instruments consisted of: (1) needs analysis interview guidelines for lecturers; (2) a learning style questionnaire for students; and (3) a teaching material needs analysis questionnaire for students. The learning style questionnaire consisted of 30 five-point Likert-scale statements, in which statements numbered 1–10 represented visual learning styles, numbers 11–20 represented auditory learning styles, and numbers 21–30 represented kinesthetic learning styles. The teaching material needs questionnaire explored the current condition of teaching materials, perceptions of STEAM and gamification, the

level of difficulty of sequences and series materials, digital platform preferences, and support for the development of teaching materials.

The instruments were organized according to the information required for each aspect of the needs analysis. The interview guidelines focused on lecturers' experiences, the availability and limitations of existing teaching materials, instructional challenges, and expectations for future teaching materials. The learning style questionnaire was organized into three groups of statements representing visual, auditory, and kinesthetic learning preferences. The teaching material needs questionnaire addressed students' experiences with existing learning resources, perceptions of the proposed instructional approaches, difficulties in understanding sequences and series, and preferences regarding digital teaching materials.

The learning style questionnaire used three dimensions, namely visual, auditory, and kinesthetic preferences, to describe students' reported learning tendencies. These dimensions were used descriptively to provide information about students' preferences and to inform the presentation of digital instructional materials. They were not intended to represent fixed cognitive characteristics or to establish that students could learn effectively through only one particular modality.

Table 1. Instruments, respondents, and types of needs analysis data

No	Instrument	Respondents	Number	Type of Data
1	Needs analysis interview guidelines	Course lecturers	3 people	Qualitative (descriptive narrative)
2	Learning style questionnaire	First-semester PGSD students	225 students	Quantitative (5-point Likert scale)
3	Needs analysis questionnaire	First-semester PGSD students	225 students	Quantitative descriptive (percentage)

2.4. Data Collection Procedures

Data collection involved three complementary procedures. First, interviews were conducted with three lecturers who taught the Basic Concepts of Elementary Mathematics course to identify the existing conditions of instructional materials, teaching challenges, and requirements for developing digital teaching materials. Second, the learning style questionnaire was administered to 225 first-semester PGSD students to identify their reported visual, auditory, and kinesthetic learning preferences. Third, the teaching material needs analysis questionnaire was administered to the same group of students to obtain information regarding their perceptions, learning difficulties, preferred digital platforms, and expectations for STEAM-based digital teaching materials with a gamification approach.

The questionnaires were distributed through Google Forms. The collected responses were organized according to their respective instruments and prepared for qualitative and quantitative analysis.

2.5. Data Analysis

Interview data were analyzed using descriptive narrative analysis through data reduction, data presentation, and conclusion drawing [34]. The interview analysis involved several interconnected steps. First, the researchers organized the interview responses and identified information relevant to the research objectives. Second, the responses were reduced by selecting and grouping statements related to the availability and limitations of teaching materials, instructional challenges, the implementation of STEAM and gamification, and lecturers' expectations. Third, relevant statements were assigned descriptive codes and grouped into broader categories based on similarities in meaning. Fourth, the categories were synthesized into major themes representing the lecturers' perspectives on the requirements for developing digital teaching materials. Finally, the identified themes were interpreted and compared with the findings from the student questionnaires.

The learning style questionnaire data were weighted as follows: Strongly Disagree = 1, Disagree = 2, Undecided = 3, Agree = 4, and Strongly Agree = 5. The average score for each group of statements was calculated for each respondent (range 1.00–5.00); the dominant learning style was determined based on the group with the highest average score. If two or three groups obtained the same highest score, respondents were categorized as having multiple learning style tendencies. The calculation was performed separately for the visual, auditory, and kinesthetic dimensions, with each dimension consisting of ten statements. The resulting scores were interpreted as indicators of students' reported learning preferences rather than definitive classifications of their learning abilities.

The needs analysis questionnaire data were analyzed using descriptive statistics in the form of frequencies and percentages based on the total number of respondents (n = 225). The percentage for each response category was calculated by dividing the frequency of responses by the total number of respondents and multiplying the result by 100%. The findings were then summarized to describe students' perceptions of existing teaching materials, their understanding of STEAM and gamification, perceived difficulties in sequences and series, preferred digital platforms, and support for the proposed teaching materials.

The integration of qualitative and quantitative findings was conducted through a comparative triangulation process. First, the researchers summarized the themes obtained from lecturer interviews. Second, the results of the learning style questionnaire and teaching material needs questionnaire were organized according to their respective analytical dimensions. Third, findings from the three instruments were compared to identify areas of convergence, complementarity, and divergence. Convergent findings were used to identify instructional needs supported by more than one data source, while complementary findings provided additional information about specific requirements that emerged from individual instruments. Any differences between lecturers' perspectives and students' responses were considered in interpreting the findings. Finally, the integrated results were translated into instructional and design implications for the proposed STEAM-based digital teaching materials with a gamification approach.

3. RESULTS

This section presents the findings of the needs analysis based on three data sources: interviews with three lecturers, a learning style questionnaire completed by 225 first-semester PGSD students, and a teaching material needs questionnaire completed by the same students. The results are organized according to the three dimensions of the needs analysis, followed by an integrated interpretation of the findings to identify priorities for developing STEAM-based digital teaching materials with a gamification approach.

3.1. Results of Lecturer Interviews

The interview results with the three lecturers revealed that the ongoing lecture process follows a curriculum aligned with the Indonesian National Qualifications Framework (KKNI), the Merdeka Belajar Kampus Merdeka (MBKM) policy, and the principles of Outcome-Based Education (OBE). The learning models implemented are varied, including Problem-Based Learning, interactive lectures, discussions, assignments, presentations, and project-based learning. However, the integration of STEAM and gamification approaches into teaching materials remains very limited.

The interview findings were grouped into five main themes. First, the availability of instructional resources remains limited, particularly teaching materials that systematically support Case Method, Project-Based Learning, and STEAM-oriented activities. Second, students demonstrate diverse levels of prior mathematical knowledge, requiring lecturers to provide differentiated instructional support. Third, students experience difficulties connecting mathematical concepts with contextual problems, determining appropriate problem-solving strategies, and explaining the logical reasoning underlying their answers. Fourth, interactive digital teaching materials that facilitate independent learning remain limited. Fifth, conceptual understanding remains a challenge, as some students can perform mathematical procedures but have difficulty explaining the underlying concepts and translating them into explanations suitable for elementary school students.

Other findings indicated that the overall topics in the course are considered difficult because they require multiple mathematical abilities simultaneously; therefore, sequences and series were selected as the research focus. The teaching materials currently used consist of required textbooks, printed modules, presentation materials, assignment sheets, internet articles, and learning videos. Although these resources provide basic instructional support, their presentation remains predominantly focused on explanations and exercises. They have not been systematically integrated into a single learning resource that combines contextual STEAM activities, structured problem-solving tasks, concept visualization, interactive feedback, and gamification elements.

The lecturers expected the availability of digital teaching materials that are easily accessible, interactive, relevant to elementary school curricula, and contain contextual problems, concept visualization, gradual exercises (scaffolding), feedback, and gamification elements, which can be used for both face-to-face learning and independent learning. These expectations indicate that the required digital teaching materials should function not merely as supplementary learning resources but as structured instructional

environments that support conceptual understanding, mathematical reasoning, and the development of pedagogical content knowledge among prospective elementary school teachers.

3.2. Results of Learning Style Questionnaire

Based on the learning style questionnaire responses, the overall average scores of respondents (n = 225) were 3.43 for visual learning style, 3.35 for auditory learning style, and 3.48 for kinesthetic learning style on a scale of 1–5. The relatively small differences among these average scores indicate that the three dimensions were reported at broadly comparable levels, with kinesthetic preferences showing the highest mean score. This pattern suggests that students reported preferences across multiple learning modalities rather than demonstrating an exclusively dominant preference for one modality. The distribution of dominant learning styles is presented in Table 2.

A total of 197 students (87.6%) had a single dominant learning style, while 28 students (12.4%) showed tendencies toward multiple learning styles, with the visual and kinesthetic combination being the most common pattern. The classification was determined by comparing each respondent's average score across the three questionnaire dimensions. A single dominant tendency was assigned when one dimension obtained the highest average score. Respondents were classified as having multiple learning style tendencies when two or three dimensions obtained identical highest average scores. These categories represent questionnaire-based preferences and should not be interpreted as fixed learning characteristics.

Table 2. Distribution of students' dominant learning style tendencies

Category	Learning Style	Number	Percentage (n = 225)
Single	Kinesthetic	89	39.4%
	Visual	72	32.1%
	Auditory	36	16.1%
	Subtotal of single learning styles	197	87.6%
Multiple	Visual & kinesthetic	14	6.0%
	Auditory & kinesthetic	9	4.4%
	Visual & auditory	4	1.6%
	Visual, auditory, & kinesthetic	1	0.4%
	Subtotal of multiple learning styles	28	12.4%

The distribution indicates that kinesthetic preferences were the most frequently identified single tendency, followed by visual and auditory preferences. However, the presence of multiple tendencies among 12.4% of respondents, together with the relatively close overall mean scores, suggests that the proposed teaching materials should provide varied forms of engagement. These findings provide descriptive information for considering interactive activities, visual representations, and verbal explanations in the instructional design, rather than establishing that any particular modality will produce better learning outcomes.

3.3. Results of Teaching Material Needs Questionnaire

Based on the teaching material needs questionnaire, the results showed that 89.3% of students stated that the main teaching materials currently used were still textbooks, with supporting materials including presentation slides, videos, articles, journals, and modules. The conditions of teaching materials and students' perceptions of STEAM-gamification are presented in Table 3. A total of 76.9% of students had used sources other than the main textbooks, and 87.1% considered the existing teaching materials appropriate to their needs. However, all respondents considered additional teaching materials important (41.8% considered them very important and 58.2% considered them sufficiently important).

These findings reveal an important distinction between the perceived suitability of existing teaching materials and the perceived need for additional resources. Although most students considered the current materials suitable for supporting their learning, all respondents indicated that additional materials were important. This suggests that the availability of textbooks and supplementary resources does not necessarily eliminate the need for more interactive and varied learning experiences.

A total of 90.2% of students expressed interest in learning integrated with STEAM, gamification, and digital technology, and 96.4% considered that these approaches have the potential to be integrated into the course. However, 65.8% stated that STEAM-gamification teaching materials were not yet available, and 43.6% admitted that they had very limited knowledge of these concepts.

The combination of high interest and limited familiarity indicates that students are receptive to the proposed approach but may require an introductory explanation of STEAM and gamification before engaging with the developed materials. Therefore, the initial design should not assume that students already understand the interdisciplinary relationships or instructional purposes of these approaches.

Table 3. Conditions of teaching materials and students' perceptions of STEAM-gamification

Aspect	Answer 1: Number (%)	Answer 2: Number (%)
Availability of learning sources other than the main textbook	Available: 173 (76.9%)	Not available: 52 (23.1%)
Suitability of teaching materials with learning needs	Suitable: 196 (87%)	Not suitable: 29 (13%)
Importance of additional teaching materials	Very important: 94 (41.8%)	Quite important: 131 (58.2%)
Opinion on integrating materials with STEAM, gamification, and digital technology	Like/strongly like: 203 (90%)	Dislike/strongly dislike: 22 (10%)
Availability of STEAM-gamification teaching materials	Available: 77 (34.2%)	Not available: 148 (65.8%)
Knowledge of STEAM and gamification	Know enough/very knowledgeable: 127 (56.4%)	Very unfamiliar: 98 (43.6%)
Potential integration of STEAM-gamification into the course	Potential/quite potential: 217 (96.5%)	Not potential: 8 (3.6%)

The needs for teaching materials were further analyzed in relation to sequences and series topics. The results presented in Table 4 show that 85.3% of students liked this topic, although 59.1% considered it difficult. A total of 93.3% were interested in using additional teaching materials, and 95.1% needed attractive alternative teaching materials. Support for the development of STEAM-gamification-based digital teaching materials was consistently above 88% for each statement, with 94.7% stating that such teaching materials should be developed.

These results demonstrate that students' positive attitudes toward sequences and series coexist with perceived learning difficulties. Therefore, interest in the topic should not be interpreted as evidence of conceptual mastery. Instead, the findings suggest a need for instructional resources that can help students move from recognizing numerical patterns to understanding relationships between terms, formulating general rules, and explaining mathematical reasoning.

Table 4. Students' conditions, needs, and support for sequences and series materials

Aspect / Statement	Positive: Number (%)	Others: Number (%)
Interest in sequences and series materials	Like/strongly like: 192 (85.3%)	Dislike/strongly dislike: 33 (14.7%)
Difficulty level of the material	Difficult/very difficult: 133 (59.2%)	Not difficult/very not difficult: 92 (40.8%)
Interest in using additional teaching materials	Interested/very interested: 210 (93.3%)	Not interested: 15 (6.7%)
Need for attractive alternative teaching materials	Need: 214 (95.1%)	Do not need: 11 (4.9%)
Materials are easier to understand when integrated with STEAM-gamification	Agree/strongly agree: 200 (88.9%)	Disagree/strongly disagree: 25 (11.1%)
Need to develop STEAM-gamification-based digital teaching materials	Agree/strongly agree: 213 (94.7%)	Disagree/strongly disagree: 12 (5.3%)
STEAM-gamification teaching materials are more attractive than ordinary textbooks	Agree/strongly agree: 199 (88.4%)	Disagree/strongly disagree: 26 (11.5%)

Regarding the presentation platform (Table 5; multiple choices allowed), the majority of students (74.2%) selected Learning Management Systems (LMS), such as Moodle or Google Classroom, followed by educational websites and online courses (23.6%), as well as interactive content creators such as H5P and Canva (17.3%).

The preference for LMS platforms indicates that students favor a centralized environment for accessing learning materials. However, the selections of educational websites and interactive content creators also indicate the relevance of integrating supplementary digital resources within the main learning environment. These preferences provide practical considerations for selecting a platform that supports accessibility, content organization, and interactive learning activities.

Table 5. Digital platform preferences for teaching material presentation (n = 225)

No.	Type of Digital Platform	Number of Selections	Percentage
1	LMS (e.g., Moodle or Google Classroom)	167	74.2%
2	Educational websites and online courses	53	23.6%
3	Interactive content and media creators (e.g., H5P, Canva)	39	17.3%

3.4. Triangulation of Findings

The three data sources produced complementary and mutually reinforcing findings, as presented in Table 6. Lecturer interviews identified instructional limitations and expectations from the perspective of course delivery, while the learning style questionnaire provided information about students' reported learning preferences. The teaching material needs questionnaire further identified students' perceptions of existing resources, perceived difficulties, and support for the proposed instructional approach.

The comparison indicates convergence in the need for more interactive and varied teaching materials. Lecturers emphasized contextual problems, visualization, scaffolding, and feedback, while students reported considerable interest in additional teaching materials and strong support for the proposed STEAM-gamification approach. The learning style questionnaire provided complementary information regarding the reported preferences that could be considered when designing the presentation of instructional content.

Sequences and series became the intersection point as a priority topic because it was considered interesting but still perceived as difficult. This finding connects lecturers' concerns about students' mathematical reasoning with students' reported difficulties in the selected topic. Nevertheless, the questionnaire findings reflect perceived difficulty rather than demonstrated mathematical performance.

Table 6. Triangulation of findings from three instruments

Finding Aspect	Lecturer Interview	Learning Style Questionnaire	Student Needs Questionnaire
Availability of STEAM-gamification teaching materials	Very limited and not systematically developed	–	65.8% stated that such materials were not available
Need for interactive and contextual teaching materials	Highly needed; containing contextual problems, visualization, and feedback	Kinesthetic 39.4% and visual 32.1%: require interactive and visual activities	93.3% interested in additional teaching materials; 95.1% need attractive alternatives
Priority topic	Problem-solving materials and mathematical literacy	–	Sequences and series: liked (85.3%) but considered difficult (59.2%)
Support for STEAM-gamification	Fully expected by both lecturers	Multimodal characteristics	94.7% agreed that it should be developed
Presentation platform	Easily accessible and flexible	–	74.2% selected LMS

The triangulation results suggest that the strongest design priorities are the integration of contextual mathematical problems, structured conceptual explanations, interactive learning activities, progressive exercises, and accessible digital delivery. These priorities were derived from the convergence of lecturers' instructional expectations and students' reported needs, while the learning style findings provided additional descriptive information for considering varied content presentation.

4. DISCUSSION

4.1. The Gap between Existing Teaching Materials and Instructional Needs

The findings indicate a discrepancy between the availability of existing teaching materials and the broader requirements of the learning process. Although 87.1% of students considered the currently used teaching materials appropriate, all students perceived additional teaching materials as important. This apparent difference suggests that students distinguish between the adequacy of existing resources for basic course requirements and the need for supplementary materials that provide more varied learning experiences.

The authors interpret that the existing teaching materials fulfill the basic need for learning resources, particularly textbooks, rather than fully addressing the need for interactive teaching materials. This interpretation is consistent with the lecturers' concerns that the current presentation remains predominantly one-directional. The findings therefore suggest that the development of digital teaching materials should not simply replace existing textbooks but should complement them through interactive and contextual learning experiences. This interpretation requires further investigation in future studies. Evidence from meta-analysis reviews showing that digital media can improve mathematics learning achievement, particularly mathematical abilities [15], [35], supports the direction of developing such digital teaching materials.

Nevertheless, the potential benefits of digital media should not be interpreted as evidence that the proposed materials will automatically improve learning outcomes. Their contribution will depend on the quality of instructional design, the relevance of the mathematical content, and the extent to which interactive features support students' conceptual understanding and mathematical reasoning.

4.2. Student Readiness and the Integration of STEAM and Gamification

The relationship between high interest and limited knowledge represents an important consideration for the development of the proposed teaching materials. Although 90.2% of students expressed interest in STEAM-gamification-based learning, 43.6% reported very limited knowledge of these concepts. This combination indicates a favorable initial reception but also highlights the need for instructional orientation. Students should understand that STEAM involves meaningful interdisciplinary connections rather than merely combining several subjects or presenting attractive activities.

This interpretation is consistent with the interdisciplinary orientation of STEAM [7], [8]. In the context of sequences and series, the integration of STEAM should be based on mathematical relationships that can be explored through relevant interdisciplinary

contexts. For example, students can investigate numerical patterns in architectural structures, repeated motifs in traditional art, population growth, or energy consumption. Science can provide phenomena involving measurable changes over time; technology can support digital visualization and simulation of numerical patterns; engineering can involve designing structures based on repeated mathematical sequences; arts can provide opportunities to investigate patterns, symmetry, and visual arrangements; and mathematics serves as the foundation for identifying terms, generalizing patterns, and determining relationships between quantities.

These examples illustrate that STEAM integration should retain the mathematical objectives of sequences and series as its central focus. Interdisciplinary activities should provide meaningful contexts for mathematical exploration rather than introduce unrelated activities from other disciplines.

4.3. Mathematical Difficulties and the Need for Conceptual Scaffolding

Initial interest can serve as a motivational foundation, while learning difficulties require support through visualization and gradual exercises. Difficulties in generalizing patterns [31] and the tendency to understand procedures without conceptual understanding [2] are consistent with lecturers' findings regarding misconceptions and difficulties in explaining logical reasoning.

For prospective elementary school teachers, the ability to explain mathematical reasoning is an essential component of content knowledge for teaching [1]. Therefore, teaching materials need to begin each unit with contextual problem-based activities [36], provide scaffolding [37], and deliver informative feedback [38], while simultaneously training students' mathematical abilities [15].

The instructional sequence should guide students from identifying patterns to explaining relationships and constructing general mathematical expressions. For example, an activity on numerical patterns may begin with a visual representation of an arrangement of objects, followed by identifying changes between successive arrangements, determining the relationship between terms, formulating a general rule, and applying the rule to solve a contextual problem. Progressive hints and feedback can help students identify errors in their reasoning rather than merely indicate whether an answer is correct or incorrect.

Such scaffolding is particularly important for prospective elementary school teachers because they need to understand not only how to obtain mathematical answers but also how to explain the reasoning underlying those answers to elementary school students.

4.4. Learning Preferences and Multimodal Digital Design

The learning style questionnaire results showed relatively close average scores across the visual, auditory, and kinesthetic dimensions, with a slightly higher mean for kinesthetic preferences. The distribution also indicated that 12.4% of students demonstrated multiple learning style tendencies. These findings provide descriptive information about students' reported preferences and suggest that the proposed teaching materials may benefit from varied forms of content presentation.

However, learning styles and multimodal design require careful interpretation. Reviews of empirical evidence conclude that there is insufficient support for the assumption that instruction tailored to individual learning styles improves learning outcomes [39]. Consequently, the visual, auditory, and kinesthetic categories should not be treated as fixed student characteristics or as evidence that matching instruction to a particular category will improve achievement. The questionnaire findings are more appropriately used as supplementary information for considering different ways of presenting and engaging with mathematical content.

The integration of visualization, interactive activities, and narration is more appropriately based on multimedia learning principles [30]. For example, numerical patterns can be presented through diagrams and animations, while interactive activities can allow students to manipulate numerical sequences, compare successive terms, and explore mathematical relationships. Audio narration can complement visual explanations, particularly when introducing mathematical concepts or providing instructions. These features should be integrated according to their instructional relevance and should avoid unnecessary multimedia elements that may distract students from the mathematical content.

Importantly, students' preferences for interactive or hands-on activities do not necessarily demonstrate that these activities produce better learning outcomes. Their effectiveness needs to be examined through subsequent empirical testing using appropriate measures of mathematical understanding and performance.

4.5. Gamification as Support for Mathematical Reasoning

Students' enthusiasm is consistent with evidence indicating that gamification generally produces positive impacts [17], [18], [19], [20]. The design of gamification should support psychological needs for autonomy, competence, and relatedness [28] and direct game elements toward targeted learning behaviors [25].

In this study, the findings indicate a need to integrate gamification in ways that support mathematical learning rather than simply increase student engagement. Points and badges can be used to recognize the completion of mathematical reasoning tasks, while levels can represent progressive mastery of increasingly complex concepts. Gradual missions can require students to identify numerical patterns, determine relationships between terms, formulate general rules, and apply those rules to contextual problems. Immediate feedback can provide explanations of incorrect responses and guide students toward revising their mathematical reasoning.

These elements may include points and badges as indicators of progress, levels and gradual missions, as well as instant feedback, while leaderboards should be optional or implemented through team-based approaches. This design consideration is particularly relevant because competitive elements should not become the primary measure of learning success. Instead, the emphasis should remain on conceptual understanding, problem-solving processes, and the quality of students' mathematical explanations.

4.6. Digital Platform Preferences and Instructional Accessibility

Ultimately, the integration of digital platforms in the development of mathematics teaching materials provides new opportunities to create collaborative, interactive learning environments that support students' digital behaviors [40], [41]. The combination of STEAM and gamification can serve as a foundation for developing teaching materials that respond to the needs of 21st-century learning.

Both approaches have different but complementary roles. STEAM assists developers in designing contextual teaching materials and connecting various fields of knowledge. Gamification assists developers in packaging learning content into a gradual and interactive pathway while providing immediate feedback so that students remain motivated and engaged [42], [43], [44].

The preference of 74.2% of students for LMS platforms provides a practical basis for considering Moodle or Google Classroom as the primary delivery environment. Such platforms can organize learning materials, instructional instructions, activities, and assessment components in a centralized location. Interactive resources developed using tools such as H5P can be incorporated into this environment to support numerical exploration, formative assessment, and feedback. However, the selection of the platform should also consider accessibility, technical compatibility, and the ability to support independent and face-to-face learning.

4.7. Implications for Teaching Material Design

The findings from the three data sources were translated into a set of instructional design principles. These principles connect the identified needs with specific features that can be incorporated into the development of STEAM-based digital teaching materials with a gamification approach. Table 7 presents this relationship..

Table 7. Needs analysis findings and their implications for teaching material design

Findings	Teaching Material Design Principles
Students have difficulties connecting concepts with contexts (lecturers)	Contextual and problem-based: each unit begins with real-world problems (e.g., building patterns, population growth, energy-saving patterns) [36]
65.8% have not encountered STEAM-gamification teaching materials; 43.6% have very limited knowledge of the concepts	STEAM integration: science (natural disaster phenomena), technology (digital simulations), engineering (structural pattern design), arts (visual patterns and motifs), and brief orientation sessions [7], [8]
90% of students like this approach	Gamification: points, levels, badges, gradual missions, instant feedback; leaderboards are optional [23], [26]
Kinesthetic 39.4%, visual 32.1%, auditory 16.1%, multiple 12.4%	Multimodal: pattern diagrams and animations, interactive activities (*drag-and-drop*, simulations), and audio narration [30]
59.2% consider the material difficult; lecturers reported misconceptions	Gradual learning: structured exercises, progressive hints, and automated feedback [37]–[38]
74.2% selected LMS	LMS compatibility: embed format, SCORM, or H5P integration on Moodle or Google Classroom
Lecturers expect independent and face-to-face learning support	Flexibility: accessible online and offline, usable inside and outside the classroom

Table 7 demonstrates that each design principle is linked to an identified instructional need rather than being selected solely because a particular digital feature is popular. The contextual and problem-based components respond to lecturers' concerns about students' difficulties in connecting mathematical concepts with real-world situations. STEAM integration addresses the need to develop interdisciplinary mathematical activities, while gamification provides a structured mechanism for organizing progressive learning challenges. Multimodal presentation considers students' reported preferences without assuming that learning style matching improves achievement. Finally, LMS compatibility and flexible access respond to students' platform preferences and lecturers' expectations regarding instructional accessibility.

4.8. Limitations and Future Research

This study has several limitations. First, the participants were drawn from a single institution, namely Samudra University. Consequently, the findings reflect the instructional conditions and student perceptions within a specific institutional context and should not be generalized to other higher education institutions without further investigation.

Second, the quantitative findings were primarily based on students' self-reported perceptions, preferences, and needs. These responses provide information about students' experiences and expectations but do not directly demonstrate their mathematical competence, conceptual understanding, or actual learning difficulties. The perceived difficulty of sequences and series, for example, was not verified through mathematical achievement tests or performance-based assessments.

Third, the visual, auditory, and kinesthetic framework provides a limited representation of students' learning preferences. The classification does not account for the complexity and flexibility of learning processes, and the resulting categories should not be regarded as fixed student characteristics or predictors of academic achievement.

Fourth, this study represents the preliminary needs analysis stage of teaching material development. It does not establish the validity, practicality, or effectiveness of the proposed STEAM-gamification-based digital teaching materials because the product has not yet been evaluated through subsequent development and testing stages.

Future research should therefore involve students from multiple institutions, incorporate mathematical diagnostic assessments and performance-based tasks, and examine the validity and reliability of the developed instructional instruments. Subsequent studies should also evaluate the feasibility, practicality, and effectiveness of the resulting digital teaching materials, particularly their contribution to students' conceptual understanding, mathematical reasoning, and problem-solving abilities.

5. CONCLUSION

This study identified the learning needs and readiness of first-semester students in the Elementary School Teacher Education Program for the development of STEAM-gamification-based digital teaching materials on sequences and series. The findings revealed a need for more interactive, contextual, and engaging learning resources to

support mathematical understanding and reasoning. Students and lecturers emphasized the importance of contextual STEAM activities, multimodal presentations, progressive learning tasks, and gamification features such as points, levels, missions, and feedback. These findings contribute to the development of digital mathematics learning materials by integrating lecturer perspectives, student characteristics, perceived learning difficulties, and instructional needs into a set of design priorities. The results provide a practical basis for lecturers, instructional designers, and teacher education institutions to design more responsive learning resources; however, the identified preferences and needs should not be interpreted as evidence of the effectiveness of the proposed materials. This study was limited to one higher education institution and relied primarily on interviews and self-reported questionnaires; moreover, the VAK results represent reported preferences rather than fixed learning styles, while perceived mathematical difficulties were not verified through diagnostic assessments. Future research should develop a prototype based on these findings, conduct expert validation and usability testing, and evaluate its practicality and potential effectiveness using appropriate measures of mathematical conceptual understanding, reasoning, and problem-solving across broader educational contexts.

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