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Development of STEAM-Based Electronic Student Worksheets (E-LKPD) for Science Learning

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Abstract

Background: The use of student worksheets that are not yet STEAM-based likely contributes to low student achievement in science learning. Therefore, it is necessary to develop STEAM-based electronic student worksheets (E-LKPD) for science subjects.
Aims: To develop STEAM-based E-LKPD that is feasible, practical, and effective to enhacing students' science learning outcomes.
Methods: This study utilized development research with the Borg & Gall development model. The instruments used in this research included learning needs observation sheets, validation sheets for media, material/content, and design, feedback sheets for teacher and student response, and learning outcome assessment sheets.
Result: The research results show: (1) material validation scored an average of 98.06%, (2) media validation scored an average of 84.18%, (3) design validation scored an average of 97.11%, three of them categorized as very feasible. (4) individual trial scored 91.50% and small group trials 97.75%, categorized as very practical. (5) field trial scored 97.75%, categorized as very practical. Furthermore, the experimental results using STEAM-based E-LKPD in the experimental class obtained an average learning outcome of 83, while the control class using LKPD published by Kemdikbud obtained learning outcomes of 78.5. Independent samples t-test result showed a significance value of $t < 0.05$ ($0.024 < 0.05$), therefore H_0 was rejected and H_1 was accepted. This means that the STEAM-based E-LKPD product developed is effective for improving student learning outcomes in science learning.
Conclusion: The STEAM-based E-LKPD is very feasible, practical, and effective for improving science learning outcomes.

A. Introduction

The 21st century is characterized by rapid progress in science and technology, globalization, and economic growth. Educational systems must equip students to address global challenges, social conditions, and future employment prospects. Achievement in 21st-century education requires three fundamental capabilities: life and career skills, learning and innovation skills, and information media and technology skills. Within the learning and innovation domain, students need to develop four crucial competencies known as the 4Cs: Communication, Collaboration, Critical Thinking, and Creativity.

Education in the 21st century emphasizes student-centered methodologies to cultivate essential capabilities (Patresia et al., 2020). The Assessment and Teaching of 21st Century Skills (ATC21S) Project identifies

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crucial thinking competencies needed for this era: problem-solving, creativity and innovation, critical thinking, and decision-making. The contemporary workforce requires employees possessing various related abilities, including creative thinking, problem-solving, and communication proficiency (Mu'minah et al., 2020). Thinking skills encompass cognitive capacities that generate and extend novel ideas and concepts, building upon established ones, alongside abilities to address challenges through multiple approaches (Salfina et al., 2015). Creativity constitutes a fundamental skill involving mental processes that generate original ideas (Dinantika et al., 2019). Students need preparation to cultivate advanced creativity levels to refine, enhance, and expand concepts while addressing challenges from diverse viewpoints (Harizah et al., 2021).

Natural Science continues as a fundamental discipline throughout educational establishments, incorporating two dimensions: process and product. From the product standpoint, Natural Science comprises a thorough knowledge collection including facts, concepts, principles, and laws describing natural occurrences. As a process, Natural Science embodies a methodical and systematic approach employed to discover concepts, principles, and laws governing natural phenomena (Rati et al., 2017).

In the junior high school curriculum, Natural Science education is an essential foundation for cultivating students' critical, creative, and innovative thinking abilities. Science teaching delivers experiential learning opportunities, strengthening students' capabilities to construct, understand, and implement acquired concepts. This instructional method trains learners to independently uncover various concepts in a comprehensive, meaningful, authentic, and practical fashion directed toward problem-solving (Putri & Hamimah, 2023). This instructional strategy corresponds with constructivist theory, which maintains that students build knowledge founded on personal experiences gained through interactions with peers and their surroundings. Modern Science education highlights conceptual understanding and emphasizes science process skills and their practical implementation in daily situations.

The unique attribute of Natural Science content involves the investigation of factual natural phenomena, whether manifested as observable realities, occurrences, or cause-effect relationships (Wisudawati & Sulistyowati, 2022). Due to Natural Science's inherent connection to the physical world and its sometimes abstract conceptual structure, students may face difficulties understanding. Therefore, effective Natural Science comprehension requires positive attitudinal orientations from learners. However, beyond developing positive attitudes, it is equally vital to nurture students' creative learning abilities, as creativity represents a key element facilitating conceptual understanding in Natural Science (Harahap, 2020). Creativity incorporates various characteristics (including self-confidence, achievement motivation, and perceptual sensitivity) and cognitive capabilities (such as ideational fluency, cognitive flexibility, and imaginative capacity) (Dewanti, 2022). Therefore, learning creativity is essential to students' comprehension of Natural Science concepts.

Research conducted by a researcher at SMP Negeri 2 Satu Atap Batang Serangan revealed significantly underdeveloped creative thinking abilities among students. Their fluency in ideation remains notably constrained, as evidenced by their limited capacity to generate multiple ideas, answers, solutions, or questions. When confronted with problems, students typically produce singular responses without adequate explanatory reasoning. Similarly, regarding inquiry skills, students demonstrate insufficient propensity for formulating questions about subject matter representing authentic problems connected to daily experiences.

Based on interviews conducted at SMP Negeri 2 Satu Atap Batang Serangan, students' creative thinking abilities are still classified as very low. Students' fluency thinking skills remain very limited, as evidenced by their lack of habit in generating multiple ideas, answers, problem solutions, or questions. When presented with questions, students can typically provide only a single answer and are unable to adequately explain their reasoning. Similarly, when asking questions, students are not accustomed to raising inquiries about material representing real-world problems related to daily life.

Likewise, with flexibility thinking skills, students are unable to generate varied ideas, answers, or questions, or view a problem from different perspectives. Students only answer questions according to explanations found in textbooks. They are not habituated to seeking various literature or knowledge sources that could enrich their understanding. Despite the rapid advancement of technology today, students can search for materials or sources from applications downloadable from the Play Store, YouTube, or other digital sources and compare them to gain multiple perspectives that broaden their knowledge. These limitations affect student learning outcomes across several core topics in science education.

The researcher suspects that students' generally low learning outcomes occur due to several factors, including teachers' use of inappropriate strategies and approaches for the learning material. Additionally,

Science education, closely related to daily life, requires integration with other disciplines such as technology, engineering, art, and mathematics. Therefore, a learning approach that integrates various disciplines and connects them to real-world problems is necessary. Furthermore, Science learning also demands mastery of concepts and natural laws through conceptual understanding via analysis and practical activities. These activities naturally require teaching materials or guides containing systematic work steps, often referred to as Student Worksheets (LKPD), with appropriate approaches.

One pedagogical strategy relevant to 21st-century requirements in Science education is the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach. The STEAM approach represents a progression from the STEM (Science, Technology, Engineering, Mathematics) approach, incorporating the Arts. When implementing the STEAM approach, instructional materials that enable students to explore and integrate various disciplines holistically are necessary. The inaugural PISA 2022 Creative Thinking Assessment has revealed an alarming global crisis in student creativity that demands immediate implementation of STEAM education frameworks. For the first time, PISA measured the creative thinking skills of 15-year-old students across 64 countries and economies, assessing their capacity to generate diverse and original ideas, and the results expose devastating disparities in creative capabilities worldwide. The Philippines scored only 14 points, way below the global average of 33, placing it among the bottom four countries, alongside Albania (13 points), Uzbekistan (14 points), and Morocco (15 points). This stark contrast with top-performing nations like Singapore, Latvia, Korea, and Denmark, where more than 88% of students demonstrated creative thinking proficiency, highlights the urgent need for educational transformation. Less than 50% of students in 20 low-performing countries reached basic creative thinking proficiency, indicating that millions worldwide lack the fundamental creative problem-solving skills essential for 21st-century innovation and economic competitiveness. The PISA data demonstrate that traditional education systems focusing solely on rote learning and standardized testing fail to develop the creative, interdisciplinary thinking that STEAM education explicitly cultivates through integrating arts with science, technology, engineering, and mathematics. This creative thinking deficit represents not just an educational failure but an economic catastrophe, as nations with the lowest creativity scores risk being left behind in the global innovation economy, where creativity, critical thinking, and cross-disciplinary collaboration are prerequisites for success. One teaching resource can be employed is STEAM-based Student Worksheets (LKPD). Student Worksheets, as written instructional materials, serve a significant function as teacher proxies in effective instructional practices to achieve learning objectives (Nyamupangedengu & Lelliott, 2015).

Student Worksheets (LKPD) have been extensively incorporated into educational methods. As a result, these teaching resources must undergo continual development to meet contemporary educational demands. Modern educational frameworks must provide students with skills and knowledge crucial for success in the 21st-century environment. Since the onset of the COVID-19 pandemic, considerable advancements in electronic Student Worksheets (E-LKPD) have occurred. During the adaptation process to new educational models necessitated by the COVID-19 pandemic, an essential requirement has been the availability of learning resources and online educational tools utilizing engaging media easily accessible to students. Educators have been challenged to create innovative instructional materials and media using online learning platforms and resources (Ghufron, 2023). Despite the conclusion of the COVID-19 pandemic, the continued development of electronic Student Worksheets (E-LKPD) remains imperative, considering their enhanced accessibility via multiple digital platforms, including laptops, computers, and mobile devices, facilitating more effective and efficient educational implementation.

The implementation of Student Worksheets lacking STEAM integration likely constitutes a contributing factor to suboptimal academic performance in Science education. Research consistently shows that the lack of STEAM integration in student worksheets is a significant factor contributing to suboptimal academic performance in science education, as STEAM-based approaches foster higher student engagement, motivation, and achievement by connecting science with real-world contexts and promoting twenty-first-century skills such as creativity, critical thinking, and collaboration (Asrizal et al., 2023; Huda et al., 2024; Mang et al., 2021; Nursakinah et al., 2023; Uyanık Aktulun et al., 2024). Meta-analyses and empirical studies demonstrate that STEAM education yields a moderate to strong positive effect on science learning outcomes, with students exposed to STEAM-integrated curricula showing greater improvements in academic performance, scientific literacy, and sustained interest in science compared to those taught with traditional, non-integrated methods (Asrizal et al., 2023; Nursakinah et al., 2023; Uyanık Aktulun et al., 2024). Moreover, STEAM's interdisciplinary and student-centered nature encourages deeper conceptual understanding, reduces misconceptions, and supports the development of skills necessary for addressing complex, real-world problems, while the absence of such integration in worksheets can lead to

disengagement, lower motivation, and diminished science achievement (Conner et al., 2017; Huda et al., 2024; Mang et al., 2021; Yulianti et al., 2024). Consequently, the development of STEAM-integrated E-LKPD for the Science curriculum becomes necessary. Within this research context, STEAM-based Student Worksheets are anticipated to provide substantive contributions toward addressing persistent challenges in Science instruction.

The primary objective of this research is to develop and evaluate the effectiveness of STEAM-integrated Electronic Student Worksheets (E-LKPD) in addressing suboptimal academic performance in Science education by creating innovative pedagogical tools that combine Science, Technology, Engineering, Arts, and Mathematics components within the existing curriculum framework. Specifically, this study aims to design a STEAM-integrated E-LKPD that effectively bridges theoretical knowledge with practical application, evaluate its impact on student academic performance compared to traditional non-integrated worksheets, and investigate the feasibility of implementation in Science classrooms, including teacher adoption and student engagement levels. Through comparative analysis of learning outcomes, student motivation, and academic achievement between students using STEAM-integrated E-LKPD versus conventional approaches, this research seeks to validate whether the integration of STEAM principles can significantly contribute to resolving persistent challenges in Science instruction, particularly those related to student comprehension, skill development, and overall academic performance, thereby providing substantive evidence for the necessity of interdisciplinary educational approaches in contemporary Science education.

B. Research Methods

This research aims to develop a STEAM-integrated Electronic Student Worksheet (E-LKPD) that demonstrates viability, practicality, and effectiveness in enhancing science educational outcomes. The research was implemented at SMP Negeri 2 Satu Atap Batang Serangan. The research population and sample comprise students from classes VIII-1 and VIII-2 at the aforementioned educational institution. Class VIII-1, consisting of 30 students, functions as the experimental group, while class VIII-2, comprising 30 students, serves as the control group. Sample selection methodology employs Cluster Random Sampling techniques, wherein sample determination proceeds according to researcher-established parameters, provided that selected samples fulfill research-specific criteria and align with the investigation's objectives.

The research and development of this instructional media implements the Research and Development methodological framework following the Borg & Gall developmental model through the stages of research and information collecting, planning, develop preliminary form of product, preliminary field testing, main product revision, main field testing, operational product revision, operational field testing, final product revision, and dissemination and implementation. The flowchart for STEAM-Based E-LKPD development using Borg & Gall development model can be seen in Figure 1 below.

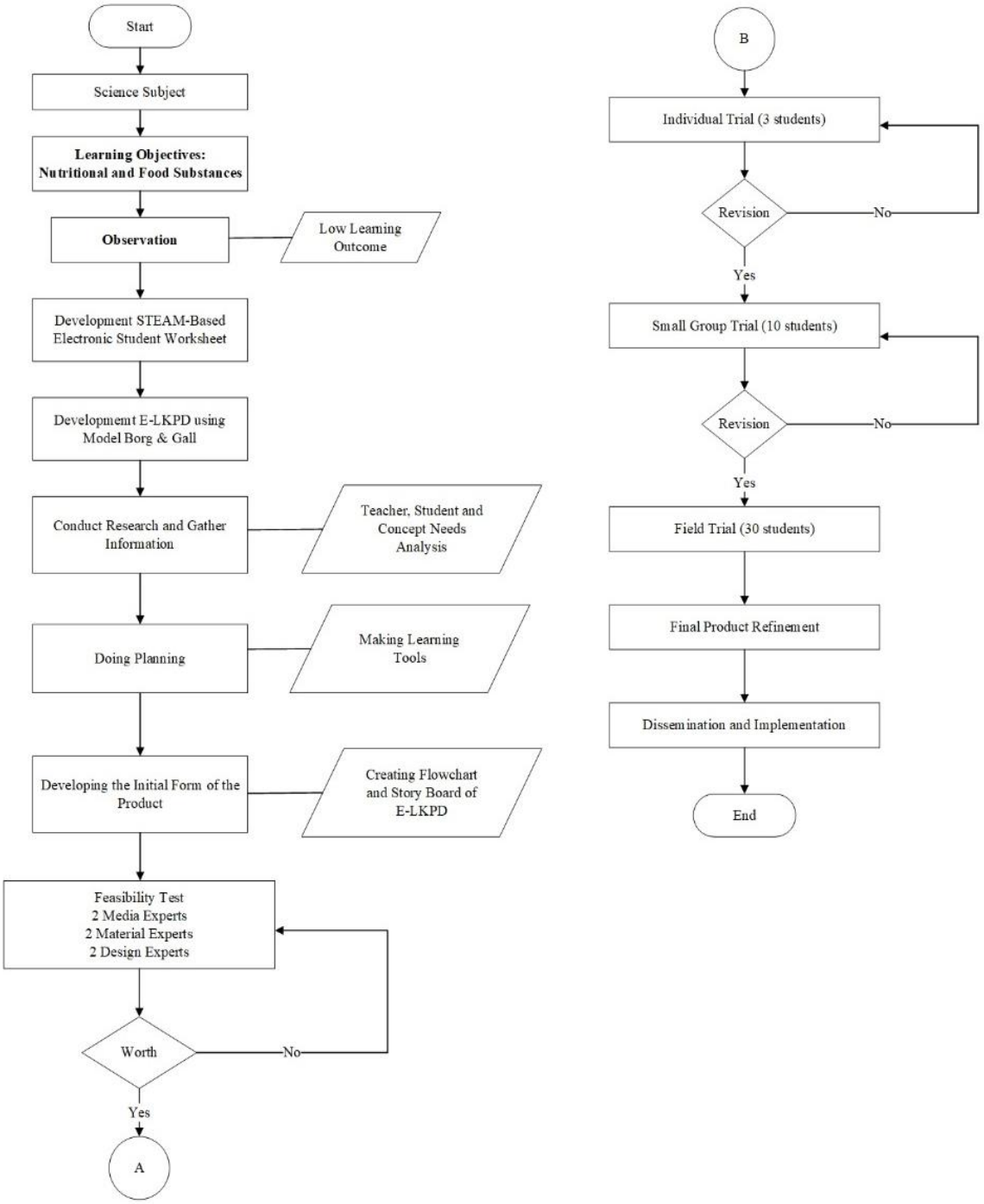

Figure 1. Flowchart for STEAM-Based E-LKPD Development using Borg & Gall Development Model

Research instruments employed in this investigation include learning needs assessment protocols, material validation instruments, media and design validation metrics, educator and student response evaluation forms, and academic achievement assessment instruments. The data analysis in this research employs quantitative descriptive analysis techniques, namely the analysis of preliminary study data, media expert data, material expert data, teacher and student responses, and effectiveness testing.

C. Results and Discussion

1. Results

This research uses a Research and Development (R&D) approach. The study resulted in the development of a STEAM-based Electronic Student Worksheet (E-LKPD) using the Borg & Gall development steps.

1.1 Need Assessment

The needs analysis revealed substantial educator demand for STEAM-integrated Electronic Student Worksheets (E-LKPD) to enhance instructional processes. Interviews with subject specialists and students confirmed the necessity for STEAM-based E-LKPD to augment educational delivery. Survey and interview data indicated that 50% of educators acknowledged their current pedagogical practices as suboptimal. Contributing factors include insufficient student engagement in learning activities, diminished motivational levels, and instructional materials restricted to a single resource. Survey findings further demonstrated that certain educators have not developed comprehensive and structurally coherent lesson preparations or constructed appropriate instructional modules aligned with curriculum requirements.

Nevertheless, educators concur that E-LKPD implementation would facilitate effective delivery of instructional content, laboratory activities, and academic assignments. Furthermore, educators report no significant challenges regarding digital instructional media utilization. They anticipate that E-LKPD implementation will enhance student learning outcomes.

Beyond educator perspectives, students completed questionnaires assessing their perceived need for E-LKPD in science instruction. Needs assessment data revealed unanimous student agreement (100%) that science education should incorporate mobile technology alongside traditional printed resources. Students expressed that E-LKPD represents an essential component in science education and supports educator utilization of E-LKPD for content delivery, laboratory experiences, and assignment administration. Moreover, 47% of students report difficulties comprehending material presented exclusively through printed textbooks. Additionally, 83% indicate infrequent internet utilization for accessing subject-related content. Table 1 shows the questionnaire results distributed to 30 students as respondents.

Table 1. Results of the Student Needs Analysis Questionnaire

No.	Question	Answer		Percentage (%)	
		Yes	No	Yes	No
1.	In your opinion, have your science teachers been teaching science material effectively and engagingly?	22	8	73%	27%
2.	Do you agree that learning processes using only one source (printed textbooks) are very boring?	30	0	100%	0%
3.	Do you experience difficulties in learning or understanding material from printed textbooks?	14	16	47%	53%
4.	Do you often use the internet to access material that is being discussed in class?	5	25	17%	83%
5.	Do you agree that science learning processes should also utilize mobile phones in addition to printed textbooks?	30	0	100%	0%
6.	In your opinion, are Electronic Student Worksheets (E-LKPD) needed in science learning?	30	0	100%	0%
7.	Do you agree if your teacher uses Electronic Student Worksheets (E-LKPD) in the learning delivery process, whether for learning materials, practicum, or assignments?	30	0	100%	0%
8.	Have you ever used Electronic Student Worksheets (E-LKPD) based on the STEAM approach?	0	30	0%	100%

1.2 Design

The design phase addressed learning objectives, research instrumentation, exercises, content development, subject analysis, instructional planning, and educational media selection. During this phase, the researcher developed the instructional media utilizing the Canva application, initiating with storyboard construction. The E-LKPD interface was configured through the Canva platform, with sequential organization conforming to STEAM learning syntax while accommodating the specific nutritional and food substance

curriculum content characteristics. This investigation encompassed the development of instructional modules, E-LKPD construction, conceptual presentation and content organization, assessment instrument creation, visual element integration, and STEAM component incorporation (see Fig.2).

Figure 2. The display of STEAM-based E-LKPD

1.3 Validation and Evaluation

The feasibility assessment of this STEAM-based Electronic Student Worksheet (E-LKPD) underwent validation by expert academicians comprising two material validators, two media specialist validators, and two design specialist validators. The validation methodology involved distributing the developed STEAM-based E-LKPD digital link to validators alongside evaluation instruments for comprehensive examination, assessment, and subsequent enhancement recommendations. In instances where inconsistencies, conceptual misrepresentations, errors, or incompatibilities were identified, validators provided recommendations that were returned to the investigator for appropriate modifications according to suggested improvements. Following revision implementation and subsequent re-examination by expert validators, evaluations were provided and subsequently quantified by the researcher to determine percentage values across individual assessment dimensions, thereby generating comprehensive validation values.

For the material aspect, validation was carried out on assessment aspects, including content, presentation, display, and language. The results of the material expert validation showed an average of 98.06%, categorized as very feasible. Validation was carried out twice against two material expert validators, where in the first assessment, there were still some shortcomings, such as in the aspects of the accuracy of STEAM (Science, Technology, Arts, and Mathematics) procedures in E-LKPD and providing opportunities for students to carry out STEAM activities. After revisions, there was an increase in validation results from the previous 97.37% for validator 1 to 100% and 95.07% to 100% for validator 2, with the category being very feasible to be field-tested. The data from the validation results, including the material expert's assessment scores and their percentages, can be seen in Table 2 below.

Table 2. Learning Material Expert Validation Table

No.	Aspec	Percentage (%)				Average (%)	Categori
		Validator 1		Validator 2			
		1st Validation	2nd Validation	1st Validation	2nd Validation		
1.	Content	98,07%	100%	86,53%	100%	96,15%	Very Feasible
2.	Presentation	90,62	100%	93,75%	100%	96,09%	Very Feasible
3.	Layout	100%	100%	100%	100%	100%	Very Feasible
4.	Language Use	100%	100%	100%	100%	100%	Very Feasible
	Total	**97,37%**	**100%**	**95,07%**	**100%**	**98,06%**	**Very Feasible**

For the media aspect, media expert lecturers conducted validation twice each. The assessment aspects in media expert validation included display, user convenience, graphics, presentation, and E-LKPD content design. The results of media expert validation showed an average of 84.18. The material expert categorized it as very feasible. Validation was carried out twice against two material expert validators, where in the first assessment, there were still some shortcomings in display, user convenience, graphics, presentation, and E-LKPD content design. After revisions, there was an increase in validation results from the previous 68.41% for validator 1 to 95.41% and 87.91% to 88.74% for validator 2, with the category being very feasible to

be field-tested. The data from the validation results, including the media expert's assessment scores and their percentages, can be seen in Table 3 below.

Table 3. Learning Media Expert Validation Table

No.	Aspec	Percentage (%)				Average (%)	Categori
		Validator 1		Validator 2			
		1st Validation	2nd Validation	1st Validation	2nd Validation		
1.	Appearance	75%	91.66%	66,66%	83,33%	79,16%	Very Feasible
2.	User-Friendliness	68,75%	100%	87,50%	93,75%	87,50%	Very Feasible
3.	Visual Design	58,33%	91,66%	91,66%	91,66%	83,32%	Very Feasible
4.	Presentation	75%	93,75%	75%	81,25%	81,25%	Very Feasible
5.	E-LKPD Content Design	65%	100%	100%	93,75%	89,68%	Very Feasible
Total		**68,41%**	**95,41%**	**87,91%**	**88,74%**	**84,18%**	**Very Feasible**

For the design aspect, design expert lecturers conducted validation twice each. The assessment aspects in media expert validation included learning design and E-LKPD characteristics. The results of design expert validation showed an average of 97.11%. Categorized as very feasible. Validation was carried out twice against two material expert validators, where in the first assessment, there were still some shortcomings in the learning design aspect. After revisions, there was an increase in validation results from the previous 94.23% to 100% for validator 1 and validator 2, categorized as very feasible to be field-tested. The validation data, including the media expert's assessment scores and their percentages, can be seen in Table 4 below.

Table 4. Instructional Design Validation Table

No.	Aspec	Percentage (%)				Average (%)	Categori
		Validator 1		Validator 2			
		1st Validation	2nd Validation	1st Validation	2nd Validation		
1.	Instructional Design	88,46%	100%	88,46%	100%	94,23%	Very Feasible
2.	Characteristics of E-LKPD	100%	100%	100%	100%	100%	Very Feasible
Total		**94,23**	**100%**	**94,23**	**100%**	**97,11%**	**Very Feasible**

These findings align with research by Martatiyana et al. (2024), which determined that student responses to STEM-PjBL-based Science e-LKPD among fourth-grade students demonstrated an average percentage of 84% during the individual evaluation phase, classified as excellent. Subsequently, during the small group evaluation phase, the average rate increased to 95%, maintaining the excellent classification. Educator responses to this e-LKPD similarly demonstrated exceptionally positive evaluations, with percentages reaching 93%. Based on these empirical findings, it can be concluded that the developed e-LKPD demonstrates high suitability for educational implementation and exhibits advantages across multiple critical educational dimensions.

Similarly, research conducted by Haifaturrahmah et al. (2020) revealed an average expert evaluation score of 4.28, classified as excellent. Concurrently, user responses (from educators and students) averaged 4.55, which was also classified as excellent. Based on these data analysis results, the developed STEAM-based e-LKPD demonstrates appropriate characteristics for implementation as supplementary instructional resources within integrated thematic educational contexts.

Overall, the validation results from material, media, and learning design expert validators on the development of STEAM-based E-LKPD stated that it has met the eligibility requirements and can be tested in science learning. Table 5 recapitulates the final validation results by expert lecturers.

Table 5. Recapitulation of Validation Results by Expert

No.	Validator	Percentage (%)	Categori
1.	Material Expert	98,06%	Very Feasible
2.	Media Expert	84,18%	Very Feasible
3.	Design Expert	97,11%	Very Feasible
Average		**93,11%**	**Very Feasible**

Table 5 above shows that the average validation result of STEAM-based E-LKPD carried out by expert lecturers in material, media, and learning design is 93.11%, categorized as very feasible overall.

The practicality test of STEAM-based E-LKPD was conducted by science subject teachers, consisting of 3 assessment aspects: content and benefits, presentation, display, and language. Based on teacher assessment, the developed STEAM-based E-LKPD is very feasible to be used in science learning, with a percentage of 100%. After the developed STEAM-based E-LKPD was declared valid by material experts, media experts, design experts, and practitioners (teachers) who utilize E-LKPD in learning, the next stage was to conduct trials that would be carried out individually, small group trials, and then the final stage of conducting field trials in the class that was used as the research subject, namely VIII-1 class. Individual trials were conducted to identify deficiencies in the developed STEAM-based E-LKPD and determine student responses to the developed media. This individual trial included three students as samples, considering the selected students have the same characteristics as the target research class. Information obtained from the individual trial results from 3 student samples showed an average of 91.50%, categorized as "very feasible". Based on these trial results, it can be concluded that the STEAM-based E-LKPD development product is categorized as "very feasible". However, things still need to be improved to be used more effectively and efficiently in the process of field trial II.

Small group trials on the STEAM-based E-LKPD development product were conducted on 10 students. Samples were taken randomly, consisting of 4 students with high learning achievement, 3 with medium learning achievement, and 3 with low learning achievement. This small group trial aimed to identify deficiencies in the developed STEAM-based E-LKPD product. The assessment from this small group trial was about the product's practicality, developed from the user's point of view, which includes several aspects of content and benefits, presentation, display, and language. From the small group trial results from 10 student samples, an average of 97.75% was obtained with the category "very feasible". Based on these trial results, it can be concluded that the STEAM-based E-LKPD development product is categorized as "very feasible". Thus, the STEAM-based E-LKPD development product is suitable for science learning.

Field trials were conducted on 30 students of the VIII-1 class as research subjects. This field trial aimed to identify deficiencies in the developed STEAM-based E-LKPD after the validation stage from the experts. The average value of the field trial results is 97.75% with very feasible criteria. With this, it can be concluded that the developed STEAM-based E-LKPD has met the eligibility requirements to be applied in science learning in the classroom. After the developed STEAM-based E-LKPD was validated by several sources related to media development and users of this E-LKPD, the recapitulation results of the STEAM-based E-LKPD validation can be seen in Table 6 below:

Table 6. Recapitulation of Trial Results

No.	Respondent/Validator	Percentage (%)	Criteria
1.	Practicality Test (Teacher)	100%	Very Feasible
2.	Individual Trial	91,50%	Very Feasible
3.	Small Group Trial	97,75%	Very Feasible
4.	Field Trial	97,75%	Very Feasible
Average		**96,75%**	**Very Feasible**

1.4 Results of Product Effectiveness Test Research

The effectiveness of STEAM-based E-LKPD in science learning can be measured by analyzing student learning outcome data. Student learning outcomes were obtained from two stages: pretest before using STEAM-based E-LKPD and posttest after utilizing STEAM-based E-LKPD.

The acquisition of student learning outcome data using STEAM-based E-LKPD in science learning obtained the lowest score of 70, the highest score of 95, the mean value of 83, the mode of 84.5, the median of 83.07, and the standard deviation of 7.92. From the student learning outcome data using STEAM-based E-LKPD, there were seven people at the average value, namely 23%, 10 people (33%) below the average learning outcome value, and 13 people (43%) above the average learning outcome value. Subsequently, the data is presented in histogram form as shown in Figure 3 below.

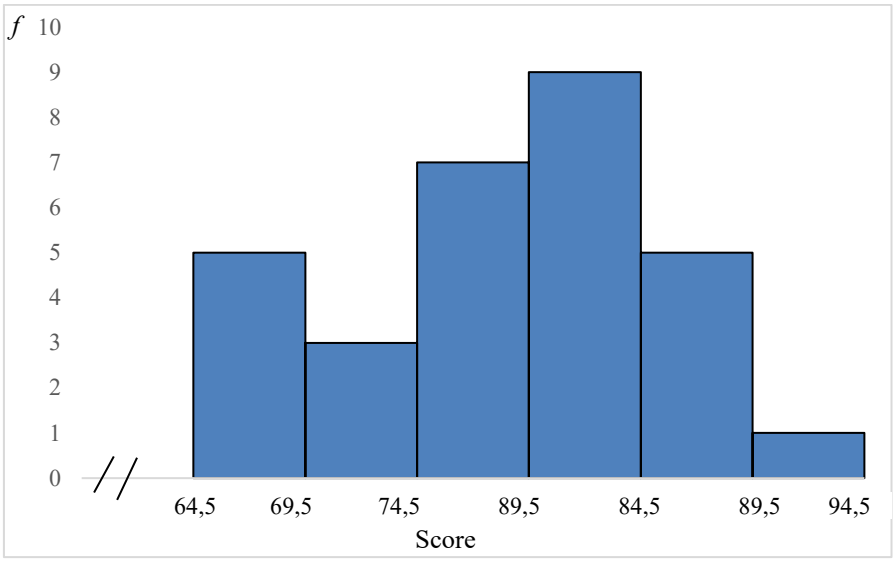

Figure 3. Histogram of Learning Outcomes Experimental Class

While the learning outcomes of students using LKPDs in printed books and E-books published by Kemdikbud, from 30 students, obtained the highest learning outcomes of 90 and the lowest of 65, with an average value of 78.5, mode 83.17, median 79.5, and standard deviation of 6.96. The learning outcomes of students using printed books and E-books published by the Ministry of Education, seven people were at an average value, namely 23%, eight people (27%) were below the average value of learning outcomes, and 15 people (50%) were above the average value of learning outcomes. Subsequently, the data is presented in histogram form as shown in Figure 4 below.

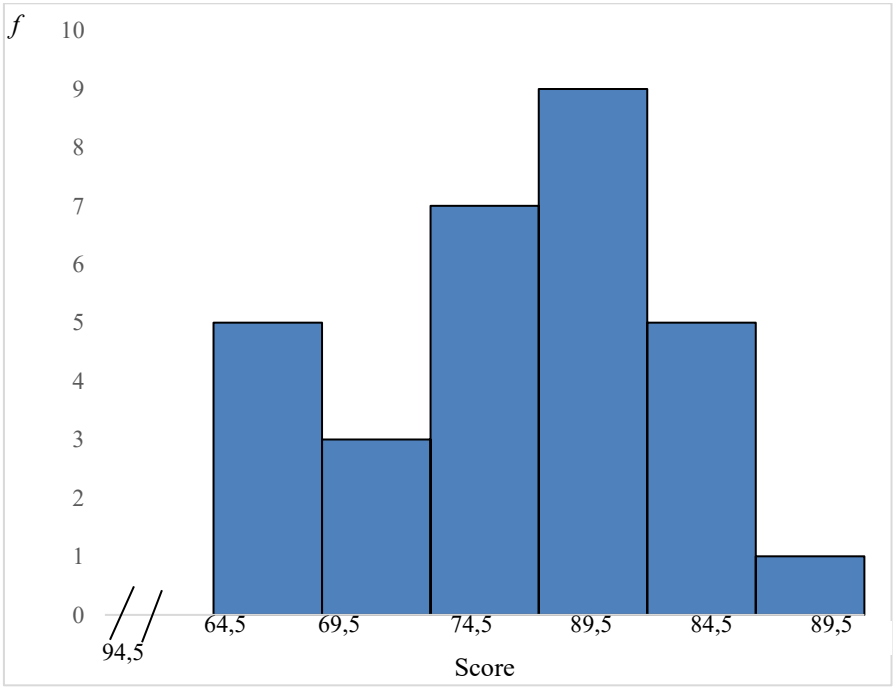

Figure 4. Histogram of Learning Outcomes Scores for Control Class

The effectiveness test of the E-LKPD based on the STEAM Approach developed was carried out by comparing the average value of the learning outcomes of the experimental class using the E-LKPD based on the STEAM Approach and the control class, which only used LKPD from printed books and E-Books published by the Ministry of Education the acquisition of learning outcomes for the experimental and control classes on food and food substances. Furthermore, from the t-test results, obtained t-count and t-table with a significance level of $\alpha = 0.05$, the results obtained t count > t table. It can be interpreted that

H_0 is rejected and H_1 is accepted. The STEAM Approach-based E-LKPD product effectively improves student learning outcomes in science subjects.

The effectiveness of E-LKPD based on the STEAM Approach will improve student learning outcomes and collaboration. It is in line with research conducted by Mariyana, Syahri, and Haryanto, who identified students' creative thinking skills at SMAN 2 Muaro Jambi, which showed an unoptimal level, as indicated by low interest in learning chemistry subjects. To overcome these problems, the development of Electronic Learner Worksheets (E-LKPD) integrated with the Problem-Based Learning approach was carried out to increase the creative thinking capacity of students on the acid-base concept. The results showed the significance of differences in learning outcomes between conditions without E-LKPD and with E-LKPD, with a difference of 11.56 points. There was a progressive increase in the average score by 5-7 points at each stage of learning, which confirmed that the E-LKPD develop effectively improved students' creative thinking skills and learning outcomes (Mariyana et al., 2023).

Likewise, Herlina, Ramlawati, and Hasri conducted research at SMAN 6 Enrekang. Based on the pretest and posttest data, the n-gain value was 0.71 with a high category. The average posttest score was 82.73, and the percentage of class completeness was 84.85%. Data analysis shows that the use of STEAM-based e-modules and E-LKPD is proven to be effective in improving student learning outcomes on colloidal system material with a high effectiveness category (Herlina et al., 2021).

Likewise, research conducted by Annisa, Effendi, and Damris at SMAN 11 Jambi City shows the results of the correlation of pretest-posttest values, 0.263 > 0.05, meaning there is no relationship between pretest-posttest values. The 2- tailed significance value of 0.000 < 0.05 shows a real difference in creative thinking ability and student learning outcomes in pretest and posttest data. Based on the study results, it can be concluded that there is a real difference in the ability of student learning outcomes with STEAM-based E-LKPD at SMAN 11 Jambi City (Annisa et al., 2019).

The ideal Student Worksheet must meet the requirements of validity, practicality, and effectiveness (Saputro et al., 2019; Subhan & Oktolita, 2018) on the results of the research that has been conducted and supported by theories from various literatures above, the E-LKPD based on the STEAM approach is effectively used in science learning.

2. Discussion

The results of this study indicate that integrating the STEAM approach into E-LKPD successfully optimized the learning process. This success is likely attributed to the characteristics of the STEAM approach, which promotes interdisciplinary and contextual learning by integrating Science, Technology, Engineering, Arts, and Mathematics within a single learning instrument. The STEAM-based E-LKPD was able to create a more contextual and enjoyable learning ecosystem that represents something novel, which attracted students' interest and enhanced their conceptual understanding of food and nutritional content material.

The effectiveness of the STEAM approach-based E-LKPD proved to enhance students' learning outcomes and improve collaboration. It aligns with research conducted by Mariyana et al. (2023), who identified that students' creative thinking skills at SMAN 2 Muaro Jambi showed suboptimal levels, indicated by low interest in learning chemistry subjects. They developed an Electronic Student Worksheet (E-LKPD) integrated with a Problem-Based Learning approach to enhance students' creative thinking capacity on acid-base concepts to address this issue. The research results demonstrated significant differences in learning achievement between conditions without E-LKPD and with E-LKPD, with a difference of 11.56 points. There was a progressive increase in average scores of 5-7 points at each learning stage, confirming that the developed E-LKPD effectively improved students' creative thinking abilities and learning outcomes.

Similarly, research conducted by Herlina et al. (2021) at SMAN 6 Enrekang showed that based on pretest and posttest score data, an n-gain value of 0.71 was obtained in the high category. The average posttest score was 82.73 with a class completion percentage of 84.85%. Data analysis indicated that using STEAM-based e-modules and e-LKPD proved effective in improving students' learning outcomes on colloid system material, with a high effectiveness category.

Likewise, research conducted by Annisa et al. (2019) at SMAN 11 Jambi City showed pretest-posttest correlation results of 0.263 > 0.05, meaning there was no relationship between pretest-posttest scores. The 2-tailed significance value of 0.000 < 0.05 indicated a significant difference in students' creative thinking abilities and learning outcomes between pretest and posttest data. Based on the research resultat there was

a significant difference in students' learning outcomes using STEAM-based E-LKPD at SMAN 11 Jambi City.

Similar findings were reported by Suparwati et al., who researched developing STEM-based chemistry E-LKPD with ethnoscience content on reaction rate material as a solution to overcome students' low chemistry mental models. The STEM-based chemistry E-LKPD with ethnoscience content produced in this study was categorized as valid, practical, and effective for improving students' chemistry mental models. Material validation testing of the STEM-based chemistry e-LKPD with ethnoscience content received a valid assessment. The practicality test results of the e-LKPD were categorized as very practical. The average N-gain of students' chemistry mental models was 0.76. Teachers and students can use This STEM-based chemistry E-LKPD in the learning process.

2. 1 Implications

This research contributes to developing a conceptual framework for the STEAM approach in science learning. It strengthens theories about how technology can be effectively integrated into science education at the junior high school level. The developed electronic student worksheets (E-LKPD) demonstrate that digital learning media can bridge abstract concepts in science, making them more concrete and easily understood. This research reinforces constructivism theory and project-based learning within the context of the STEAM approach. Students do not merely receive knowledge passively but actively construct their understanding through direct experiences and projects that integrate various disciplines.

This research provides practical references for science teachers designing innovative learning with the STEAM approach. The developed electronic student worksheets (E-LKPD) can serve as a model for teachers to develop similar teaching materials that align with students' needs and characteristics. The research findings can be used as material for evaluating and developing of science curricula that are more responsive to students' needs and contemporary developments. The STEAM approach in the E-LKPD can inspire the development of more integrated and contextual curricula.

The STEAM-based electronic student worksheets (E-LKPD) developed can improve the quality of science learning at SMP Negeri 2 Satu Atap Batang Serangan. Students can learn more actively, creatively, and meaningfully as the learning is designed by integrating science, technology, engineering, arts, and mathematics. The developed STEAM-based E-LKPD contributes to developing students' 21st-century skills, such as critical thinking, creativity, collaboration, and communication. It is essential for preparing students to face future challenges. Implementing STEAM-based E-LKPD can increase student motivation and learning outcomes because the learning is designed to be more engaging, interactive, and relevant to daily life.

The implementation of E-LKPD encourages optimal technology utilization in schools. It can catalyze for schools to develop better technological infrastructure and promote digital literacy among students and teachers.

2.2 Research Contribution

The results of this study indicate that integrating the STEAM approach into electronic student worksheets (E-LKPD) successfully optimized the learning process. This success is likely due to the characteristics of the STEAM approach that encourages interdisciplinary and contextual learning, integrating Science, Technology, Engineering, Arts, and Mathematics into a single learning instrument. The STEAM-based E-LKPD was able to create a learning ecosystem that is more contextual, enjoyable, and innovative, which captured students' interest and enhanced their conceptual understanding of food and nutrient materials.

2.3 Limitations

This research was conducted with a sample limited to students at SMP Negeri 2 Satu Atap Batang Serangan, so the results may not be widely generalizable to larger or more diverse population contexts. The specific characteristics of this 'one-roof' school may have learning dynamics that differ from other regular schools. The trial of the STEAM-based E-LKPD product was conducted with only 30 students as research samples, which may allow bias factors to still influence the research results. The adaptation process of the STEAM approach, which is relatively new in the Indonesian learning context, especially in rural areas like Batang Serangan, requires substantial adjustment to previously established learning cultures. Resistance to changing the learning approach presents its challenge. Implementing STEAM-based E-LKPD faces challenges in the form of gaps in teachers' facilitative competencies in guiding students through the STEAM learning stages. Teachers tend to still apply conventional approaches despite using digital media.

2.4 Suggestions

The STEAM-based E-LKPD that has been carefully designed should be used under the supervision of science teachers during the learning process. Considering that accessing this media requires an internet connection through smartphones or laptops/computers, supervision is needed to ensure students do not open other sites unrelated to learning.

D. Conclusion

Based on the research problem formulation, objectives, results, and discussion of the development of the STEAM approach-based Electronic Student Worksheets (E-LKPD) in science learning, the following conclusions can be drawn:

1. This research was conducted using the Borg & Gall development model utilizing Canva and Heyzine Flipbook applications, resulting in a product in the form of STEAM approach-based Electronic Student Worksheets (E-LKPD) that can be utilized at SMP Negeri 2 Satu Atap Batang Serangan.
2. The feasibility of the developed STEAM approach-based E-LKPD, based on product feasibility test results validated by six expert lecturers in media, material/content, and instructional design, indicates that the E-LKPD is suitable for use at SMP Negeri 2 Satu Atap Batang Serangan.
3. The developed STEAM approach-base E-LKPD's practicality KPD, based on trial results by teachers and students, demonstrates that the product suitable for use in 8th grade science learning at SMP Negeri 2 Satu Atap Batang Serangan.
4. The effectiveness was tested through effectiveness testing by examining student learning outcomes after using the STEAM approach-based E-LKPD product, which shows that the product is effective for use due to improvements in student learning outcomes.

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F. Author Contribution Statement

VP, designed the study, developed the STEAM-based E-LKPD, collected and analyzed data, and wrote the original manuscript. **AH,** supervised the research methodology, guided STEAM framework implementation, and critically revised the manuscript. **ST,** supervised the pedagogical development, validated learning materials, and reviewed the manuscript for educational content accuracy. All authors contributed to study conceptualization, participated in research supervision meetings, and approved the final manuscript.

References

Annisa, R., Effendi, M. H., & Damris, D. (2019). Peningkatan Kemampuan Berpikir Kreatif Siswa Dengan Menggunakan Model Project Based Learning Berbasis Steam (Science, Technology, Engineering, Arts Dan Mathematic) Pada Materi Asam Dan Basa Di Sman 11 Kota Jambi. *Journal of The Indonesian Society of Integrated Chemistry*, *10*(2), 14–22. https://doi.org/10.22437/jisic.v10i2.6517

Asrizal, A., Dhanil, M., & Usmeldi, U. (2023). The Effect of STEAM on Science Learning on Student Learning Achievement: A Meta-Analysis. *Jurnal Penelitian Pendidikan IPA*, *9*(4), 1650–1657. https://doi.org/10.29303/jppipa.v9i4.3108

Conner, L. D. C., Tzou, C., Tsurusaki, B. K., Guthrie, M., Pompea, S., & Teal-Sullivan, P. (2017). Designing STEAM for Broad Participation in Science. *Creative Education*, *08*(14), 2222–2231. https://doi.org/10.4236/ce.2017.814152

Dewanti, B. A. (2022). Comparing Student Creativity Skills in Experiment-Based and Project- Based Science Learning. *Prisma Sains: Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, *10*(3), 786–794. https://doi.org/10.33394/j-ps.v10i3.5348

Dinantika, H. K., Suyanto, E., Dewa, I., & Nyeneng, P. (2019). *Pengaruh Penerapan Model Pembelajaran Project Based Learning Terhadap Kreativitas Siswa Pada Materi Energi Terbarukan*. *11*(2), 73–80. https://doi.org/10.30599/jti.v11i2.473

Ghufron, S. (2023). *Development of Electronic Student Worksheets (E-LKPD) Based on Stad-Type*

Cooperative Learning on Writing Materials. *X*(V), 128–135. https://doi.org/10.51244/IJRSI

Haifaturrahmah, Hidayatullah, R., Maryani, S., & Nurmiwati. (2020). *Pengembangan Lembar Kerja Siswa Berbasis STEAM untuk Siswa Sekolah Dasar*. *6*(2), 310–318. https://dx.doi.org/10.33394/jk.v6i2.2315

Harahap, S. (2020). Identifikasi Kreativitas Siswa Terhadap Mata Pelajaran IPA. *Integrated Science Education Journal (ISEJ)*, *1*(1), 16–22. https://doi.org/10.37251/isej.v1i1.21

Harizah, D. T. D., Sumarmi, & Bachri, S. (2021). Pengaruh Model Pembelajaran Project Based Learning Terhadap Kreativitas dan Hasil Belajar Geografi Siswa. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan*, *6*(5), 2015–2019. http://dx.doi.org/10.17977/jptpp.v6i5.14846

Herlina, Ramlawati, & Hasri. (2021). Efektivitas Penggunaan e- Modul Berbasis STEAM Pada Materi Sistem Koloid untuk Meningkatkan Hasil Belajar Peserta Didik Kelas XI SMAN 6 Enrekang. *Prosiding Seminar Nasional Pendidikan IPA II "Optimalisasi Literasi Digital Melalui Pendekatan STEM,"* *1*(1), 63–70. https://doi.org/10.26858/semnaspendipa.v1i1.30546

Huda, N., Fransiska, F. W., Mokodenseho, S., Tabilantang, B. H., & Mokodompit, A. (2024). The Influence of STEAM Education on Students' Interest in Technology at Middle Schools in Indonesia. In *The Eastasouth Journal of Learning and Educations* (Vol. 2, Issue 01, pp. 50–62). https://doi.org/10.58812/esle.v2i01.226

Mang, H. M. A., Chu, H. E., Martin, S. N., & Kim, C. J. (2021). An SSI-Based STEAM Approach to Developing Science Programs. In *Asia-Pacific Science Education* (Vol. 7, Issue 2). https://doi.org/10.1163/23641177-bja10036

Mariyana, Syahri, W., & Haryanto. (2023). *Based E-LKPD Development Based Problem Based Learning to Improve Students' Creative Thinking Skills on Acid-Base Material*. *15*(2), 163–169. https://doi.org/10.24114/jpkim.v15i2.48264

Martatiyana, D. R., Nasbey, H., & Utami, N. C. M. (2024). *Praktikalitas E-LKPD Berbasis STEM-PjBL dalam Pembelajaran IPA Fase B*. *10*(1), 57–66. https://doi.org/10.31602/muallimuna.v10i1.15771

Mu'minah, Iim Halimatul, & Suryaningsih, Y. (2020). *Implementasi STEAM (Science, Technology, Engineering, Arts and Mathematics) dalam Pembelajaran Abad 21*. *5*(1), 65–73. https://www.jurnal.unma.ac.id/index.php/BE/article/view/2105

Nursakinah, Y., Prima, E. C., & Agustin, R. R. (2023). *The Development of FunLABS Android-Based Application Using Unity Software as Learning Media to Explore Students' Motivation on Acid, Base, and Salt Topic*. *6*(March). https://doi.org/10.17509/jsl.v6i2.50447

Nyamupangedengu, E., & Lelliott, A. D. (2015). An exploration of learners' use of worksheets during a science museum visit an exploration of learners' use of worksheets during a science museum visit. *African Journal of Research in Mathematics Science and Technology Education*, *16*(1), 85–99. https://doi.org/10.1080/10288457.2012.10740731

Patresia, I., Silitonga, M., & Ginting, A. (2020). Developing biology students' worksheet based on STEAM to empower science process skills. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *6*(1), 147–156. https://doi.org/10.22219/jpbi.v6i1.10225

Putri, N. M., & Hamimah, H. (2023). Pengembangan Multimedia Interaktif Wordwall Menggunakan Model Problem Based Learning (PBL) pada Pembelajaran IPA. *Journal of Practice Learning and Educational Development*, *3*(1), 95–99. https://doi.org/10.58737/jpled.v3i1.99

Rati, N. W., Kusmaryatni, N., & Rediani, N. (2017). Model Pembelajaran Berbasis Proyek, Kreativitas dan Hasil Belajar Mahasiswa. *Jurnal Pendidikan Indonesia*, *6*(1), 60–71. https://doi.org/10.23887/jpi-undiksha.v6i1.9059

Salfina, Hatibe, A., & 2, M. P. (2015). Pengaruh Metode Mind Map terhadap Ketrampilan Berfikir Kreatif dan Kemampuan berkomunikasi tentang Fisika Siswa Kelas Vii SMP Negeri 1 Biromaru. *E-Jurnal Mitra Sains*, *3*(2), 1–8. https://doi.org/10.22487/mitrasains.v3i2.88

Saputro, R., Setiawan, D., & Saragih, D. (2019). The Development of Students Worksheet (SW) based on Inquiry to Improve Activity and Learning Outcomes in Civic Lesson of Students Grade VII. *Proceedings of the 1st International Conference on Social Sciences and Interdisciplinary Studies (ICSSIS 2018)*, *208*(1), 299–304. https://doi.org/10.2991/icssis-18.2019.62

Subhan, M., & Oktolita, N. (2018). Developing Worksheet (LKS) Base on Process Skills in Curriculum 2013 at Elementary School Developing Worksheet (LKS) Base on Process Skills in Curriculum 2013 at Elementary School Grade IV, V, VI. *IOP Conf. Series: Materials Science and Engineering 335*, *335*(2018), 1–8. https://doi.org/10.1088/1757-899X/335/1/012108

Uyanık Aktulun, Ö., Kaya, Ü. Ü., Gözüm, A. İ. C., Kalogiannakis, M., & Papadakis, S. (2024). Igniting Curiosity: The Role of STEAM Education in Enhancing Early Academic, Language Skills and Motivation for Science. *International Journal of Modern Education and Computer Science*, *16*(5),

1–20. https://doi.org/10.5815/ijmecs.2024.05.01
Wisudawati, A. W., & Sulistyowati, E. (2022). *Metodologi pembelajaran IPA*. Bumi Aksara. Google Scholar
Yulianti, E., Suwono, H., Abd Rahman, N. F., & Phang, F. A. (2024). State-of-the-Art of STEAM Education in Science Classrooms: A Systematic Literature Review. *Open Education Studies*, *6*(1). https://doi.org/10.1515/edu-2024-0032