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# STEAM-Integrated PjBL Learning Tools for Newton's Laws to Improve High School Students' Creative Thinking Skills

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***Abstract –*** *Creative thinking skills are essential competencies in physics education because students are expected not only to understand scientific concepts but also to apply them creatively in solving contextual problems. However, learning in physics on Newton's Laws is often still dominated by routine problem-solving and formula-based instruction, which provides limited opportunities for students to develop fluency, flexibility, originality, and elaboration. This study aimed to develop and evaluate STEAM-integrated Project-Based Learning (PjBL) learning tools on Newton's Laws to improve students' creative thinking skills. This research employed a Research and Development design using the 4-D model, consisting of Define, Design, Develop, and Disseminate stages, with dissemination limited to classroom implementation and academic reporting. The developed products included a teaching module, student worksheets, and a creative thinking skills test instrument. The study involved 55 eleventh-grade science students at SMA Labschool UNESA 1 Surabaya, selected through purposive sampling. Data were collected through expert validation, learning implementation observation, pre-test and post-test, and student response questionnaires. Data were analyzed using descriptive statistics, normalized gain, and a paired t-test. The results showed that the developed learning tools were very valid, with an average validation score of 88.30%. The effectiveness test indicated a substantial increase in students' creative thinking skills, with the pre-test average increasing from 38.14 to 89.86 in the post-test, an n-gain score of 0.85 in the high category, a significant paired t-test result (Sig. < 0.05), and positive student responses of 85%. The novelty of this study lies in the explicit integration of PjBL syntax, STEAM components, and indicators of creative thinking into structured learning tools for Newton's Laws. These findings indicate that the developed learning tools are valid, practical, and effective, and that they contribute to physics education by offering a contextual, interdisciplinary, and student-centered instructional design to foster creative thinking skills.*

***Keywords:*** *creative thinking; Newton's laws; physics education; project-based learning; steam learning*



## I. INTRODUCTION

Creative thinking skills have become an essential competency in contemporary science education, particularly in physics, where students are expected not only to understand scientific concepts but also to apply them to solve complex, contextual problems. In the framework of twenty-first-century education, creative thinking is commonly associated with the ability to generate diverse ideas, construct alternative solutions, view problems from multiple perspectives, and elaborate ideas into meaningful products or explanations (OECD, 2019; Partnership for 21st Century Skills, 2019; Acar et al., 2017). These abilities are increasingly important because students must respond to dynamic social, technological, and environmental challenges that cannot be addressed solely through memorization or routine problem-solving. Therefore, the development of creative thinking skills aligns closely with the orientation of twenty-first-century learning, which emphasizes student-centered learning, contextual experiences, and the strengthening of competencies such as creativity, collaboration, communication, and critical thinking (Bell, 2010; Partnership for 21st Century Skills, 2019).

In physics education, creative thinking plays a particularly significant role because physics concepts often involve abstract principles that must be connected to observable phenomena and real-life applications. Physics is frequently perceived as difficult because it involves complex, abstract concepts, and students often struggle to connect theoretical principles to experimental or real-world phenomena (Wang et al., 2025). Students are therefore required to analyze relationships among variables, interpret physical events, construct explanations, and apply mathematical representations to understand natural phenomena. Newton's Laws, for example, constitute a fundamental topic in mechanics because they provide a conceptual basis for explaining motion, force, acceleration, interaction, and equilibrium. Recent literature on Newton's Second Law also emphasizes that students' limited understanding of force and motion is often associated with traditional instruction that presents physics as distant from everyday life and overly focused on mathematical problem solving (Parra-Zeltzer et al., 2025). However, students frequently have difficulty understanding Newton's Laws when learning is dominated by formula-based instruction and procedural exercises. Such instruction tends to emphasize correct numerical answers rather than conceptual exploration, alternative reasoning, and creative application. As a result, opportunities for students to develop fluency, flexibility, originality, and elaboration in physics learning remain limited (Riberio, 2023; Witdiya et al., 2023; Ulfa et al., 2024).

Several studies have indicated that conventional physics instruction is often insufficient to foster higher-order thinking skills, particularly when classroom activities rely heavily on teacher explanation, textbook examples, and routine problem sets. Although these approaches may support basic conceptual acquisition, they do not always provide adequate space for students to formulate ideas, test solutions, revise designs, or communicate creative products. A systematic review of K–12 STEM instructional design by Halawa et al. (2024) shows that instructional designs such as inquiry-based, project-based, and design-based learning are increasingly used because they provide opportunities for questioning, experimenting, analyzing, collaborating, communicating, and reflecting. This condition becomes important because creative thinking in science requires active engagement with authentic problems, opportunities for exploration, and meaningful interaction between concepts and real-world contexts. In line with this argument, Kuo (2025) found that structured STEAM-PBL can improve students' scientific and social creative thinking, particularly their ability to generate diverse ideas, produce original ideas, and evaluate or improve ideas. Therefore, physics learning needs to be designed to enable students to investigate phenomena, construct knowledge collaboratively, and translate scientific concepts into practical, innovative solutions.

One instructional model that has been widely discussed as a means of supporting higher-order thinking is Project-Based Learning (PjBL). PjBL provides students with opportunities to learn through authentic projects that involve inquiry, collaboration, planning, product development, and reflection (Kokotsaki et al., 2016; Zhou, 2023). Through these stages, students are encouraged to identify problems, propose possible solutions, test ideas, and present outcomes in a structured learning process. In science education, PjBL is considered relevant because it allows students to actively construct knowledge rather than passively receive information. Moreover, the project process can stimulate creative thinking because students are required to generate ideas, make decisions, solve unexpected problems, and refine their products based on evidence and feedback (Aldabbus, 2023). Thus, PjBL has strong potential to improve both conceptual understanding and creative thinking skills when it is implemented systematically.

Nevertheless, the effectiveness of PjBL depends greatly on the quality of the learning design, the clarity of instructional stages, and the alignment between project activities and intended learning outcomes. Although PjBL is widely recognized as a student-centered model that can support inquiry, collaboration, and problem-solving, recent studies emphasize that its impact is strongly influenced by how projects are structured and embedded within the curriculum (Kokotsaki et al., 2016; Halawa et al., 2024). PjBL that is implemented only as a general project activity may not automatically improve creative thinking if the project is not explicitly connected to learning objectives, scientific concepts, and thinking indicators. In STEAM-based learning, Kuo (2025) shows that structured project activities are needed to stimulate scientific and social creative thinking because students require opportunities to generate diverse ideas, evaluate alternatives, and improve their initial ideas. In the context of Newton's Laws, students therefore need systematic guidance to connect project activities with scientific reasoning, mathematical analysis, technological use, engineering design, and creative representation. This is consistent with recent evidence that curriculum-embedded STEAM-PBL models are more promising when they combine creativity development with academic learning in a structured classroom design (Zhao & Abdullah, 2025). Therefore, learning tools such as teaching modules, student worksheets, and assessment instruments must be carefully developed to ensure that each stage of the project contributes to the intended learning outcomes. Student worksheets, in particular, can serve as instructional scaffolds that guide learners through inquiry, collaboration, and creative problem-solving activities, as shown in studies on STEM/STEAM-based worksheets that develop creative thinking skills in physics learning (Anugrah et al., 2023; Sabrina & Jatmiko, 2025). Without such integration, project activities may become product-oriented tasks that lack conceptual depth and do not systematically develop students' fluency, flexibility, originality, and elaboration.

The Science, Technology, Engineering, Arts, and Mathematics (STEAM) approach offers a relevant framework for strengthening PjBL in physics learning. STEAM promotes interdisciplinary learning by integrating scientific understanding with technological application, engineering design, artistic creativity, and mathematical reasoning (Liao, 2016; Henriksen et al., 2019; Rahmawati et al., 2019). The inclusion of the arts component distinguishes STEAM from STEM by providing space for imagination, aesthetics, communication, and creative expression in the learning process. In physics learning, this integration can help students understand concepts not only as abstract theories but also as principles that can be applied in designing, testing, and presenting meaningful products. Several studies have reported that STEAM-based learning can contribute to the development of creativity, problem-solving ability, and student engagement in science classrooms (Ellianawati et al., 2025; Hebebci & Usta, 2022; Muntazah et al., 2025).

The integration of STEAM and PjBL is therefore pedagogically promising because both approaches emphasize active learning, interdisciplinary problem-solving, and student creativity (Kuo, 2025; Mota et al., 2025). PjBL provides a project structure that guides students from problem identification to reflection, while STEAM enriches the project by incorporating multiple disciplinary perspectives. In the context of Newton's Laws, this integration enables students to investigate motion and force through scientific inquiry, use technology or simulations to support observation, design simple engineering products, apply mathematical calculations, and present their ideas creatively through visual or artistic elements. Such learning experiences are expected to support the four indicators of creative thinking: fluency, flexibility, originality, and elaboration. Recent empirical evidence by Kuo (2025) shows that STEAM-PBL significantly improves students' ability to generate diverse and creative ideas, and to evaluate or improve them, which closely corresponds to fluency, originality, and elaboration. Fluency may emerge when students generate various ideas for solving motion-related problems; flexibility may develop when they consider different approaches or designs; originality may be reflected in unique project solutions;

and elaboration may appear when they refine, explain, and present their products in detail (Kuo, 2025; Al-Kamzari & Alias, 2025; Acar et al., 2017).

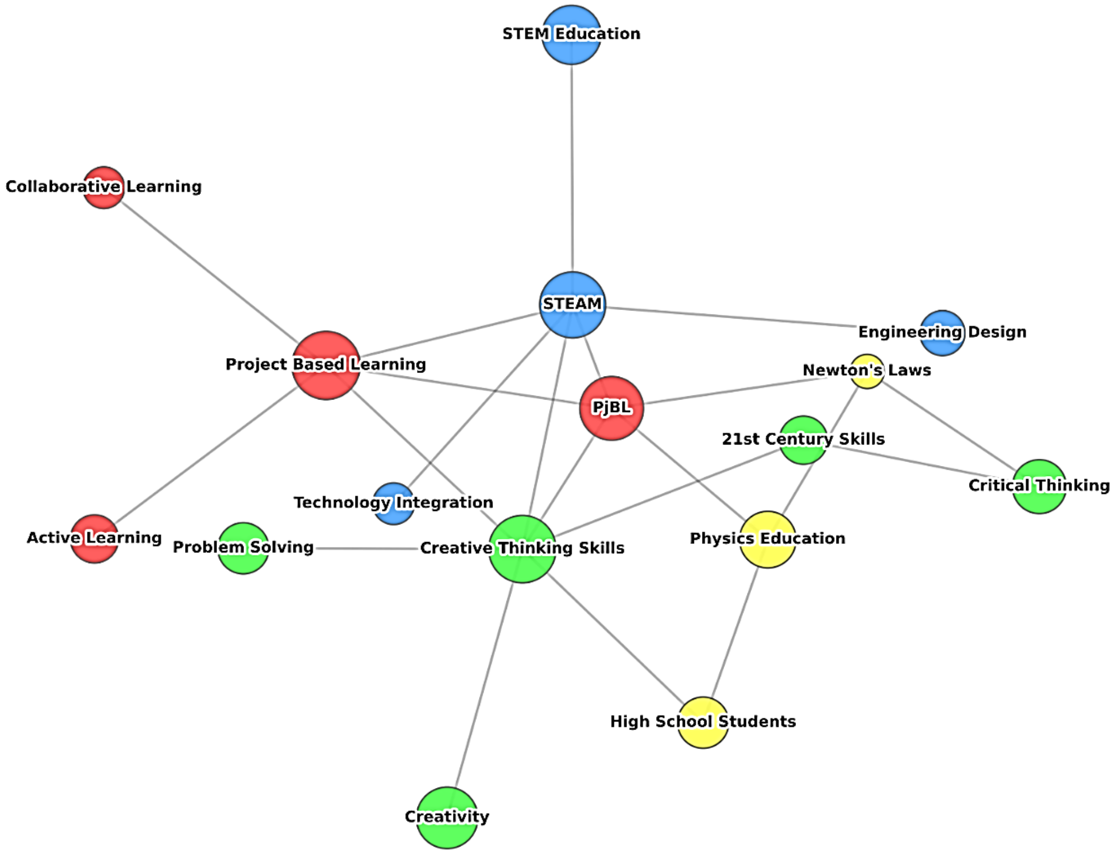


**Figure 1.** Research trend map of PjBL, STEAM, and creative thinking skills in the 2021–2026 period

To strengthen the study's positioning, a bibliometric analysis of publication trends related to PjBL, STEAM, and creative thinking skills was conducted for the 2021–2026 period. The mapping results presented in Figure 1 indicate that the keywords PjBL and STEAM are strongly associated with twenty-first-century and creative thinking skills. However, the direct connection between STEAM-integrated PjBL and physics education, particularly in the topic of Newton's Laws and among senior high school students, remains relatively limited. The need to strengthen research on innovative learning designs in physics education is also supported by studies that map popular topics in reputable international physics education journals, which show sustained attention to learning models, students' competencies, and instructional improvement (Nurazmi & Bancong, 2024). This finding is consistent with recent systematic and bibliometric studies showing that PjBL research has grown substantially and is strongly connected to STEM, collaboration, problem-solving, and self-regulated learning, yet structured applications in secondary school physics still require more theoretically grounded design frameworks (Mota et al., 2025; Al-Kamzari & Alias, 2025). In addition, bibliometric evidence on STEAM education shows that research themes have increasingly evolved toward creativity, computational thinking, sustainability, equity, and maker education, indicating the need for more focused empirical studies that connect STEAM with specific subject-matter learning tools (Nurazmi et al., 2025). This finding suggests that although STEAM, PjBL, and creative thinking have each received increasing scholarly attention, studies that specifically develop structured, STEAM-integrated PjBL learning tools for Newton's Laws remain needed. Thus, there is a clear opportunity to contribute to the literature by designing learning tools that explicitly connect PjBL syntax, STEAM elements, and indicators of creative thinking in a physics learning context.

Based on this gap, the present study aims to develop and evaluate STEAM-integrated PjBL learning tools on Newton's Laws to improve senior high school students' creative thinking skills. The developed learning tools include teaching modules, student worksheets, and instruments for creative thinking skills tests. These tools are designed to systematically integrate PjBL stages with STEAM components and to align learning activities with the indicators of fluency, flexibility, originality, and elaboration. The feasibility of the learning tools is evaluated in terms of validity, practicality, and effectiveness. Therefore, this study is expected to contribute theoretically by enriching the discussion of interdisciplinary and project-based physics learning, and practically by providing structured learning tools to support teachers in implementing contextual, creative, and student-centered physics instruction within the Independent Curriculum context.

## II. METHODS

This study employed a quantitative research design to analyze the quality of a cognitive ability test instrument developed on the topic of temperature and heat. Quantitative research is appropriate for studies that systematically examine data using structured instruments and measurable procedures, particularly when the objective is to empirically evaluate variables and produce scientifically accountable findings (Creswell & Creswell, 2018). In this study, the Rasch model was used as the main analytical framework because it provides a more comprehensive evaluation of item functioning and respondent ability than conventional scoring approaches. Rasch analysis is particularly useful for assessing item fit, person fit, item difficulty, dimensionality, and potential item bias, thereby strengthening the psychometric quality of educational instruments (Anugrah et al., 2023; Sabrina & Jatmiko, 2025).

This study employed a Research and Development (R&D) design to produce and evaluate STEAM-integrated PjBL learning tools for Newton's Laws. The main objective of the development process was to generate learning tools that were valid, practical, and effective for improving senior high school students' creative thinking skills. The development procedure followed the 4-D model, consisting of Define, Design, Develop, and Disseminate stages, because this model provides a systematic framework for identifying instructional needs, designing learning products, validating prototypes, and implementing the developed tools in an educational setting (Anugrah et al., 2023; Sabrina & Jatmiko, 2025). In this study, all four stages were conducted; however, the dissemination stage was limited to classroom implementation and academic reporting. The overall flow of the development process is presented in Figure 2.

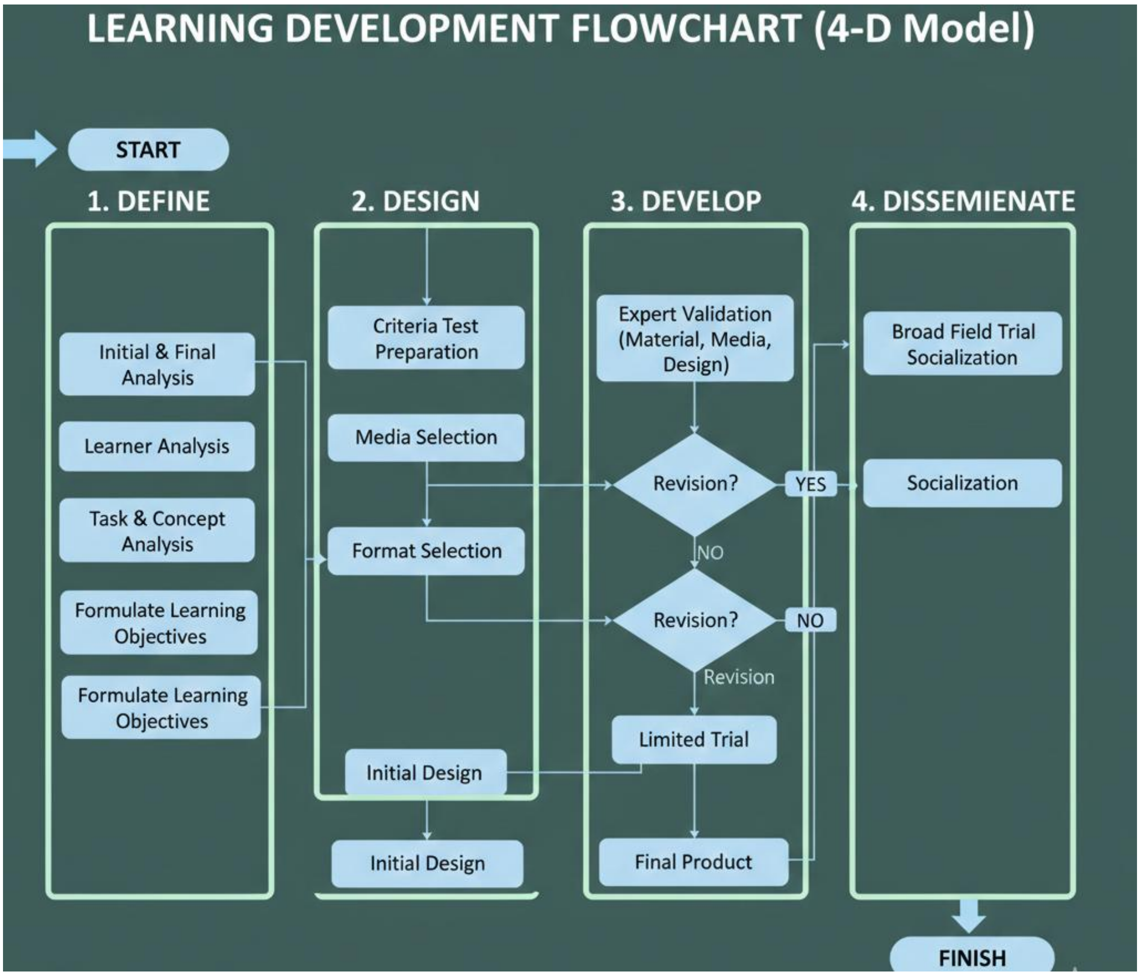


**Figure 2.** Learning device development flow based on the 4-D model

The Define stage was conducted to identify instructional problems, student characteristics, curriculum requirements, and indicators of creative thinking relevant to learning about Newton's Laws. Classroom observations and interviews with physics teachers were used to obtain information about existing learning practices and the extent to which creative thinking skills were facilitated in physics instruction. This stage was important because instructional development requires an accurate understanding of the learning context and learner needs before a product is designed. The analysis focused on the suitability of Newton's Laws material for project-based activities and on the integration of creative thinking indicators, namely fluency, flexibility, originality, and elaboration, into physics learning activities.

The Design stage focused on developing the initial structure of the learning tools, comprising teaching modules, STEAM-based student worksheets, and creative thinking skills test instruments. The learning design was developed by aligning PjBL syntax with STEAM elements in each project stage. The Science component was represented through concepts from Newton's Laws, Technology through digital tools or simulations, Engineering through project design, Arts through visual and creative product representation, and Mathematics through force and acceleration analysis. This alignment was intended to ensure that the developed tools not only presented project activities but also systematically guided students in connecting physics concepts to interdisciplinary problem-solving and creative thinking.

The Develop stage included expert validation, limited trials, and effectiveness testing. The developed learning tools were validated by three experts: two physics education lecturers with expertise in instructional design and one senior high school physics teacher with more than 10 years of teaching experience. The validation examined content suitability, construct validity, language clarity, instructional feasibility, and the consistency of STEAM-PjBL integration. Expert validation is an important component of R&D studies because it provides evidence that the developed product meets theoretical, pedagogical, and practical standards before implementation in the classroom (Lynn, 1986; Yusoff, 2019). The validation results were used to revise the learning tools prior to classroom implementation.

The research was conducted in the odd semester of the 2025/2026 academic year at SMA Labschool UNESA 1 Surabaya, East Java. The participants were 55 eleventh-grade science students selected through purposive sampling. This sampling technique was used because the study required participants who met specific criteria aligned with the research objectives, particularly students with relatively homogeneous basic physics abilities and at least one previous experience in PjBL. In educational development studies, participant selection should align with the characteristics of the instructional product being tested and the learning context in which it will be implemented (Creswell & Creswell, 2018; Anazifa & Djukri, 2017). The implementation lasted four weeks and included product development, expert validation, limited trials in two small trial classes, and the main trial in the experimental class during regular physics learning hours.

The effectiveness test employed a one-group pretest–posttest design. Students' creative thinking skills were measured before and after implementing the STEAM-integrated PjBL learning tools. This design enabled the researchers to examine changes in students' creative thinking skills after the learning intervention. However, because the design did not include a control group, the interpretation of effectiveness was made cautiously, as external factors such as prior learning experience, teacher influence, and classroom environment may have contributed to the observed improvement. Therefore, future studies are recommended to use quasi-experimental designs with control groups to strengthen causal claims and increase the generalizability of the findings.

Data were collected using expert validation sheets, learning implementation observation sheets, creative thinking skills tests, and student response questionnaires. The validation sheets were used to assess the feasibility of the teaching modules, student worksheets, and test instruments based on development product quality criteria (Lynn, 1986; Yusoff, 2019). Observation sheets were used by the researchers and physics teacher to examine the practicality of implementation during classroom learning (Creswell & Creswell, 2018). The creative thinking skills test was developed as a set of performance-based questions aligned with the fluency, flexibility, originality, and elaboration indicators. Student response questionnaires were used to obtain students' perceptions of the learning tools and learning process.

The data analysis procedures were adjusted to the type of data obtained from each instrument, as summarized in Table 1.

**Table 1.** Research data analysis techniques

| No | Research instruments | Data obtained | Data analysis techniques | Decision criteria |
|---|---|---|---|---|
| 1 | Validation sheet for learning devices (teaching modules and student worksheets) | Validator assessment score | Quantitative descriptive analysis (mean score) | Device validity criteria |
| 2 | Validation sheet for creative thinking skills test instrument | Validator assessment score | Quantitative descriptive analysis (mean score) | Instrument validity criteria |
| 3 | Learning implementation observation sheet | Observation score | Descriptive percentage analysis | Practicality criteria of the device |
| 4 | Creative thinking skills test (pre-test and post-test) | Test scores | Normalized gain (n-gain) calculation | N-gain criterion (Hake, 1998) |
| 5 | Creative thinking skills test (pre-test and post-test) | Test scores | Shapiro-Wilk normality test | Sig. > 0.05 (data is normally distributed) |
| 6 | Creative thinking skills test (pre-test and post-test) | Test scores | Paired t-test | Sig. < 0.05 (there is a significant difference) |
| 7 | Student response questionnaire | Questionnaire score | Descriptive percentage analysis | Student response categories |

Validity data from the learning tools and test instruments were analyzed descriptively by calculating the average validation score and referring to validity criteria. Content validity was also assessed using the content validity index, as content validation is an essential procedure to ensure that research instruments adequately represent the measured construct (Lynn, 1986; Yusoff, 2019). Practicality was analyzed through the percentage of learning implementation and teacher perceptions. The effectiveness of the learning tools was determined by comparing pre-test and post-test scores using normalized gain (n-gain), a measure commonly used in physics education research to quantify learning improvement (Hake, 1998; McKagan et al., 2022). Before conducting inferential analysis, the normality of the pre-test and post-test data was assessed using the Shapiro–Wilk test, which is widely used to evaluate whether sample data are normally distributed prior to applying parametric statistical tests (American Statistical Association, 2022; Shapiro & Wilk, 1965; Mishra et al., 2019). After the data were confirmed to be normally distributed, a paired t-test was used to determine whether the difference between pre-test and post-test scores was statistically significant, as this test is appropriate for comparing two related measurements obtained from the same group before and after an intervention (Rietveld & van Hout, 2017). Student questionnaire responses were analyzed descriptively using percentages to determine the categories of students' responses to the STEAM-integrated PjBL learning tools.

## III. RESULTS

This study used the Rasch model to evaluate the quality of a cognitive ability test instrument based on Marzano's Taxonomy on the topic of temperature and heat. The analysis focused on item fit, item difficulty, unidimensionality, reliability, the Wright map, and Differential Item Functioning (DIF) based on gender. Overall, the results provide evidence on the instrument's psychometric quality and identify several aspects that require further refinement.

The results of this study are presented according to the stages of the 4-D development model: Define, Design, Develop, and Disseminate. The presentation of results focuses on the development process and the feasibility of the STEAM-integrated PjBL learning tools for Newton's Laws in terms of validity, practicality, and effectiveness. The developed products consisted of a teaching module, student worksheets, and instruments for creative thinking skills tests. These products were designed to support the development of students' creative thinking skills by integrating PjBL syntax and STEAM elements.

### Define stage

The Define stage was conducted to identify learning needs, student characteristics, curriculum demands, and the indicators of creative thinking skills to be developed through the learning tools. The results of classroom observations and interviews with physics teachers indicated that learning activities on Newton's Laws were still largely focused on routine problem-solving, textbook-based exercises, and procedural use of formulas. Although these activities supported basic conceptual understanding, they did not sufficiently provide opportunities for students to generate multiple ideas, propose alternative solutions, or elaborate on their reasoning creatively.

The analysis of student characteristics showed that Grade XI students had heterogeneous cognitive abilities and different levels of readiness in learning physics. However, students generally showed interest in practical activities, experiments, and project-based tasks. This finding indicated that students had the potential to be actively engaged in contextual learning activities, although they still required structured guidance to connect physics concepts to real-life situations and to creative problem-solving. Regarding creative thinking skills, the study focused on four indicators: fluency, flexibility, originality, and elaboration. These indicators served as the basis for designing learning activities, worksheets, and assessment instruments during the subsequent development stages.

**Design stage**

The Design stage resulted in the initial structure of the STEAM-integrated PjBL learning tools. The teaching module was developed to guide teachers in implementing project-based physics learning on Newton's Laws. The student worksheets was designed to guide students through project activities, starting from identifying contextual problems, planning projects, conducting investigations, developing products, presenting results, and reflecting on the learning process. The creative thinking skills test instrument was prepared to measure students' ability to demonstrate fluency, flexibility, originality, and elaboration in physics-related problem situations.

The learning design was structured by integrating the stages of PjBL with STEAM components. The Science component was represented through conceptual understanding of Newton's Laws. The Technology component was integrated using digital tools or simulations to support observation and analysis. The Engineering component was reflected in the design and development of project products. The Arts component was included through visual design, creativity, and product presentation. The Mathematics component was applied by analyzing the relationships among force, mass, and acceleration. The detailed design of the learning tools is presented in Figure 3.

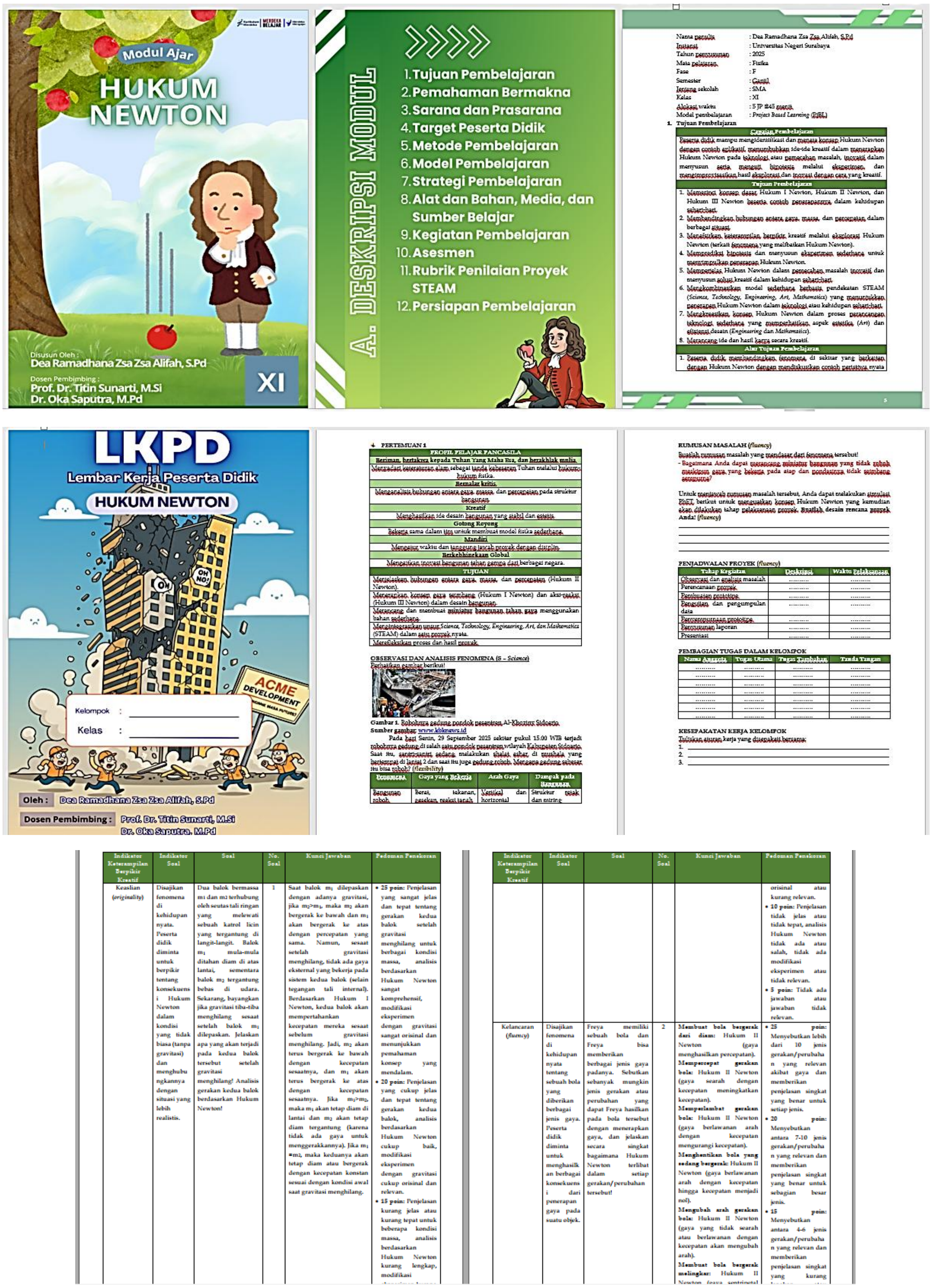


**Figure 3.** Learning device design

The integration shown in Figure 3 illustrates that the developed learning tools were not designed as separate project activities but as structured instructional products that connect physics concepts, interdisciplinary STEAM elements, and indicators of creative thinking. This design became the basis for expert validation and classroom implementation.

**Develop stage**

The development stage involved expert validation and limited trials of the learning tools. Validation was conducted by three validators to determine the feasibility of the teaching module, student worksheets, and the creative thinking skills test instrument. The validation focused on the suitability of the content, clarity of language, completeness of PjBL syntax, consistency of STEAM integration, and alignment of learning activities with creative thinking indicators. The validation results are presented in Table 2.

**Table 2. Device validation results**

| Component | Average score (%) | Category |
|---|---|---|
| Teaching module | 91.00 | Very valid |
| student worksheets | 88.00 | Very valid |
| Test instrument | 86.00 | Very valid |
| Average | 88.30 | Very valid |

As shown in Table 2, the teaching module obtained an average validation score of 91.00%, the student worksheets obtained 88.00%, and the creative thinking skills test instrument obtained 86.00%. The overall average score was 88.30%, which was categorized as very valid. These results indicate that the developed learning tools met the criteria for content feasibility, construct suitability, instructional clarity, and consistency with the objectives of STEAM-integrated PjBL learning. The teaching module received the highest score, indicating that the learning syntax, instructional sequence, and integration of Newton's Laws with project activities were considered highly appropriate. The student worksheets and test instrument were also categorized as very valid, showing that both products were suitable for guiding student activities and measuring creative thinking skills.

The validation results also indicated that the learning tools were appropriate for classroom trials after revision based on the validators' suggestions. Revisions were made to improve clarity of instructions, alignment between project activities and STEAM components, and the precision of assessment indicators. After this revision process, the learning tools were implemented in the classroom to examine practicality and effectiveness.

**Disseminate stage and implementation results**

The Disseminate stage was conducted through classroom implementation in Grade XI. The implementation aimed to examine the effectiveness of the developed learning tools in improving students' creative thinking skills. The effectiveness test was conducted using pre-test and post-test scores, normalized gain analysis, paired t-test, and student response questionnaire. The quantitative results are presented in Table 3.

**Table 3.** Quantitative results of the effectiveness of STEAM-integrated PjBL learning tools

| Indicator | Result |
|---|---|
| Pre-test average | 38.14 |
| Post-test average | 89.86 |
| Score improvement | 51.72 |
| N-gain | 0.85 |
| Paired t-test Sig. | < 0.05 |
| Student response | 85% |

Table 3 shows that the average pre-test score of students' creative thinking skills was 38.14, while the average post-test score increased to 89.86 after the implementation of the STEAM-integrated PjBL learning tools. The difference between the pre-test and post-test averages was 51.72 points. This increase indicates that students demonstrated substantial improvement in creative thinking skills after participating in the learning process. The n-gain value of 0.85 was categorized as high, indicating that the developed learning tools were effective in improving students' creative thinking skills.

The paired t-test showed a p-value $< 0.05$, indicating a statistically significant difference between students' pre-test and post-test scores. This result supports the finding that the improvement in students' creative thinking skills occurred after the implementation of the developed learning tools. In addition, the student response questionnaire showed a positive response of 85%. This indicates that students generally perceived the STEAM-integrated PjBL learning process as engaging, understandable, and useful for learning Newton's Laws through contextual project activities. The qualitative interpretation of the effectiveness results is presented in Table 4.

**Table 4.** Qualitative interpretation of the effectiveness of learning tools

| Indicator | Category |
|---|---|
| Pre-test average | Low |
| Post-test average | Very high |
| Score improvement | Significant |
| N-gain | High |
| Paired t-test Sig. | Significant |
| Student response | Positive |

As shown in Table 4, the pre-test average was categorized as low, indicating that students' initial creative thinking skills were still limited. After the learning intervention, the post-test average reached the very high category. The score improvement was categorized as significant, while the n-gain result was categorized as high. The paired t-test also confirmed a significant difference between pre-test and post-test scores. Furthermore, students' responses were categorized as positive, suggesting that the developed learning tools were well received during the learning process.

## IV. DISCUSSION

The findings of this study provide empirical evidence regarding the quality of a cognitive ability test instrument developed based on Marzano's Taxonomy and analyzed using the Rasch model. Overall, the results indicate that the instrument has an adequate psychometric foundation, although several aspects still require refinement to improve measurement precision, construct representation, and fairness. These findings are important because the quality of an assessment instrument depends not only on its theoretical framework but also on the extent to which its items function consistently and meaningfully in actual measurement contexts.

This study aimed to develop and evaluate STEAM-integrated PjBL learning tools on Newton's Laws to improve senior high school students' creative thinking skills. The findings show that the developed learning tools were valid, practical, and effective in supporting physics learning and enhancing students' creative thinking skills. These results confirm that instructional tools designed through a systematic development process can help transform abstract physics concepts into more meaningful, contextual learning experiences for students. In the context of twenty-first-century education, this finding is relevant because creative thinking is widely recognized as an essential competency that enables learners to generate diverse ideas, construct alternative solutions, and elaborate their reasoning in response to complex problems (OECD, 2019; Partnership for 21st Century Skills, 2019; Acar et al., 2017). Therefore, the results of this study support the argument that physics learning should not only emphasize conceptual mastery and formula application but also provide structured opportunities for students to develop creativity through authentic, interdisciplinary activities.

The high validity of the developed learning tools indicates that the teaching module, student worksheets, and the creative thinking skills test instrument fulfilled the expected content, construct, language, and instructional design criteria. This result suggests that the integration of concepts from Newton's Laws, PjBL syntax, STEAM elements, and creative thinking indicators was deemed appropriate by expert validators. In R&D-based educational studies, expert validation is an important step because it ensures that the developed product is theoretically grounded, pedagogically feasible, and suitable for implementation in the target learning context (Lynn, 1986; Yusoff, 2019). The very valid categories obtained from the teaching module, student worksheets, and test instrument demonstrate that the instructional design was sufficiently aligned with the learning objectives and assessment indicators. This alignment is particularly important because creative thinking skills cannot be developed incidentally; they require deliberate instructional planning that connects learning activities with specific indicators such as fluency, flexibility, originality, and elaboration.

The validity results also reflect the importance of designing learning tools that explicitly guide both teachers and students throughout the learning process. The teaching module provided a structured sequence for implementing STEAM-integrated PjBL, while the student worksheets functioned as a scaffold to help students identify problems, plan projects, conduct investigations, analyze data, and present creative products. This finding is consistent with the view that PjBL must be supported by clear instructional stages so that project activities do not become merely product-oriented tasks but remain connected to conceptual understanding and the development of thinking skills (Kokotsaki et al., 2016; Aldabbus, 2023; Bell, 2010). In the context of Newton's Laws, such structure is essential because students need to relate abstract principles of force, motion, and acceleration to observable phenomena and project-based solutions. Similar findings were reported by Sari et al. (2025), who showed that STEAM-based learning tools on Newton's Laws can improve the quality of instruction and support students' conceptual understanding when the learning design is systematically organized.

The practicality of the learning tools was evident in the successful implementation of the learning syntax and the positive student involvement during classroom activities. Teachers consistently implemented the learning stages, while students actively participated in discussions, investigations, product development, and presentations. This finding indicates that the developed tools were not only theoretically feasible but also operationally applicable in real classroom conditions. Practicality is a crucial aspect of learning tool development because an instructional product must be usable by teachers and understandable for students in authentic learning settings (Creswell & Creswell, 2018; Anugrah et al., 2023; Sabrina & Jatmiko, 2025). The student worksheets played an important role in supporting practicality by providing step-by-step guidance that helped students organize their project activities and connect each activity to the intended learning outcomes. This supports the argument that PjBL fosters authentic learning conditions in which students learn through active investigation, collaboration, and meaningful product development (Bell, 2010).

The effectiveness results showed a substantial improvement in students' creative thinking skills after the implementation of the STEAM-integrated PjBL learning tools. The increase from the pre-test average to the post-test average, the high n-gain score, and the significant paired t-test result indicate that students' creative thinking skills improved after participating in the learning process. The n-gain value of 0.85, categorized as high, indicates that the learning intervention strongly supported students' development of creative thinking. This finding is consistent with Nurazmi and Bancong (2021), who reported that an integrated STEM-PBL model produced better outcomes in students' critical thinking skills in physics than conventional learning. This result is consistent with previous studies showing that project-based and STEAM-oriented learning can enhance students' higher-order thinking, creativity, and problem-solving abilities (Witdiya et al., 2023; Dewi et al., 2025; Retno et al., 2025). The significant difference between pre-test and post-test scores further strengthens the empirical evidence that students benefited from learning activities requiring them to generate ideas, explore alternative solutions, design products, and communicate their reasoning.

The improvement in creative thinking skills can be interpreted through the characteristics of STEAM-integrated PjBL. PjBL allows students to engage in authentic projects that involve problem identification, planning, implementation, presentation, and reflection (Kokotsaki et al., 2016; Al-Kamzari & Alias, 2025). These stages provide opportunities for students to move beyond passive reception of information and become active constructors of knowledge. At the same time, STEAM integration enriches the project process by encouraging students to use scientific concepts, technological tools, engineering design, artistic representation, and mathematical reasoning in an interconnected manner (Liao, 2016; Henriksen et al., 2019; Kelley & Knowles, 2016). In this study, students were required not only to understand Newton's Laws theoretically but also to apply them in project activities involving observation, design, calculation, visualization, and presentation. Such multidimensional experiences likely supported fluency by encouraging students to generate a range of ideas, flexibility by allowing them to consider different solution strategies, originality by motivating them to create unique project products, and elaboration by requiring them to explain and refine their ideas in detail.

The findings also suggest that integrating the arts component into STEAM contributed to the development of creativity in physics learning. The arts component provided students with opportunities to express scientific understanding through visual design, product aesthetics, and creative presentation. This is important because creativity in science education is not limited to producing new scientific ideas; it also includes the ability to communicate, represent, and elaborate on concepts in meaningful ways. The inclusion of arts distinguishes STEAM from STEM by emphasizing imagination, design, and expressive representation as part of the learning process (Liao, 2016; Henriksen et al., 2019). Previous studies have also reported that STEAM-based learning can improve creativity and problem-solving skills by connecting scientific reasoning with interdisciplinary and creative practices (Ellianawati et al., 2025; Hebebci & Usta, 2022; Rahmawati et al., 2019). Therefore, the positive results of this study indicate that integrating artistic elements into physics projects can help students transform abstract concepts into concrete, communicable learning products.

Another important interpretation concerns the role of contextual learning in strengthening students' engagement and conceptual understanding. Newton's Laws were introduced through project activities related to students' daily experiences and local environmental phenomena, such as transportation systems, everyday motion, and simple engineering problems in the surrounding community. This contextualization helped students connect abstract physics principles with familiar situations, thereby making learning more relevant and meaningful. The result is consistent with constructivist perspectives, which emphasize that students build knowledge through interaction with authentic experiences and social learning environments (Bell, 2010; Kokotsaki et al., 2016; Anazifa & Djukri, 2017). In addition, contextual project activities can reduce the gap between theoretical physics and real-world applications, a challenge often encountered in physics instruction. By situating Newton's Laws within meaningful project contexts, students were encouraged to see physics not merely as a set of formulas but as a framework for explaining and solving real problems.

The positive student response of 85% provides additional evidence that the developed learning tools were well received by learners. Students' positive responses indicate that the STEAM-integrated PjBL approach was perceived as engaging, useful, and supportive of learning Newton's Laws. Student acceptance is important because affective and motivational aspects can influence participation in inquiry, collaboration, and creative production. When students perceive learning activities as meaningful and relevant, they are more likely to engage actively in the learning process. This finding supports the idea that student-centered and project-oriented learning can foster active participation and collaboration, which are essential features of twenty-first-century science learning (OECD, 2019; Partnership for 21st Century Skills, 2019; Bell, 2010). Thus, the positive student response strengthens the practical contribution of this study by demonstrating that the developed learning tools are not only statistically effective but also acceptable from learners' perspectives.

Compared with previous research, this study makes a more specific contribution by focusing on developing structured, STEAM-integrated PjBL learning tools for Newton's Laws within the Independent Curriculum context. Previous studies have shown that STEAM learning and PjBL can improve creativity and higher-order thinking skills (Witdiya et al., 2023; Dewi et al., 2025; Retno et al., 2025; Panduweni et al., 2024). However, many studies have positioned STEAM as a general learning approach without explicitly mapping each STEAM component onto the syntax of PjBL and the indicators of creative thinking. The present study addresses this limitation by designing teaching modules, student worksheets, and assessment instruments that directly connect PjBL stages with STEAM elements and creative thinking indicators. This explicit integration constitutes the study's novelty and provides a practical model for teachers seeking structured guidance in implementing interdisciplinary, project-based physics learning.

From a theoretical perspective, this study reinforces the argument that creative thinking skills can be systematically developed when learning environments are designed to combine disciplinary understanding, interdisciplinary application, and authentic problem-solving. The findings show that creativity in physics learning can be fostered through carefully structured activities that require students to investigate phenomena, develop project products, and communicate their ideas. This aligns with the literature emphasizing that creative thinking involves idea generation, the development of alternative solutions, originality, and elaboration (OECD, 2019; Partnership for 21st Century Skills, 2019; Acar et al., 2017; Pinar et al., 2025). From a practical perspective, the developed learning tools can serve as an instructional alternative for physics teachers who aim to implement student-centered learning while maintaining conceptual rigor. The tools provide a framework for organizing learning about Newton's Laws that integrates scientific inquiry, technology use, engineering design, artistic expression, and mathematical analysis.

Despite these positive findings, the results should be interpreted with methodological caution. The effectiveness test employed a one-group pretest–posttest design without a control group. Although this design allows researchers to measure improvement before and after the intervention, it does not fully control for external variables such as prior learning experiences, teacher influence, classroom climate, or students' exposure to related materials outside the intervention. Therefore, the significant improvement in students' creative thinking skills should be understood as evidence of learning progress associated with the implementation of the developed tools, rather than as a definitive causal claim. This limitation does not diminish the value of the development results, but it indicates the need for further studies employing quasi-experimental or experimental designs with control groups.

## V. CONCLUSION AND SUGGESTION

This study developed and evaluated STEAM-integrated PjBL learning tools on Newton's Laws to improve senior high school students' creative thinking skills. The findings show that the developed teaching module, student worksheets, and the creative thinking skills test instrument were valid, practical, and effective for classroom implementation. The validity results indicated that the learning tools met the required criteria for content suitability, instructional design, language clarity, STEAM integration, and alignment with creative thinking indicators. The effectiveness results also showed a substantial improvement in students' creative thinking skills, as reflected in the significant increase from pre-test to post-test scores, the high n-gain value, and positive student responses. These findings indicate that the explicit integration of PjBL syntax and STEAM elements can facilitate students' fluency, flexibility, originality, and elaboration in learning Newton's Laws.

This study has several limitations. The effectiveness test was conducted using a one-group pre-test–post-test design without a control group, so the results should be interpreted carefully, as external factors may have influenced students' improvement. In addition, the implementation was limited to a single school and a single physics topic, which may limit the generalizability of the findings. Future research is recommended to employ quasi-experimental or experimental designs with control groups, larger sample sizes, and more diverse school contexts. Further studies may also examine the implementation of STEAM-integrated PjBL learning tools in other physics topics and investigate their long-term impact on students' creative thinking, conceptual understanding, and problem-solving skills. Despite these limitations, this study contributes to the field of physics education by providing a structured, validated instructional design that integrates PjBL syntax, STEAM components, and indicators of creative thinking within the Independent Curriculum context.

## REFERENCES

Acar, S., Burnett, C., & Cabra, J. F. (2017). Ingredients of creativity: Originality and more. *Creativity Research Journal, 29*(2), 133–144. https://doi.org/10.1080/10400419.2017.1302776

Aldabbus, S. (2023). Project-based learning: Implementation and challenges. *International Journal of Education, Learning and Development, 6*(3), 71-79. https://eajournals.org/ijeld/vol-6-issue-3-march-2018/project-based-learning-implementation-challenges/

Al-Kamzari, F., & Alias, N. (2025). A systematic literature review of project-based learning in secondary school physics: Theoretical foundations, design principles, and implementation strategies. *Humanities and Social Sciences Communications, 12*(286), 1-18. https://doi.org/10.1057/s41599-025-04579-4

American Statistical Association. (2022). *American statistical association ethical guidelines for statistical practice.* Zenodo. https://doi.org/10.5281/zenodo.7092386

Anazifa, R. D., & Djukri, D. (2017). Project-based learning and problem-based learning: Are they effective to improve students' thinking skills? *Jurnal Pendidikan IPA Indonesia, 6*(2), 346–355. https://doi.org/10.15294/jpii.v6i2.11100

Anugrah, A., Herlina, K., & Suyatna, A. (2023). Inquiry-integrated STEM on electronic student worksheet: An effort to stimulate creative thinking and collaborative skills. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni, 12*(2), 251-263. https://doi.org/10.24042/jipfalbiruni.v12i2.17306

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 83*(2), 39–43. https://doi.org/10.1080/00098650903505415

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.

Dewi, D., Mukaromah, A., Ilham, M., & Arifin, Z. (2025). The effectiveness of project-based learning in improving students' critical thinking skills. *Journal of English Language and Education, 10*(4), 1139-1145. https://jele.or.id/index.php/jele/article/view/1292

Ellianawati, E., Subali, B., Putra, B. R., Wahyuni, S., Dwijananti, P., Adhi, M. A., & Yusof, M. M. M. (2025). Critical thinking and creativity in STEAM-based collaborative learning on renewable energy issues. *Journal of Education and Learning (EduLearn), 19*(1), 112-119. https://doi.org/10.11591/edulearn.v19i1.21638

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*(1), 64–74. https://doi.org/10.1119/1.18809

Halawa, S., Lin, T. C., & Hsu, Y. S. (2024). Exploring instructional design in K–12 STEM education: A systematic literature review. *International Journal of STEM Education, 11*(43), 1-15. https://doi.org/10.1186/s40594-024-00503-5

Hebebci, M. T., & Usta, E. (2022). The effects of integrated STEM education practices on problem solving skills, scientific creativity, and critical thinking dispositions. *Participatory Educational Research, 9*(6), 358-379. https://doi.org/10.17275/per.22.143.9.6

Henriksen, D., Mehta, R., & Mehta, S. (2019). Design thinking gives STEAM to teaching: a framework that breaks disciplinary boundaries. *STEAM Education,* 57-78. https://doi.org/10.1007/978-3-030-04003-1_4

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*(11), 1–11. https://doi.org/10.1186/s40594-016-0046-z

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools, 19*(3), 267–277. https://doi.org/10.1177/1365480216659733

Kuo, H. C. (2025). Transforming tomorrow: A practical synthesis of STEAM and PBL for empowering students' creative thinking. *International Journal of Science and Mathematics Education, 23*, 2061-2087. https://doi.org/10.1007/s10763-024-10511-0

Liao, C. (2016). From Interdisciplinary to transdisciplinary: An arts-integrated approach to STEAM education. *Art Education, 69*(6)*,* 44-49. https://doi.org/10.1080/00043125.2016.1224873

Lynn, M. R. (1986). Determination and quantification of content validity. *Nursing Research, 35*(6), 382–386. https://doi.org/10.1097/00006199-198611000-00017

McKagan, S. B., Sayre, E. C., & Madsen, A. (2022). *Normalized gain: What is it and when and how should I use it?* PhysPort. https://www.physport.org/recommendations/Entry.cfm?ID=93334

Mishra, P., Pandey, C. M., Singh, U., Gupta, A., Sahu, C., & Keshri, A. (2019). Descriptive statistics and normality tests for statistical data. *Annals of Cardiac Anaesthesia, 22*(1), 67-72. https://doi.org/10.4103/aca.ACA_157_18

Mota, F. B., Cabral, B. P., Braga, L. A. M., & Lopes, R. M. (2025). Mapping the global research on project-based learning: A bibliometric and network analysis (2014–2024). *Frontiers Education, 10*, 1-12. https://doi.org/10.3389/feduc.2025.1522694

Muntazah, A., Elizar, E., Apriza, B., & Suprapto, I. (2025). The effectiveness of STEAM learning model implementation in primary school students' IPAS learning: a systematic literature review. *Journal for Lesson and Learning Studies, 8*(1), 75–85. https://doi.org/10.23887/jlls.v8i1.89722

Nurazmi, N., & Bancong, H. (2021). Integrated STEM-problem based learning model: Its effect on students' critical thinking. *Kasuari: Physics Education Journal, 4*(2), 70–77. https://journalfkipunipa.org/index.php/kpej/article/view/219

Nurazmi, N., & Bancong, H. (2024). Exploring physics education research: Popular topics in prestigious international journals in the period of 2009–2019. *AIP Conference Proceedings, 2799*(1). https://doi.org/10.1063/5.0183452

Nurazmi, N., Bancong, H., Nurfadilah, N., & Yusal, Y. (2025). Mapping the evolution of STEAM education: A bibliometric analysis of global trends from 2016 to 2025. *International Journal of Learning, Teaching and Educational Research, 24*(9), 940-965. https://doi.org/10.26803/ijlter.24.9.45

OECD. (2019). *Future of education and skills 2030: OECD learning compass 2030*. OECD Publishing. https://www.oecd.org/education/2030-project/

Panduweni, M., Suhartini, E., & Haerani, R. P. R. (2024). Revitalizing creativity: Enhancing students' creative thinking through STEAM and project-based learning in human respiration studies. *Scientiae Educatia: Jurnal Pendidikan Sains, 13*(2), 172-181. http://dx.doi.org/10.24235/sc.educatia.v13i2.18223

Parra-Zeltzer, V. R., Huincahue, J., & Abril, D. (2025). Newton's second law teaching strategies—Identifying opportunities for educational innovation. *Education Sciences, 15*(6), 1-25. https://doi.org/10.3390/educsci15060748

Partnership for 21st Century Skills. (2019). *Framework for 21st century learning definitions*. P21. http://static.battelleforkids.org/documents/p21/P21_Framework_DefinitionsBFK.pdf

Pinar, F. I. L., Panergayo, A. A. E., Sagcal, R. R., Acut, D. P., Roleda, L. S., & Prudente, M., S. (2025). Fostering scientific creativity in science education through scientific problem-solving approaches and STEM contexts: a meta-analysis. *Disciplinary and Interdisciplinary Science Education Research, 7*(18), 1–17. https://doi.org/10.1186/s43031-025-00137-9

Rahmawati, Y., Ridwan, A., Hadinugrahaningsih, T., & Soeprijanto, S. (2019). Developing critical and creative thinking skills through STEAM integration in chemistry learning. *Journal of Physics: Conference Series, 1156*, 1-7. https://doi.org/10.1088/1742-6596/1156/1/12033

Retno, R. S., Purnomo, P., Hidayat, A., Mashfufah, A., & Umah, E. C. (2025). Students' creative thinking in STEM integrated project-based learning (PjBL-STEM). *Journal of Education Research and Evaluation, 9*(1), 142–152. https://doi.org/10.23887/jere.v9i1.84704

Riberio, A. S. F. (2023). A systematic review for creative thinking skills in physics subjects. *EduFisika: Jurnal Pendidikan Fisika, 8*(2), 154–163. https://doi.org/10.59052/edufisika.v8i2.25281

Rietveld, T., & van Hout, R. (2017). The paired t test and beyond: Recommendations for testing the central tendencies of two paired samples in research on speech, language and hearing pathology. Journal of Communication Disorders, 69, 44–57. https://doi.org/10.1016/j.jcomdis.2017.07.002

Sabrina, N. M. N., & Jatmiko, B. (2025). Implementation of PJBL-based worksheet with a STEAM approach to improve high school students' creative thinking abilities: A synthesis of empirical insights. *Issue & Trend of Digital Technology in Physics Education, 1*(1), 1-12. https://journal.unesa.ac.id/index.php/dpe/article/view/38997

Sari, W. W., Dwikoranto, D., & Bergsma, L. N. (2025). A futuristic STEAM-integrated PBL model enhanced by digital technology to foster high school students' creative thinking in physics learning. *Issue & Trend of Digital Technology in Physics Education, 1*(1), 1-21. https://journal.unesa.ac.id/index.php/dpe/article/view/39000

Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality: Complete samples. Biometrika, 52(3–4), 591–611. https://doi.org/10.2307/2333709

Ulfa, M., Wahyudi, W., Gunawan, G., & Gunada, I. W. (2024). The effect of project-based learning on student creativity in physics learning. *Indonesian Journal of STEM Education, 6*(2), 75–85. https://journal.publication-center.com/index.php/ijse/article/view/1648

Wang, X. M., Yu, X. H., Yu, D. D., Hwang, G. J., & Lan, M. (2025). Does combining real and virtual experiments improve learning achievement in physics? Evidence from a meta-analysis (2001–2021). *Education and Information Technologies, 46*, 1-13. https://doi.org/10.1016/j.edurev.2024.100661

Witdiya, T., Supriadi, G., Supriatin, A., & Annovasho, J. (2023). The effect of STEAM learning on improving each indicator of students' creative thinking in physics learning. *Jurnal Ilmiah Pendidikan Fisika, 7* (1), 42-50. https://doi.org/10.20527/jipf.v7i1.7158

Yusoff, M. S. B. (2019). ABC of content validation and content validity index calculation. *Education in Medicine Journal, 11*(2), 49–54. https://doi.org/10.21315/eimj2019.11.2.6

Zhao, S., & Abdullah, A. H. (2025). Integrated STEAM and problem-based learning: A teaching framework to enhance undergraduates' creative thinking. *International Journal of Academic Research in Progressive Education and Development, 14*(1), 866–877. https://doi.org/10.6007/IJARPED/v14-i1/24490

Zhou, C. (2023). The impact of the project-based learning method on students. *2nd International Conference on Education Reform, Humanities and Social Studies, 9*, 20-25. https://doi.org/10.54691/bcpep.v9i.4603