JURNAL ABSIS
Jurnal Pendidikan Matematika dan Matematika
Vol. 8 No. 1, April 2025

DESIGNING GAMIFICATION-BASED WORKSHEETS TO ENHANCE STUDENT LEARNING OUTCOMES IN ABSTRACT ALGEBRA COURSE

Nina Agustyaningrum[1], Paskalia Pradanti[2]
[1,2] Universitas Tidar, Indonesia
nina@untidar.ac.id

ABSTRACT Many studies report that abstract algebra is a subject students find difficult to understand, although it is a core course in the mathematics education curriculum. This research was motivated by lecturers' challenges in developing innovative teaching materials that engage students and improve conceptual understanding. The aim was to develop gamification-based student worksheets (LKM) that are valid, practical, and effective in supporting learning outcomes. The research employed the 4D development model by Thiagarajan, which consists of the define, design, development, and dissemination stages. The participants were mathematics education students at Universitas Tidar enrolled in the ring theory course. Research instruments included validation sheets to assess the validity of the materials, student response questionnaires to evaluate practicality, and learning outcome tests on ring theory to assess effectiveness. The results showed that the developed of LKM achieved very high validity (92%), practicality (80%), and effectiveness based on the Wilcoxon test. Therefore, the developed materials are considered appropriate to enhance the learning of abstract algebra in a more interactive and enjoyable manner. The researchers recommend that lecturers of the ring theory course use this LKM as an alternative teaching material to improve students' understanding of abstract concepts in a more engaging and meaningful way.

Keywords: abstract algebra, gamification, student worksheets, ring theory.

ABSTRAK Banyak penelitian menunjukkan bahwa aljabar abstrak merupakan mata kuliah yang sulit dipahami mahasiswa, meskipun termasuk mata kuliah inti dalam kurikulum pendidikan matematika. Penelitian ini dilatarbelakangi oleh tantangan dosen dalam mengembangkan bahan ajar inovatif yang menarik dan memudahkan pemahaman konsep. Tujuannya adalah mengembangkan Lembar Kegiatan Mahasiswa (LKM) berbasis gamifikasi yang valid, praktis, dan efektif untuk mendukung hasil belajar mahasiswa. Metode yang digunakan adalah model pengembangan 4D dari Thiagarajan, yang terdiri atas tahap define, design, development, dan dissemination. Subjek penelitian adalah mahasiswa Pendidikan Matematika Universitas Tidar yang mengambil mata kuliah Teori Ring. Instrumen penelitian yang digunakan meliputi lembar validasi bahan ajar untuk menilai kevalidan bahan ajar, angket respon mahasiswa untuk menilai kepraktisan bahan ajar, serta tes hasil belajar pada materi ring untuk menilai keefektifan bahan ajar. Hasil penelitian menunjukkan bahwa LKM

berbasis gamifikasi yang dikembangkan memenuhi kriteria sangat valid (92%), praktis (80%), dan efektif berdasarkan hasil uji Wilcoxon. Dengan demikian, bahan ajar ini dinilai layak digunakan untuk mendukung pembelajaran aljabar abstrak yang lebih interaktif dan menyenangkan. Peneliti merekomendasikan penggunaan LKM ini oleh dosen pengampu mata kuliah Teori Ring sebagai alternatif bahan ajar yang dapat meningkatkan pemahaman mahasiswa terhadap konsep-konsep abstrak secara lebih menarik dan menyenangkan.

Kata-kata kunci: aljabar abstrak, gamifikasi, lembar kerja mahasiswa, teori ring

INTRODUCTION

Abstract algebra, also known as algebraic structures, is one of the core courses in the mathematics education curriculum at universities (Saragih, 2019; Lestari, 2018; Fadhilah & Jamilah, 2016). This course has a crucial objective, which is to develop students' abilities in logical, analytical, systematic, critical, and creative thinking to solve various mathematical problems (Saragih, 2019). Abstract algebra serves as a crucial foundation for teaching school mathematics as it equips pre-service teachers with a deep understanding of mathematical structures and the interrelation of various concepts. Research has shown that prospective teachers recognize the relevance of abstract algebra, not only due to its strong connections to school mathematics content but also to its applicability in real-life contexts, making it an essential component in their professional preparation (Saragih & Listiani, 2023). Furthermore, knowledge of abstract algebra allows them to perceive conceptual connections across different branches of mathematics in a more comprehensive and meaningful way (Veith et al., 2024). Álvarez et al. (2021) further emphasize that integrating abstract concepts such as groups, rings, and fields into the context of secondary mathematics teaching helps bridge the vertical gap between university-level theory and classroom practice, while simultaneously strengthening the conceptual understanding of pre-service teachers. Therefore, studying abstract algebra is essential in preparing competent and reflective future mathematics educators.

However, abstract algebra frequently presents a significant challenge for students due to its inherently abstract and complex nature. The concepts introduced in this course are deeply embedded in mathematical proofs and demand advanced cognitive skills such as logical reasoning and analytical thinking (Arnawa, 2019; Yerizon et al., 2019; Saefudin & Kintoko, 2018). Previous research has consistently shown that the majority of students face considerable difficulties in mastering abstract algebra (Gnawali, 2024; Alam & Mohanty, 2024; Veith et al., 2022; Subedi, 2020; Arnawa, 2019; Yerizon et al., 2019; Fortes, 2016; Agustyaningrum & Yusnita, 2017; Agustyaningrum et al., 2018; Agustyaningrum et al., 2019; Agustyaningrum et al., 2020). These difficulties include challenges in comprehending abstract definitions and formal proofs that lack real-world context, limited prior knowledge, unfamiliarity with numerous symbols and terminology, ineffective and non-

https://doi.org/10.30606/absis.v8i1.3019

interactive teaching methods, unengaging instructional materials, inadequate integration of technology in instruction, and assignments that do not align with students' levels of understanding. Furthermore, based on observations and interviews with students, a key issue identified is the absence of engaging learning materials and the insufficient integration of technology in the learning process.

Although previous research by Agustyaningrum (2019) have focused on analyzing students' learning difficulties and developing a textbook, challenges continue to emerge, with students still struggling to understand abstract algebra concepts. According to Saefudin & Kintoko (2018), changes in teaching strategies are needed to enhance learning effectiveness in line with rapid information development. These changes require support from appropriate learning tools, defined by Azhar & Yaya (2011) as materials, tools, media, instructions, and guidelines in learning. Learning tools are crucial for educators as guidelines in teaching activities to facilitate the delivery of material. The goal of developing learning tools is to produce products that support students in the learning process, as stated by Amalia et al., (2019) that the proper use of learning tools significantly impacts student learning outcomes.

To address these instructional challenges, researchers have explored various technology-integrated learning approaches. Among these, gamification has emerged as a promising strategy in mathematics education at the tertiary level. For instance, the use of leader board based gamification has been shown to improve student achievement and engagement in calculus courses (Ortis-Rojaz et al., 2025). A 2024 meta-analysis of 13 experimental studies also confirmed the significant positive effects of game-based learning on students' higher-order mathematical thinking. Wang et al., (2025) further reported that gamification can enhance engagement and academic performance in university classrooms. Benefits of gamified instruction include reduced academic stress, increased enjoyment, and improved class participation.

The rise of gamification is closely linked to the increasing importance of digital literacy as a core 21st-century skill, particularly for students and pre-service teachers navigating technology-rich educational environments (Silamut & Petsangsri, 2020; Zan et al., 2021). Digital literacy facilitates the adoption of innovative instructional models such as gamification. As defined by Deterding (2011), gamification involves the use of game elements in non-game contexts to improve engagement and motivation. These elements—such as points, badges, leaderboards, and rewards—are designed to foster participation and a sense of achievement. Jusuf (2016) outlined steps for implementing gamification in learning, including defining objectives, designing scenarios, and applying game dynamics. Studies by Yan & Matore (2023), and Pusztai (2021) have shown that gamification not only supports collaborative learning and retention but also enhances intrinsic motivation and academic performance. These findings highlight the potential of gamification to be

applied in abstract algebra instruction, a subject often regarded as difficult and disengaging.

This potential becomes especially relevant when considering the challenges observed in abstract algebra instruction. The researcher's experience in teaching this subject shows that student learning outcomes are still below expectations, with more than 50% of midterm and final exam grades over the past three years not reaching the B grade criterion. The main issues identified from observations and interviews with students are the perceived difficulty of the course, particularly due to its heavy reliance on proofs, use of unfamiliar mathematical symbols and terms. The primary teaching materials are not attractive, and the limited integration of technology is a factor in learning difficulties. The learning process tends to use discussion, lecture, and Q&A methods, with technology limited to PowerPoint use, e-learning, and the simple quiz application Quizizz. Improvements are needed through the provision of more interactive teaching materials, encouraging active student participation in building concepts, and enhancing technology integration to support learning motivation and digital literacy of students.

To achieve optimal learning objectives, lecturers need to make careful learning planning (Samo & Nubatonis, 2021). Learning tools, including Semester Learning Plans (SLP), Semester Assignment Plans (SAP), teaching materials, learning media, assessment instruments, and other supporting documents, should ideally be self-developed. This planning must consider the background, abilities, and socio-cultural environment of students, prioritizing the use of technology. Good, systematic, and structured planning positively impacts the learning process, learning outcomes, learning interest, and students' positive attitudes (Andari & Lusian, 2014).

Several studies related to the development of abstract algebra teaching materials and learning tools have been conducted. Research by Fadillah & Jamilah (2016) developed abstract algebra teaching materials, showing validity in terms of content, readability, language, and format, with an 18.84% increase in students' mathematical proof abilities. Furthermore, Kusumawati & Kurniawan (2020) developed algebraic structure teaching materials with guided discovery, resulting in valid, practical, and effective materials for enhancing students' abstract thinking and proof-writing abilities. Research by Samo & Nubatonis (2021) developed online learning tools for the algebraic structure course, showing good validity and effectiveness in trials, but highlighting the need for further research to assess the effectiveness of online learning using LMS in assessing process activities and students.

Previous research by Agustyaningrum & Yusnita (2017) have developed abstract algebra teaching materials in the form of modules, but their use was not effective due to material limitations and implementation time constraints. The development of an abstract algebra book by Agustyaningrum et al. (2019) also did not provide maximum impact, with most students still struggling to understand concepts. One

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of the shortcomings of the previously developed teaching material is that it is highly textual, featuring static proofs and providing minimal formative feedback. Such an approach is considered less appropriate for the digital-native generation. So, the novelty in this research focuses on the development of learning tools in the form of gamification-based student worksheets. The objective of this study is to produce teaching materials in the form of gamification-based student worksheets that are valid, practical, and effective in supporting learning outcomes in abstract algebra courses. The worksheets are not only expected to improve student learning outcomes but also help students develop the digital literacy needed in the current technological era. Therefore, this research will integrate technology-based gamification methods, including the use of the online quiz platform Wordwall and providing learning resources through instructional videos embedded in QR codes. Through this research, the researchers hope to make a significant contribution to the development of abstract algebra learning in higher education. The gamification-based learning tools developed are expected to serve as a model for other lecturers in creating more interactive, engaging, and relevant learning experiences for current student needs.

METHODS

This research employed the 4D development model (Define, Design, Develop, Disseminate) by Thiagarajan (1974), which can be used to develop teaching materials or learning tools. The 4D development model consists of four main stages as presented in Figure 1.

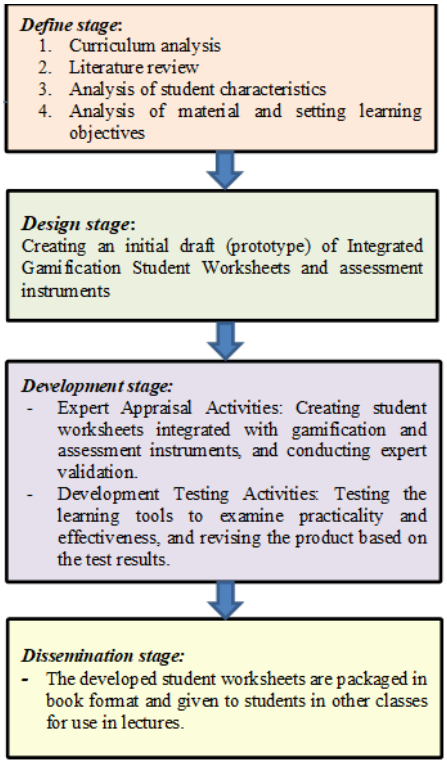

Figure 1. 4D Research Stages

Following Thiagarajan (1974) and as illustrated in Figure 1, the define stage aims to identify the need for developing learning tools by analyzing the curriculum, literature, student characteristics, and materials, and formulating learning objectives. During the design stage, initial design of learning tools (prototype) is carried out based on the previous analysis results. In the develop stage, there are two main activities: Expert Appraisal, where the product is assessed by experts to measure its validity, and Developmental Testing, which involves testing the product on students to measure its practicality and effectiveness. The final stage, disseminate, involves spreading the product to other classes or universities for wider use. The main goal of dissemination is to further test the effectiveness of the tools in various learning contexts.

This research involved 105 Mathematics Education students from Tidar University taking the Ring Theory course, divided into three classes. One class was involved in instrument testing and another class for product testing. The research instruments used included learning outcome tests in the ring theory course, validation sheets, and student response questionnaires for practicality testing. The analysis first conducted was validity testing aimed at assessing the level of validity of the gamification-based learning tools developed. The results of the validator assessments on all evaluated aspects were calculated for the average percentage score and classified according to the criteria in Table 1. Similarly, practicality testing was conducted through a Likert-scale practicality questionnaire for the teaching materials. The average score calculations were then classified according to the criteria in Table 1. Teaching materials are considered valid and practical if the average validity and practicality scores are at least in the "valid" and "practical" categories. For the validation sheets, the researcher used a Likert scale interval of 1-5, while for the practicality questionnaire, a scale of 1-4 was used.

Table 1. Validity and Practicality Assessment Criteria

Theoretical Interval	Validity Score Interval	Practicality Score Interval	Criteria
$M_i + 1{,}5S_i < X$	$4 < X$	$3.25 < X$	Highly Valid/Highly Practical
$M_i + 0{,}5S_i < X \leq M_i + 1{,}5S_i$	$3.33 < X \leq 4$	$2.75 < X \leq 3.25$	Valid/Practical
$M_i - 0{,}5S_i < X \leq M_i + 0{,}5S_i$	$2.67 < X \leq 3.33$	$0{,}5S_i < X \leq 2.75$	Moderately Valid/Moderately Practical
$M_i - 1{,}5S_i < X \leq M_i - 0{,}5S_i$	$2 < X \leq 2.67$	$1.75 < X \leq 2.25$	Less Valid/Less Practical
$X \leq M_i - 1{,}5S_i$	$X \leq 2$	$X \leq 1.75$	Not Valid/Not Practical

Source: Azwar (2013)

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Description:

X = Total actual score

Mi = Ideal mean score = $\frac{1}{2}$(maximum score + minimum score)

Si = Ideal standard deviation = $\frac{1}{6}$(maximum score - minimum score)

The final analysis involves evaluating the effectiveness of the gamification-based Abstract Algebra worksheets through an experimental procedure using a One-Group Pretest-Posttest Design, focusing on the learning outcome variable. The first step in this effectiveness assessment is to test the normality assumption of the pretest and posttest learning outcome data. Following this, a Paired Sample T-Test is conducted to determine whether there is a statistically significant difference in the mean scores between the pretest and posttest results. This trial was conducted in a single 100-minute learning session due to time constraints within the instructional context. The material tested was Worksheet 1 (LKM 1), which covers the definition and types of rings. The learning session was conducted by applying gamification principles embedded in the worksheet, beginning with a summary review activity, followed by watching an instructional video where students were asked to formulate questions, and a set of challenges consisting of practice exercises and a quiz. These activities incorporated a point-based system and allowed for flexible implementation using various game-based learning strategies. The developed learning materials are considered effective if the results of the Paired Sample T Test show statistically significant improvement.

FINDING AND DISCUSSION

This development research produced a teaching material product in the form of student worksheets integrated with gamification. The gamified student worksheets developed consist of several components: narrative (summary of the material), progressive (student learning flow), and challenge (structured exercises and game-based quizzes). Each challenge activity provides 100 points, and students can achieve maximum points by completing all activities correctly. The research and development stages of the instructional materials are outlined as follows.

Define Stage

Curriculum Analysis

This stage involved observing the learning process of abstract algebra and discussions with course instructors regarding the curriculum, material content, instructional materials used, teaching methods, and student characteristics. It was found that the abstract algebra course is divided into two semesters: Group Theory in the 4th semester and Ring Theory in the 5th semester. The curriculum follows an outcome-based education (OBE) framework, incorporating assessment components such as projects and case methods. Teaching methods vary, including expository, cooperative, and collaborative learning. However, game-based methods have rarely

been implemented. Additionally, gamification-based student worksheets have not been previously used.

Literature Review

Relevant literature on gamification approaches and their integration into lesson plans was reviewed. The researcher analyzed materials by collecting and reviewing relevant references such as the existing syllabus and abstract algebra textbooks to systematically develop learning objectives for the instructional materials.

Student Analysis

To determine students' needs in abstract algebra learning, a needs assessment survey was distributed to 46 students enrolled in the ring theory course. Results showed that 76% of respondents found abstract algebra challenging, and over 90% expressed interest in trying game-based learning methods.

Material Analysis and Setting Learning Objectives

Material analysis involved identifying key topics, gathering and selecting relevant materials, and systematically organizing them. The instructional materials focused on the Ring Theory course being taught during the odd semester of the 2024/2025 academic year. The learning objectives encompassed the semester's nine subtopics: (1) Definitions of ring, unity ring, commutative ring, and commutative ring with unity; (2) Properties of rings; (3) Subring and subring theorems;(4) Zero divisors, units, integral domains, fields, and subfields; (5) Idempotents and nilpotents; (6) Ideals and ideal theorems; (7) Principal, prime, and maximal ideals; (8) Factor rings; (9) Homomorphisms, kernels, images, monomorphisms, and epimorphisms.

Design Stage

This stage focused on creating a blueprint for the gamified SWs based on the define stage findings. Research instruments, including validation questionnaires, student response surveys, and learning outcome tests, were also developed. The SWs contained material summaries, example problems with solutions, instructional videos, practice exercises, and gamified activities using platforms like Wordwall and QuizWhizer. Each subtopic consisted of (1) Narrative: A summary of the topic presented as text or video; (2) Progressive: The sequence of tasks students follow; and (3) Challenge: Exercises and game-based quizzes. The progressive flow of scaffolded tasks is illustrated in Figure 2.

Figure 2. Progressive Flow in the Student Worksheet

https://doi.org/10.30606/absis.v8i1.3019

Tahap Development

Expert Appraisal

This stage involved validating the product's feasibility. Subject matter experts from three universities evaluated the student worksheets: Universitas Ahmad Dahlan, STPN Yogyakarta, and STKIP PGRI Bangkalan. The student worksheets were deemed valid but received feedback to incorporate more modern computational or visual approaches rather than relying on classical textual methods. However, given the basic level of the material, the abstract concepts required strong foundational understanding before advancing. Table 2 shows the summarized results of the validation assessment by the three validators.

Table 2. Analysis of Student Worksheet Validation Results

Aspect Assessed	Score Percentage	Validity Category
Presentation Feasibility	92%	Highly Valid
Content Feasibility	91.85%	Highly Valid
Construction Feasibility	91.11%	Highly Valid
Language Feasibility	93.33%	Highly Valid
Overall Feasibility	92%	Highly Valid

Based on expert evaluations, the gamification-integrated student worksheets developed is deemed highly valid.

Developmental Testing

At this stage, the revised and validated student worksheets were tested to gather student responses toward the developed learning module. The trial was conducted during the initial learning of ring theory in student worksheets material 1, which covers the Definition and Types of Rings. The researcher implemented a gamification-based learning experiment using a game inspired by the game show Hexagon War. Before the lesson, students were given a pretest to assess their prior knowledge of the material. Following this, the lesson was conducted, and a posttest was administered to evaluate learning outcomes. Additionally, a student response questionnaire was distributed to assess the practicality of the developed learning material, with the results shown in Table 3.

Table 3. Practicality Analysis Results

Aspect	Percentage Score	Overall Percentage	Category
Material Presentation	81.2	80	Practical
Motivation	78.72		

Aspect	Percentage Score	Overall Percentage	Category
Gamification	81.41		

Given that all participants had no prior instruction in ring theory, the pretest served as a baseline diagnostic of their initial understanding. The effectiveness of the learning intervention was primarily evaluated by the improvement in students' posttest scores. Table 4 presents the pretest and posttest scores assessing students' learning outcomes in ring theory.

Table 4. Learning Outcomes Test Scores

Description	Pretest Score	Posttest Score
Average	39.47	76.50
Standard Deviation	13.191	14.104
Variance	174.014	198.92
Maximum Score	64	100
Minimum Score	17	52
Number of Students	34	34

Based on Table 4, there is a significant increase from the pretest results to the posttest results. However, to see the effectiveness of the Student Activity Sheet (LKM), a paired t-test was conducted. But first, the normality prerequisite test was conducted with the Kolmogorov-Smirnov test using SPSS. The results for the pretest data showed a Sig. value of 0.133, which is greater than 0.05 (alpha), meaning the data is normally distributed. However, for the posttest data, the Sig. value was 0.046, which is less than 0.05 (alpha), meaning the data is not normally distributed. Therefore, a non-parametric statistical test, the Wilcoxon test, was conducted to determine if there was a significant difference between the pretest and posttest scores. The test was carried out using SPSS, and the results are presented in Table 5.

Table 5. Wilcoxon Rank Test Output

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between Pretest and Posttest equals 0.	Related-Samples Wilcoxon Signed Rank Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Based on the output in Table 5, the Wilcoxon test result showed a Sig. value of 0.000. Since the significance level used in this study is 0.05, the obtained Sig. value is less than 0.05, leading to the rejection of H0. This means there is a significant difference between the pretest and posttest scores, with the posttest scores being better than

https://doi.org/10.30606/absis.v8i1.3019

the pretest scores. This indicates that the gamification-integrated abstract algebra learning tool developed has met the effectiveness criteria.

Disseminate Stage

In this phase, the product was only applied to students of the Mathematics Education study program at Universitas Tidar outside of the trial class. The product is expected to be used more widely in other universities. The gamification-based student worksheets developed aim to integrate game elements into the learning process. Additionally, in terms of material reinforcement, not only are material summaries provided, but other learning resources in the form of instructional videos can also be accessed by scanning the barcode as shown in Figure 3.

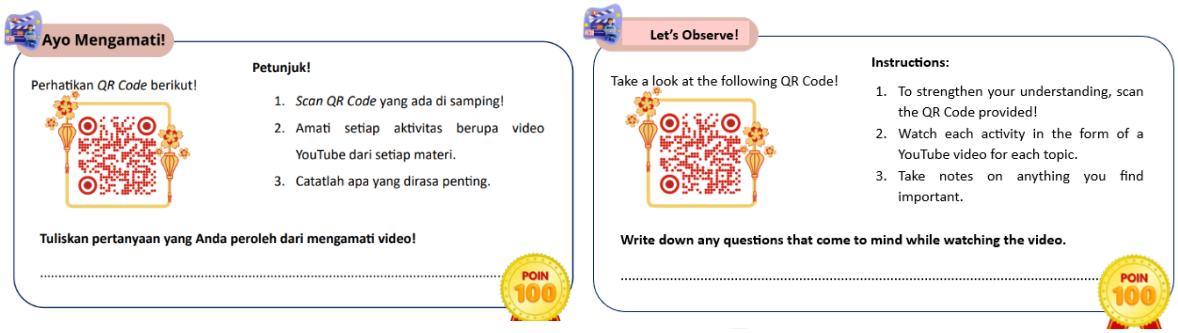

Figure 3. Exploration of Learning Resources in Student Worksheet

Meanwhile, a sample of the challenge activity is presented in Figure 4.

Figure 4. Challenges Activities in Student Worksheets

This study focuses on the development of gamification-based student worksheets as an innovative solution to address learning difficulties in the Abstract Algebra course, particularly in Ring Theory. These challenges are not new, as the abstract nature of the concepts and the complexity of mathematical notations often serve as significant barriers for students in grasping the material (Arnawa et al., 2019). By integrating gamification elements such as point systems, tiered challenges, and interactive digital media, the researchers have developed instructional materials in the form of abstract algebra worksheets that meet the criteria for validity with a validity score of 92%, and practicality with a practicality score of 80%. A significant

improvement in pretest and posttest scores further demonstrates that the gamification approach effectively enhances students' learning outcomes.

According to Hamari et al., (2014), gamification elements such as point systems, tiered challenges, and digital games can increase students' motivation. This approach enhances active participation and fosters a sense of achievement that encourages greater student engagement in the learning process. The presence of these worksheets introduces a model of active, student-centered learning. The structure of the materials and activities within the worksheets is designed to be narrative-based, progressive, and challenge-oriented, allowing students to construct their conceptual understanding gradually. With this model, students do not merely receive content passively but are required to explore, apply, and test their knowledge in scenarios that resemble educational games (Felszeghy et al., 2019). This aligns with constructivist principles, in which knowledge is built through experience and active engagement in the learning process.

Beyond supporting active participation, the gamified worksheets also offer a technological learning experience through exploration activities in which students are directed to access learning resources, such as instructional videos via QR codes, and complete digital quizzes. These activities indirectly train students' technological literacy. Technological proficiency is a vital 21st-century competency, especially for prospective mathematics teachers who are expected to integrate learning and technology effectively (Silamut & Petsangsri, 2020; Zan et al., 2021). The adaptation of a gamification approach supported by technology in these worksheets aligns with the characteristics of the current generation of students—digital natives familiar with digital interaction and visual content. The use of educational games and interactive visuals makes learning more engaging and suited to their learning preferences (Girón-García & Gargallo-Camarillas, 2021). Furthermore, the competitive aspects and rewards embedded in gamification foster a greater sense of responsibility in students to demonstrate their abilities, which positively impacts their learning outcomes.

Overall, the development of these gamification-based worksheets has successfully provided a relevant, interactive, and contemporary alternative to address the challenges of learning abstract algebra. In addition to improving learning outcomes, this approach also promotes the development of technological skills and active student participation. While further research is needed to assess the comprehensive effectiveness of the worksheets, the findings of this study offer a strong foundation for replicating and adopting the gamification approach in abstract algebra courses in particular and in other mathematics courses in higher education more broadly.

However, this study is not without limitations. The analysis of effectiveness was conducted in a single university setting and involved only one class without the inclusion of a control group. This experimental design limits the generalizability of the findings. Furthermore, the implementation of the trial was constrained by time,

https://doi.org/10.30606/absis.v8i1.3019

allowing only one of the nine developed topics to be tested. This partial implementation means that the full potential and applicability of the gamification-based worksheets across the entire course content remain uncertain. Future research is needed to extend the trials to all topics and across multiple institutional contexts to confirm the robustness and adaptability of the gamification-based worksheets in real classroom settings.

CONCLUSIONS AND RECOMMENDATIONS

Based on the research results, it can be concluded that the developed gamification-based abstract algebra learning tools, in the form of Student Activity Worksheets, are declared valid with a validity level of 92% (highly valid category) based on expert (validator) assessments, practicality level of 80% (practical category) based on student response questionnaires, and effective based on the Wilcoxon test results. Based on these research results, it is suggested that lecturers who teach ring theory courses can use these learning tools as interactive and enjoyable teaching materials.

However, several recommendations for further development should be considered. Among them, the content coverage of the worksheets is currently limited to the subtopic of Ring Theory. The development of worksheets for other core topics in the Abstract Algebra course, such as Group Theory, is necessary to enable the comprehensive implementation of this gamification strategy. Another aspect that needs improvement in the future is the evaluation of the long-term impact of the instructional materials. The effectiveness test in this study was conducted using a One-Group Pretest-Posttest design within a limited time frame. Therefore, further research using quasi-experimental or longitudinal designs is needed to assess long-term retention, the enhancement of higher-order thinking skills, and the impact on students' final academic achievement.

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