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The Design and Validity of STEM-EDP-gamification Worksheet: Ways to Improve Students' Perception of Their STEM Skills and Motivation

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Abstract

This article discusses the design and validity of STEM gamification worksheets as a means to improve students' perceptions of skills and motivation in STEM learning. This study encourages student motivation and engagement in STEM learning more engagingly and innovatively. This study uses a mixed-method approach with an Educational Design Research (EDR) approach. The EDR method consists of three phases: the first phase is analysis and exploration, the second phase is design and construction, and the third phase is evaluation and reflection. The STEM gamification worksheet was designed using the EDP (Engineering Design Process) learning model designed for four meetings. The worksheet obtained an average assessment for all aspects, namely the content and feasibility aspects of the STEM gamification-based worksheet product of 89.3% which is included in the "Very Valid" category and can be used in science learning. With an overall Aiken's Test value of 0.845 with a very high interpretation. The worksheet also received suggestions and input from game experts and practitioners for improvement and has been revised. The appearance of the worksheet is very important because it can make students, as users, more motivated and interested in learning. This STEM gamification worksheet is expected to be a breakthrough for the world of education in the future, especially in the application of sustainable development principles, SDGs 4, including innovation in improving STEM, SDGs 11, gamification of innovation and infrastructure with engineering design learning methods, and applying environmentally friendly principles in learning.

Keywords: *Motivation, STEM gamification, STEM skill, Worksheet*

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INTRODUCTION

As the 21st century progresses, it is impacting various sectors. Education is one of those affected (Pratama et al., 2024) . Education is the primary foundation for every citizen. Indonesia is one of the countries that strives for good education (Amirah & Sutrisno, 2025). With the development of digital technology in the current era, education requires special attention in its application. In line with Mu'minah's opinion in (Hasanah et al., 2025).Education also increasingly requires improved skills, such as the ability to create new things, think imaginatively and critically, and solve problems.

The current problem is low student motivation and science skills, particularly in critical thinking. Critical thinking skills are very important to have because they can solve problems logically (Erlinawati et al., 2025). According to Dermawan (Yusra et al., 2025), students' critical thinking skills in Indonesia are still relatively low. This presents a challenge for educators and students to improve their motivation and science skills. The skills needed in the current era are in accordance with the criteria of STEM skills (Science, Technology, Engineering, and Mathematics), where these skills are the provisions for the success of current innovation developments (Hamdu & Rostiana, 2020). In accordance with research results showing that this STEM approach can be an effective way to improve students' critical thinking skills and scientific understanding, it also provides an overview of the development of more innovative science learning methods in the future. (Widyastika et al., 2025). Judging from the low scientific abilities of students in describing scientific events by 34.4 %,

evaluating and designing scientific investigations by 36.6%, and concluding scientific data and evidence by 33.3% (Pisa, 2023). It has been proven that many students still have difficulty understanding STEM learning concepts and lack motivation in learning. This condition makes it urgent in education to improve students' science abilities, especially in STEM skills.

Various approaches to improving STEM skills involve two psychological components of successful learning and subsequent career paths, specifically STEM perception and motivation. This is the first step in understanding the challenges and opportunities at the elementary school level. According to Bandura, improved self-perception is closely linked to positive learning experiences, which in turn affect students' learning outcomes and their motivation to engage in STEM learning actively. (Samsudin et al., 2020). Students with high self-perception maturity in STEM subjects tend to show stronger motivation to be active in STEM-related learning activities (Luo et al., 2021). This has a significant impact on the success of STEM implementation, which depends on students' potential and relevant skills for future careers in these disciplines. Therefore, it is very necessary to have an appropriate learning approach and model for developing students' abilities, especially in STEM (Anggraini et al., 2025). One of which is presented through the STEM-EDP-Gamification approach.

According to Kapp in (Ariani, 2020), gamification is a program that uses a game-based way of working, displays engaging content, and encourages a way of thinking like in a game. Gamification approaches engage and encourage deep users to perform specific activities, making it a promising approach to address low motivation and students' perceptions in understanding the lesson material (Gini et al., 2025). In its application, gamification does not differentiate among students in learning; everyone can participate actively to make learning more exciting and attract students' attention, including those with high and low learning abilities (Khafidh et al., 2025). It is not surprising that this strategy is receiving increasing attention in educational research. STEM gamification worksheets can be one way to improve students' perceptions of STEM skills and motivation.

Several previous studies also revealed the advantages of using STEM gamification worksheets (Mahendra et al., 2023). The results of the study proved to have a good influence on learning. After applying gamification, students were able to develop more effective learning methods. Researchers also found that in STEM learning, gamification improved STEM learning outcomes. Likewise, results from research on the effectiveness of the EDP learning model used in worksheets are available. According to Sumiyati and Alatas (2025), the EDP learning model has a positive impact on skills, starting from the define, research, and create stages, which are able to progress, and the ability to test, evaluate, and communicate has progressed further than before. Research by (Huda et al., 2025) also provides evidence regarding the results of research related to STEM-based worksheets used in learning, which are declared effective and suitable for use in improving students' critical thinking skills.

Research on STEM worksheets has been widely discussed in previous studies, but this study offers something different, namely the novelty of worksheets using a STEM gamification approach, modified with the steps of the EDP learning model for solving problems about sustainable development in accordance with the SDGs 4 (Quality Education) and SDGs 11 (Sustainable Cities & Communities) goals in an integrated manner, so that it is aligned with the learning process. In this article, we will discuss the design and validity of STEM gamification worksheets that can improve students' perceptions of STEM skills and motivation. This study has two main objectives: (1) to determine the feasibility of the STEM-EDP-Gamification LKPD in improving students' STEM skills. (2) to test the design of the STEM-EDP-Gamification LKPD. This study only discusses the expert validation and design parts. For the continuation of writing articles, we expect better support and contributions in the future.

METHOD

This research uses a mixed-method approach with an Educational Design Research (EDR) approach. Definition Educational Design Research (EDR) as presented by Barab and Squire (Nieveen et al., 2006) is an approach that aims to create new theories, products, and concrete models that explain how learning occurs and can influence learning in a natural environment. The EDR method consists of three phases: the first phase is analysis and

exploration, the second phase is design and construction, and the third phase is evaluation and reflection. The developed worksheet will be implemented in one of the elementary schools in Samarinda City. Its effectiveness will be reviewed quantitatively, and the qualitative phase will explore stakeholder perceptions, advantages, and disadvantages of implementation.

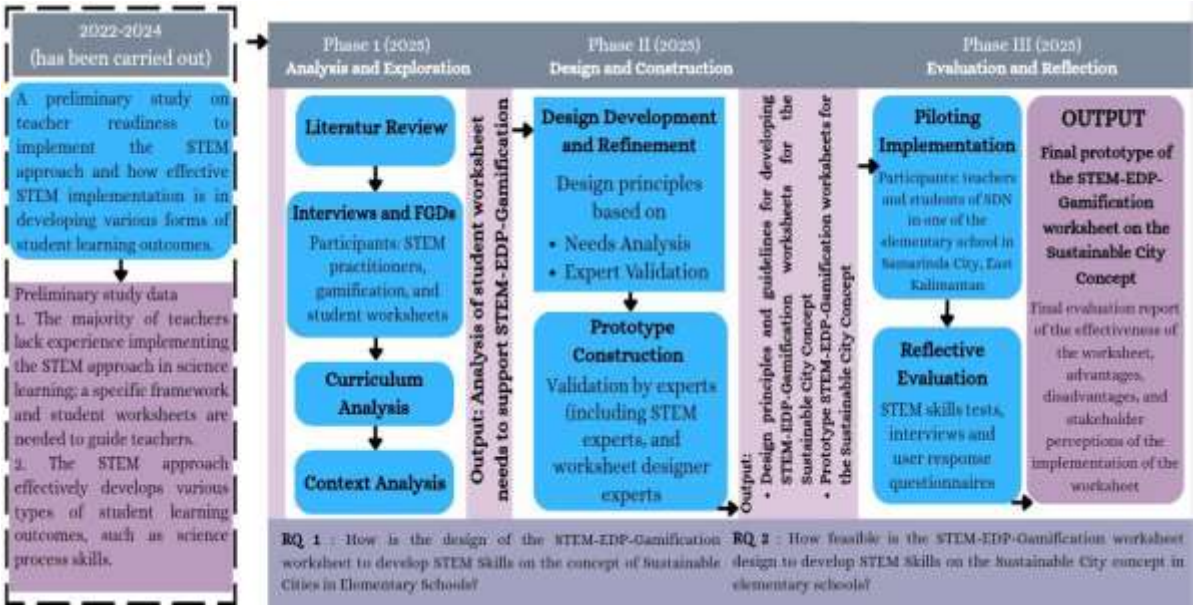

Figure 1. Research flowchart

The methods used include interviews, Focus Group Discussions (FGDs), and content analysis tools that will analyze needs through curriculum and STEM analysis. The collected data will be analyzed quantitatively, descriptively, and qualitatively (data reduction, data display, and conclusion drawing/verification). The respondents in the FGD, interviews, and validity tests of the worksheet were five experts, including a science lecturer, a game expert, a STEM expert, and two expert practitioners.

The research instruments used were STEM practitioner interview guidelines and validity data of student worksheets on gamification to explore the design needs to be developed. The interview guidelines covered the suitability of the worksheets to the curriculum, the use of appropriate language, and the accuracy of the STEM gamification design. Data from the interviews included comments and suggestions about terms in the worksheets that were difficult for students to understand, and they suggested changing the wording to make them easier to understand. The data generated is in the form of a validity sheet.

The students' worksheet was reviewed for content validity, feasibility, and graphic feasibility. The content feasibility aspect test included needs, novelty, material coverage, design accuracy, up-to-dateness, contextuality, and compliance with laws and regulations. The graphic feasibility aspect included the worksheet's size, cover design, and content design. The total number of statements across all aspects was 27. The instrument used for data collection was a validation sheet in the form of a questionnaire, with a Likert scale of 1-4, to determine whether the worksheet was valid. The following is a display of the Likert scale used:

The instrument used for data collection is a validation sheet in the form of a questionnaire, with a Likert scale of 1-4, to determine whether the worksheet is valid. According to Sugiyono in (Athallah et al., 2025) with the scale and categories: (1) not feasible, (2) quite feasible, (3) feasible, and (4) very feasible, with percentage criteria obtained from expert and practitioner validation including: invalid (0-20%), less valid (21-40%), quite valid (41-60%), valid (61-80%), and very valid (81-100%) (Meldra & MArdiansyah, 2025). Furthermore, validity is assessed through the Aikens'V test with interpretation details according to Kustoro in (Suhardi, 2022): (0.8-1) very high, (0.6-0.79) high, (0.4-0.59) sufficient, (0.2-0.39) low, (<0.2) very low. In writing this article, we discuss only the design and feasibility of the worksheet; it

does not include results from implementing the worksheet after use.

RESULTS AND DISCUSSION

The results of this study include the design and validation of the feasibility of STEM-EDP-Gamification student worksheets, designed to be integrated with 21st century learning to support students' STEM skills. Five experts have also validated the worksheets. This worksheet research was developed using the Educational Design Research (EDR) method through 3 stages: analysis and exploration, design and construction, and evaluation and reflection. The explanation of the stages is as follows.

Analysis and exploration

STEM is an approach that combines four components of knowledge: Science, Technology, Engineering, and Mathematics (Riyanto et al., 2021). In elementary school, students are trained to develop high-level thinking skills; one way to do this is through STEM learning. In line with research findings that the STEM approach significantly improves students' critical thinking skills, project-based and experimental learning methods actively involve students in solving complex problems, encouraging them to think critically and analyze information more deeply (Zalsa et al., 2025).

STEM demonstrates excellence in curriculum implementation. The STEM curriculum integrates the development and in-depth analytical skills of four disciplines: science, technology, engineering, and mathematics, to prepare the younger generation for the changing times. Students' STEM skills are not only expected to be relevant in education but also to contribute in global development through a social and creative approach (Ridwan et al., 2024). Regarding the implementation of the curriculum in science learning, this research focuses on solving STEM problems in accordance with the SDGs goals. The SDGs goals included in the worksheet are SDGs 4, namely quality education, where STEM skills are an innovation for the development of learning in the 21st century. And there is SDGs 11 which implements that in the implementation of student worksheets, it is stated in the gamification of student collaboration to create engineering designs for a project to overcome problems in sustainable development, learn how to consume and produce responsibly, such as overcoming various environmental problems, providing environmentally friendly energy alternatives, preventing natural disasters, using environmentally friendly vehicles, in order to create a sustainable city that educates, inspires, and provides clean energy.

However, implementing STEM still faces various challenges. Gulhan and Sahin (Ridwan et al., 2024) also confirmed that STEM implementation remains ineffective, with many obstacles, including inadequate preparation and training for practitioners. This can result in low student perception and motivation, which are not yet developed due to insufficient learning, and STEM remaining a distant memory. Therefore, support from the government and educational institutions is needed to ensure the successful implementation of STEM.

In this study, to support students' STEM learning, it is necessary to use appropriate media, namely STEM gamification worksheets based on the EDP (Engineering Design Process) learning model. The EDP learning model is a series of stages of activities that identify problems, conduct investigations, design, make, test, and improve (Fitriana et al., 2023). The EDP model is considered very suitable for STEM learning. This is in line with the opinion (Lestari et al., 2025) that the STEM approach using the EDP (Engineering Design Process) steps can make students' engineering more focused.

In the current learning application, there are more innovations to encourage students to have enjoyable experiences, learn more actively, and better understand concepts. One promising innovative approach is Gamification (Azwah et al., 2025). STEM gamification contained in the worksheet in this study includes game procedures, how to get additional points if you win in the game, student collaboration to provide the best solution to the fill-in questions about overcoming problems in sustainable cities, getting the best solution recommendations if you are lucky from the stages in the game, which are then poured into a 2D design image. From the 2D image designed together, it can be realized in the form of a 3D prototype as part of addressing sustainable city problems. Groups that use good strategies and cooperation will be superior in the game and will get a more complete solution reference for sustainable city design.

This makes the worksheet highly appealing to STEM practitioners and experts. It is also expected to serve as a basic guideline for achieving optimal student learning outcomes.

Based on interviews, several inputs and recommendations from STEM practitioners and content experts were incorporated into the worksheet to ensure optimal results (Wulandari & Yahfizham, 2025). These inputs and recommendations included addressing inappropriate language in the worksheet for the students' age range, suggesting that the worksheet be modified to include more easily understood words. The color scheme and font combination on the worksheet also need to be consistent. Therefore, the interview results provide positive support for the improvements made.

Design and construction

The worksheets are used not only as a companion to the board game but also as a practice tool to connect science skills to students' real-world understanding in the context of sustainable cities. The worksheets are described in a design that begins with learning outcomes, STEM integration, and relevant STEM projects, as outlined in Tables 2 and 3.

Table 1. Worksheet achievement

CP	Indicator	STEM	STEM Projects
Understanding of Science and Social Sciences: Students describe the threat of an energy crisis and propose individual and collective efforts to conserve energy and find alternative energy sources, using existing resources in their surroundings. Students reflect on how changes in Earth's surface conditions occur due to natural factors and human actions. Identify lifestyle patterns that cause environmental problems and predict its impact on social and economic conditions.	Process Skills 1. Observe At the end of phase C, students observe phenomena and events using only their five senses, record their observations, and look for similarities and differences. 2. Questioning and predicting With guidance, students can ask further questions to clarify observations and make predictions about scientific investigations. 3. Planning and conducting investigations Students independently plan and execute operational steps to answer the posed questions. They use appropriate tools and materials, prioritizing safety. They use measuring instruments to obtain accurate data. 4. Processing, analyzing data, and information Present data in tables or graphs and explain observations and patterns or relationships within the data, either digitally or non-digitally. Compare data with predictions and use them as evidence in developing scientific explanations.	Science	Students describe the threat of an energy crisis and propose individual and collective efforts to conserve energy and identify alternative energy sources. Analyzing and reflecting on changes in natural conditions on the Earth's surface that occur due to natural factors and human actions, identifying lifestyle patterns that cause environmental problems, and predicting their impact on social and economic conditions.
		Technology	Use of the internet to search for information on the topic of sustainable city concepts. Prototyping technologies that can be applied to sustainable cities, for example, solar panels, simple water filters, flood sensors, *and* sensors on trash bins.
		Engineering	Designing and building sustainable city projects to address issues including energy crises, extreme natural disasters, traffic congestion, air pollution, and littering.

CP	Indicator	STEM	STEM Projects
	5. Evaluate and reflect Evaluate conclusions through comparison with existing theories. Reflect on the investigative process, including reflecting on the validity of a test. 6. Communicating results Communicate the results of the investigation in full, supported by arguments, language, and general scientific conventions according to the specified format.	Mathematics	Calculating the costs required to design a sustainable city project. Develop a logical reasoning for the relationship between the proposed sustainable city design and the solution of the oriented problem.

According to Erol in (Yolida et al., 2025), integrating STEM and EDP has a positive impact on students' critical thinking and problem-solving. The EDP learning model is known for supporting students' collaboration skills (Fitriana et al., 2023). Jolly's opinion in (Sumiyati & Alatas, 2025) EDP emphasizes the stages of defining the problem, researching, imagining, planning, creating, testing and evaluating, redesigning, and communicating. In another view, the EDP learning model also has several stages, starting with determining objectives and problems, analyzing, developing solutions, prototyping, testing and evaluating, and redesigning (Yolida et al., 2025). The following is a display of a worksheet using the EDP (Engineering Design Process) learning model, which contains a systematic structure of student activities, defined stages, and engineering principles. The learning is divided into four meetings: meeting 1: define stage, meeting 2: Learn and Plan a solution stage, meeting 3: Try a solution and Decide stage, meeting 4: communicate stage, with each meeting designed to guide students through the EDP stages, starting with problem identification, design, testing, reflection, and evaluation results.

Table 2. Stages of learning model in the worksheet

EDP Stage	Worksheet Content Design		Gamification
	Student Experiment Steps	Display on Worksheet	
Define Stage	Students are asked to define problems with various questions based on problem statements to realize sustainable cities.		N/A

EDP Stage	Worksheet Content Design		Gamification
	Student Experiment Steps	Display on Worksheet	
Learn Stage	Students learn more about sustainable cities and address sustainable city issues through the *SustainCity STEM Board Game*.		Students work in groups to complete board game missions using strategy and teamwork to complete project cards and build a comprehensive 2D design for a sustainable city. Groups that fail will have their 2D design affected and receive a lower score.
Plan A Solution Stage	Students plan by drawing a 2D STEM project model of a sustainable city to solve the problem, and by selecting the tools and materials to build the 3D project.		Students work in groups to plan the 2D design of the city to be created, and maximize the funds provided in selecting good tools and materials for the 3D design.
Try a Solution Stage	Students convert 2D images into 3D models of simple STEM projects and test the designs against the desired criteria.		Students work in groups to realize 2D designs into 3D sustainable cities and test the success of the designed prototypes.

EDP Stage	Worksheet Content Design		Gamification
	Student Experiment Steps	Display on Worksheet	
Decide Stage	Students decide on the designs for sustainable cities and can solve problems.		Students work in groups to decide on the experiment's results and predict that the chosen prototype can solve sustainable city problems.
Communicate Stage	Students present the results of the 2D and 3D sustainable city model designs that they have created.		Students work in groups to present their prototypes and proposed solutions. Students who successfully explain their solutions will receive additional points, while those who fail to create and present their prototypes will receive lower marks.

Based on the worksheet created, students are expected to be active at every meeting, maintain team unity, and improve their own performance. By working well together, you can easily achieve perfect results. The gamification in the worksheets creates a more engaging form of competition. Learning using games has an appeal that makes students more enthusiastic in learning and makes it easier to understand (Mahendra et al., 2023). This can influence the development of student motivation in STEM learning. Not only motivation, but students' STEM abilities can also be developed at each step in solving problems on the worksheet. The worksheet has passed the validation stages of design and media experts, which are presented in the following table.

Table 3. Expert validation

Aspect	Indicator	Percentage Indicator	Percentage Aspect	Category
Content Eligibility	Need	88%	88.6%	Very valid
	Renewability	88%		
	Coverage of material	80%		
	Design accuracy	93%		
	Up-to-date and contextual	90%		
	Compliance with laws and regulations	93%		
Graphical Eligibility	Worksheet Size	95%	90%	Very valid
	Cover Design Worksheet	85%		
Average			89.3%	Very valid

Based on the results of the validation sheet completed by experts, the score for the content aspect's feasibility was 88.6%, and for the graphics aspect, 90%. Thus, the average assessment for all aspects of the STEM gamification-based worksheet product was 89.3%, which falls into the "Very Valid" category and can be used in science learning.

The expert validation table shows that the superior graphic feasibility aspect has a higher percentage than the content feasibility aspect. Based on the content feasibility aspect, the developed worksheet received a score of 88.6%, indicating it is very valid and suitable for use. This suggests that the worksheet covers four areas of knowledge: science, technology, engineering, and mathematics. In science, students can practice their scientific thinking skills. Meanwhile, in technology, engineering, and mathematics, students can learn to think critically and creatively (Mahjatia et al., 2021). In terms of content suitability, there is an indicator that gets the lowest percentage, which is the material coverage indicator at 80%, while the highest is the indicator of design accuracy and compliance with laws and regulations at 93%.

And in terms of graphical feasibility, the developed worksheet received a score of 90% in the very valid category and is suitable for use. This is in line with Mustofa's opinion in (Simamora et al., 2022b): development products can be used effectively if they meet several criteria, namely valid content or relevance, valid language, and graphic validity. The indicator in the graphic feasibility aspect that received the lowest percentage was the worksheet cover design, with 85%, and the highest was the worksheet size indicator, with 95%. Indicators play a vital role in the design of learning preparation, as a good teaching and learning process must be well planned. The development of good indicators will measure the basic competencies and competency standards desired by the curriculum in schools, as indicators are markers of the achievement of these competencies, as evidenced by measurable student behavior, including attitudes, knowledge, and skills (Rahmah et al., 2025). In addition to the validity test that has been carried out, the Aiken test calculation formula is then applied.

The results obtained from Aiken's V Test on the worksheet stated that the validity was very high, in accordance with the interpretation according to Kustoro in (Suhardi, 2022) for the content feasibility aspect and the graphic feasibility aspect, as evidenced by the following Table 4.

Table 4. Aiken's V result

Statement	Aspect	V	Information
Items 1-18	Content Eligibility	0.84	Very high
Items 19-27	Graphical Eligibility	0.85	Very high

Aiken's test with a total of 27 statement items for all aspects, namely the feasibility aspect and the graphical aspect in the worksheet, the overall average Aiken's validity for the worksheet was found to be 0.845, with a very high interpretation. Validation of content and graphical feasibility is essential in developing teaching materials, as these aspects underlie the quality and success of the materials (Budi Astuti et al., 2024).

Evaluation and reflection

After passing the design stage and the worksheet being declared highly valid, the worksheet still requires input and recommendations from the validators to improve its usability. The worksheet has also undergone revision. The following shows the worksheet's improvements before and after the revisions.

Tabel 5. Input and Recommendations from Validator

Appearance Before Repair	Comments and Suggestions	Repair	After Repair View
	The worksheet cover needs to be brighter. There are too many font combinations; the title "Sustainable City" is underexposed; the colors lack contrast; and the worksheet needs clarification with game component images and more illustrations.	Suitable for use with revision	

Appearance Before Repair	Comments and Suggestions	Repair	After Repair View
	Learn section, add explanation about Sustainable Cities	Suitable for use with revision	
	In the game content explanation on the worksheet, there are still too many terms that elementary school students may not understand, such as Foraging, Lamp Conversion, and Vertical Garden. Perhaps they can be replaced with simpler terms.	Suitable for use with revision	

The worksheet appearance has been revised based on input from the validators and is suitable for use, with a very valid percentage. Some input and suggestions from the validators refer to the appearance and language used in the worksheet. The worksheet's function is not merely as an aid technical work, but also a pedagogical instrument that encourages meaningful learning,, is appropriate to the context, and is focused on students (Simamora et al., 2022a). Therefore, the appearance of the worksheet is significant because it can make students as users, more motivated and interested in learning, increase students' focus on the lesson topic, provide students with indirect experience, and provide positive impression of the material presented, thereby encouraging students to learn more. And the use of language in the worksheet must be appropriate to the reader's age, based on research results indicating that when students experience difficulties in recognizing words correctly and quickly, this can interfere with understanding the entire reading text (Kusumaningtyas et al., 2025).

In addition to developing student motivation in STEM learning, the STEM steps outlined in the worksheet are also expected to improve students' STEM abilities. This aligns with the EDP stages: defining, planning the design, realizing the design into a prototype, and presenting it to the class. All EDP stage encompass the integration of four disciplines: science, technology, engineering, and mathematics, with real life contexts to solve problems relevant to everyday life (Syarifah Ayu & Rahayu, 2022).

Worksheet development cannot be rushed: it must be carefully designed and consider several important aspects (Simamora

et al., 2022a). Worksheet are considered adequate when they support student's learning abilities. This aligns with research on the impact of worksheet use at SD Negeri 15 Banda Aceh, which showed that worksheet use significantly improved student learning outcomes (Diana, 2025).

CONCLUSION

A well-designed STEM gamification worksheet can be an effective tool for improve students' perceptions of STEM skills and motivating them to be more active and interested in STEM learning. The result of the study demonstrate that the STEM gamification worksheet is suitable for use in developing student's STEM motivation and perceptions, with regard in design and validity feasibility. The worksheet is equipped with steps in the EDP (Engineering Design Process) learning model that are in accordance with STEM objectives. Each meeting in the worksheet includes procedures for activities students will carry out, making it easier for them to follow the learning process. This is evidenced by the study's results, which show that the worksheet obtained a validity value 89.3%, indicating very valid criteria. Likewise, the results of Aiken's V test for the worksheet were 0.845, indicating a very high interpretation. This worksheet is expected to be a research contribution that has a positive impact on the world of education in Indonesia, especially for improving students' STEM skills.

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