JPPIPA 10(2) (2024)

Jurnal Penelitian Pendidikan IPA
Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Development of Student Worksheets Using the Engineering Design Process to Practice Physics Problem-Solving Skills for Vocational School Students

Toni Rahmanto[1*], Insih Wilujeng[2]

[1] Physics Education Program on Graduate School, Faculty of Mathematics and Natural Sciences, Yogyakarta State University, Yogyakarta, Indonesia.
[2] Department of Science Education, Faculty of Mathematics and Natural Sciences, Yogyakarta State University, Yogyakarta, Indonesia.

Received: August 13, 2024
Revised: November 27, 2024
Accepted: February 25, 2024
Published: February 29, 2024

Corresponding Author:
Toni Rahmanto
tonirahmanto.uny2020@gmail.com

DOI: 10.29303/jppipa.v10i2.4969

Abstract: Improving of physics learning process in vocational schools is very urgent to do so that it can improve the problem-solving skills. The purpose of this study was to produce student worksheets based on the engineering design process to practice physics problem-solving skills. This research method is research and development (R&D) using the ADDIE model. The research instruments consisted of learning observation sheets, interview sheets, feasibility & practicality assessment sheets, student response questionnaires, and questions. Product implementation as well as legibility assessment using 10th-grade automotive engineering students. Student worksheets are equipped with assignments to train students' problem-solving skills. To find out the criteria for increasing students' problem-solving abilities, the N-Gain equation is used. The results of the assessment showed that the student worksheets met the criteria of being very eligible (92.67%) and Very Practical (98.20%). Analysis of problem-solving tasks shows an average value of 88.89. As for the test results, it is known that as many as 78% of students are included in the High criteria, and 22% of students are included in the Moderate criteria. The conclusion of the research is that the use of EDP-based student worksheets can improve the problem-solving skills of students.

Keywords: Engineering design process; Physics problem-solving skills; Student worksheet development; Vocational high school

Introduction

One of the problems of learning physics in vocational schools is the process of learning does not training students in improving their problem-solving skills (Faozi et al., 2020; Jaenudin et al., 2020). Physics is a subject that forms the basis of areas of expertise for competency skills (Khoeriah et al., 2020). The purpose of learning physics at vocational schools is not limited to rote memorization of formulas and concepts but to improve problem-solving (Docktor et al., 2016; Anggraini et al., 2022). Problem-solving skills are very fundamental abilities in vocational schools and need to be developed in the learning process (Chiang & Lee, 2016). This is in line with the demands of 21st-century learning, namely that the physics learning process must be designed to develop problem-solving skills. It is necessary to develop learning based on problem solving (Ince, 2018; Tapilouw et al., 2021; Roemintoyo & Budiarto, 2023). Students must be actively involved in the activity of building ideas and solutions in order to solve problems (Koenig, 2019).

However, there are several main problems with learning physics in vocational schools today, that do not train students' problem-solving skills (Supriyadi et al., 2019). In addition, physics learning relatively only emphasizes understanding concepts (Chiang et al., 2016; Supriyadi et al., 2019). Learning tools have not been optimally developed to train problem-solving abilities (Salam et al., 2023; Wahyuni et al., 2019). Another

How to Cite:
Rahmanto, T., & Wilujeng, I. . (2024). Development of Student Worksheets Using the Engineering Design Process to Practice Physics Problem-Solving Skills for Vocational School Students. *Jurnal Penelitian Pendidikan IPA*, *10*(2), 545–556. https://doi.org/10.29303/jppipa.v10i2.4969

problem is the teacher-centered physics learning process, which has an impact on low student learning outcomes and causes physics problem-solving abilities to be low and not optimally developed (Lisanti et al., 2022). Students experience problems understanding and solving physics problems (Maknun, 2020). One of the main causes of achieving less than optimal physics test results is a low ability to understand how to solve physics problems (Ibnusaputra et al., 2023).

The analysis of the physics skills of students shows that students' ability to solve problems in electricity material is still low (Anggraini et al., 2022). In addition, physics learning still uses conventional teacher-centered models (Ridlo et al., 2022; Salam et al., 2023). Such learning causes students to tend to be passive and less enthusiastic (Sakdiah et al., 2022). Learning using a scientific approach is able to train and develop students' learning activities, motivation, and problem-solving abilities (Nasrullah et al., 2018). One of the learning methods based on the scientific approach and the student-centered approach is learning using an engineering process approach (Precharattana et al., 2023). Learning implements the process of providing techniques and opportunities for students to apply concepts of physics in problem-solving (Nurtanto, Pardjono, et al., 2020).

Students are cultivated to collaborate, and learning materials are sought for solving real problems (Hartini et al., 2020; Stehle & Peters-Burton, 2019). Problem-solving skills can be developed in engineering design-based physics learning (Hartini et al., 2020). Practice-based learning or projects can improve problem-solving skills through a series of activities to make a product (Chiang et al., 2016). The engineering design learning process applies the concepts of physics and mathematical logic to solve real problems in life (Deininger et al., 2017). Students use physics concepts and equations to solve problems by making certain products (Umamah & Andi, 2019; Wahyuni et al., 2019). Based on these studies, it is necessary to develop student worksheets that are able to train students' problem solving skills.

The engineering design process is a process in which the concepts of science, mathematics, and the application of engineering are used to improve effective problem-solving (Ali & Tse, 2023; Soe et al., 2018). The engineering design process (EDP) describes the stages of activity in the practice-based learning process of making products (Vistara et al., 2022). The practice-based learning process can be carried out effectively and efficiently if there are materials, guidelines, and instructions in the form of special teaching materials (Sari et al., 2016). One of the main components of learning tools to support the implementation of good learning is student worksheets (LKPD) (Ekantini & Wilujeng, 2018). student worksheets (LKPD) is structured to facilitate the learning process of students so that they are more active in learning (Asma et al., 2020).

Based on the results of the several studies of physics learning tools, it is known that teachers have not developed student worksheets optimally to develop thinking skills and problem-solving skills (Salam et al., 2023). Student worksheets are structured to facilitate students in constructing understanding in a structured and systematic way, as well as to develop students' physics problem-solving abilities to the fullest (Asma et al., 2020; Lisanti et al., 2022). Student worksheets need to be developed to support lesson plans and learning objectives (Nuryadin et al., 2023). Other information was obtained from the results of interviews with class X students majoring in motorcycle engineering and business; as many as 85% of the total respondents stated that they were more enthusiastic about learning physics using practical learning methods.

Based on the description of the information that has been presented, it is necessary to have practice-based physics learning with the help of worksheets. Engineering Design Process (EDP)-based student worksheets are used as guidelines in the physics learning process. In learning physics, students apply the concept of physics to motorcycle electrical problems. In physics learning activities that implement student worksheet based on the engineering design process (EDP). Students are trained to analyze and solve problems and situations in the context of engineering (Lin et al., 2021). Students encounter problems and discuss in solving physics problems. Students identify and define problems, collect relevant information so that creative ideas are produced, develop them, and re-evaluate their ideas (Ali & Tse, 2023; Piawi et al., 2018). Engineering-based learning objectives enable students to develop problem solving skills.

Physics practical learning using student worksheets based on the engineering design process can provide opportunities for students to develop skills in applying physics concepts to solving electrical problems through manufacturing products, according to automotive majors (Nurtanto et al., 2018; Soe et al., 2018). This research and development aim to produce student worksheets using the engineering design process to train students' problem-solving skills, especially in dynamic electricity material, and determine product feasibility and practicality, as well as student and teacher responses to student worksheets. The results of this study can be used as an alternative reference source in the development of physics teaching materials, especially for vocational schools. So that learning physics at vocational schools becomes more varied, and innovative, and by the demands of the curriculum and the characteristics of physics at vocational schools.

Method

This research was carried out at a vocational school in the special region of Yogyakarta, in the academic year 2022–2023. Product implementation (student worksheets) used a sample of nine class X students majoring in Motorcycle Engineering and Business. After completing the lesson, the teacher and students provide practical assessments and responses to the student worksheets that have been used. The instruments used in this study included feasibility assessment sheets, practicality assessment sheets, problem-solving ability questions, and teacher and student interview guidelines.

This type of research is research & development (R&D). The development model used is the ADDIE model, which consists of five stages: analysis, Design, Development, Implementation, and Evaluation Stage. ADDIE's flow of stages is presented in Figure 1.

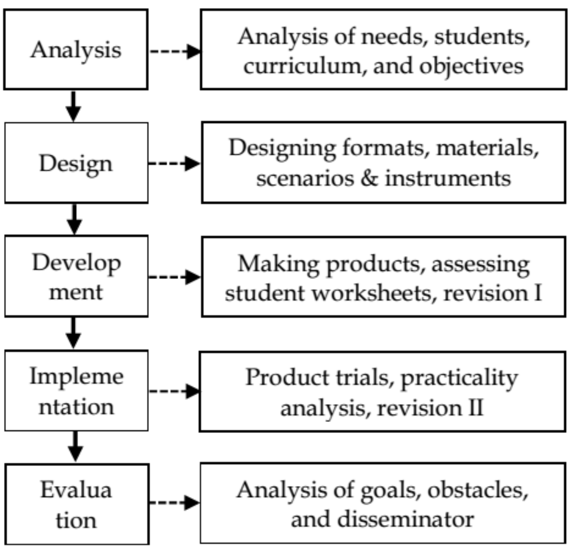

Figure 1. Product research and development flow

Data analysis in this study included four analyses: data analysis on the feasibility assessment; data analysis on the practicality; analysis of problem-solving skills assignments; and analysis of N-Gain scores. *An analysis* of task scores is used to determine the extent to which competency or problem-solving skill indicators are achieved by students. The product feasibility assessment was carried out using the Guttman scale, while the practicality (readability) assessment used the Likert scale. The scoring criteria are presented in Tables 1 and 2.

Table 1. Criteria for Guttman Scale Data

Alternative Answer	Score
Yes	1
No	0

The Likert scale is used for practicality assessments. Statements related to student work sheet are presented, then students vote certain answers. There are four answer choices that students can choose for response data on student worksheets.

Table 2. Criteria for Likert Scale Data

Alternative Answer	Score
Strongly Agree	4
Agree	3
Don't Agree	2
Strongly Disagree	1

Data from the feasibility and practicality assessments are then averaged and converted into percentage data using Equation 1.

$$P = \frac{\sum X}{\sum X_i} \, x \; 100\% \tag{1}$$

Description:
P = Percentages
ΣX = Total score obtained
ΣX_i = The maximum score of the assessment

Data in the form of percentages is then converted into feasibility and practicality criteria. The eligibility criteria for student worksheet products are presented in Table 3.

Table 3. Student Worksheet Eligibility Criteria

Percentage (%)	Criteria
80 < P ≤ 100	Very Worthy
60 < P ≤ 80	Worthy
40 < P ≤ 60	Less Eligible
20 < P ≤ 40	Not feasible
0 - 20	Very Unworthy

The practicality assessment percentage of student answer sheets is interpreted into practical criteria (readability). The five product practicality criteria are presented in Table 4.

Table 4. Criteria for the Practicality of Student Worksheets (Haerani et al., 2023)

Percentage (%)	Criteria
80 < P ≤ 100	Very Practical
60 < P ≤ 80	Practical
40 < P ≤ 60	Less Practical
20 < P ≤ 40	Impractical
0 - 20	Very Impractical

Product implementation using pre-test and post-test group design Task score analysis uses the four scoring criteria presented in Table 5. Task score analysis is used to determine the achievement of students' problem-solving skills indicators during the learning process.

Table 5. Task Scoring Criteria

Alternative Answers	Score
Correct and Complete Answers	3
Correct and Incomplete Answers	2
Incorrect and Incomplete Answers	1
No answer	0

An N-Gain analysis is used to determine the criteria for increasing problem-solving abilities before and after learning to use student worksheets. As for the analysis of the value of N-Gain (g) using equation 2.

$$g = \frac{Posttest\ score - Pretest\ score}{Maximum\ score - Pretest\ score} \tag{2}$$

The results of calculating the N-gain value are *then* interpreted into categories. The criteria for the normalized *N-gain value,* according to Richard R. Hake, can be seen in Table 6.

Table 6. Category of N-Gain Values

N-Gain Value	Criteria
g > 0.70	High
0.70 > g > 0.30	Moderate
g < 0.30	Low
g = 0.00	No Increase

Result and Discussion

This development research produced student worksheets that were used as physics study guides for class X students in the Motorcycle Engineering and Business Competence. Activities on student worksheets are specifically designed to train students' physics problem-solving skills on dynamic electricity material through practical activities such as making replicas of motorcycle turn signal electrical circuits. The development of student worksheet activities refers to the stages of the engineering design process (EDP), which consists of 7 (Manalu et al., 2022; Wind et al., 2019), namely identifying problems, gathering information to determine solutions, identifying problem-solving solutions, designing product prototypes into models, creating and testing the effectiveness of models, reflecting on products, and presenting products.

The results of the student analysis showed that class X motorcycle engineering and business students more easily understood physics and were eager to learn when practicing. Students are more interested in learning physics, not only theory but also practice applying formulas (Safarati & Zuhra, 2023). The implementation of the physics curriculum in vocational schools requires that physics learning processes and materials refer to productive needs, so learning physics should be more adaptive (Aristawati et al., 2023). One of the needs of teaching materials in the form of student worksheets is that they are developed to support physics learning based on competency skills and to develop students' problem-solving skills (Nisa et al., 2020).

The second stage is the design stage. A review of various sources, such as articles, books, and curricula, is carried out in order to compile the design, format, and details of the content (material) on the student worksheets. The design of student worksheets includes cover and content displays, a selection of fonts, font sizes, and font colors (Fatimah & Rohani, 2022). The cover and contents of student worksheets are made colorful so that their appearance becomes more attractive (Ekantini & Wilujeng, 2018). In addition, the selection of motorcycle images, images of motorcycle turn signals, image positions, and the vocational schools logo are included in the display elements of student worksheets with the aim that student worksheets are in accordance with the theme of learning material and look more attractive.

Figure 2. Student worksheet design (a) Front cover; (b) Use of assignment column illustrations

The activity steps on the worksheet are adjusted to the stages of the engineering design process (EDP) and indicators of problem-solving ability adapted from the synthesis of several experts. The physics material on student worksheets is dynamic electricity material applied to motorcycle turn signal electrical systems, which are systematically arranged it aims to train students to solve problems through practical activities according to their interests and majors. At this stage, the design of student worksheets as well as the grid of assessment sheets and assessment instruments are also made rigid. The assessment grid is carried out as well as a feasibility assessment sheet and a practicality assessment questionnaire (readability).

In the third stage (development) the product development of student worksheets is carried out according to the format and grid that have been prepared before. The display of the cover and contents of the completed student worksheet is presented in Figure 2. At this stage, the feasibility assessment and stage 1 revision of the student worksheet are carried out before being implemented in vocational schools.

The cover of the student worksheet contains a picture of a motorcycle, class identity and student expertise competence, university logo, and the title of the student worksheet. Worksheets that have been completed are then assessed on the six feasibility indicators for student worksheets. The results of the feasibility assessment are presented in Table 7.

Table 7. Results of the Student Worksheet Feasibility Assessment

Component	Average Percentage (%)	Category
Suitability of goals and materials	93.33	Very Worthy
Conformity to the EDP Model	100	Very Worthy
Indicator of problem-solving ability	100	Very Worthy
Presentation	88.89	Very Worthy
Appearance	90.47	Very Worthy
Language	83.33	Very Worthy
Percentage average	92.67	Very Worthy

The data in Table 7 shows that all of the student worksheet indicators are included in the very Eligible category, with an assessment percentage of 92.62%. Based on the feasibility assessment, the lowest percentage is on the language indicator, which is equal to 83.33%. The conformity indicator on the worksheet to the EDP model and the problem-solving ability indicator obtained a percentage of 100%. This shows that learning scenarios designed on student worksheets have fulfilled the eligibility requirements for competency-based physics learning and can be used to train students' problem-solving abilities. Even so, there are several improvements, including the proportion of the image being too small.

The fourth is the implementation stage. Worksheets that have been declared feasible and have been revised according to the assessor's suggestions and comments are then tried out in schools. At this stage, it is used to determine the practicality of student worksheet products obtained from student response questionnaire data. The practical assessment is carried out after the lesson is finished. In addition, at the implementation stage, pre-test and post-tests were carried out to find out the increase in problem-solving skills before and after using student worksheets using the engineering design process (EDP) model. The results of the practicality assessment of student worksheets are presented in Table 8.

Table 8. Practicality Assessment Results

Component	Average Percentage (%)	Category
Content suitability	99.07	Very Practical
Convenience	96.83	Very Practical
Clarity	100	Very Practical
Appearance	95.83	Very Practical
language	97.92	Very Practical
Percentage average	98.20	Very Practical

Based on the data in Table 8, it is known that the highest percentage is the clarity indicator of 100%, while the lowest percentage is the student worksheet appearance indicator. On the percentage appearance indicator of 95.83. In general, it can be concluded that the student worksheets that have been developed fulfill the practical requirements with an average percentage of 98.20% in the Very Practical category. Student worksheets can be used widely in physics learning to help students carry out practical activities.

At each stage of the practical learning process, students are trained in skills for identifying problems of electricity to motorcycle signals. Students seek information from various learning sources and use the data to design strategies to overcome various obstacles in making replicas of turn signal circuits. The final stage is that students evaluate solutions by piloting a series of turn signal replicas. At each stage, student performance is assessed based on the ability of each indicator through an analysis of the tasks students are working on. Learning activities that involve students in building understanding can stimulate students' cognitive abilities (Hartini et al., 2020; Siregar et al., 2023). Understanding the learning material can improve problem solving skills of student (Mohd Abeden & Siew, 2022; Setyarini et al., 2021).

Table 9. Task Analysis of Problem-Solving Ability

Indicator Problem-Solving	Score
Identify the problem	88.89
Devise a strategy	100
Apply strategy	88.89
Evaluate solutions	77.78
Average	88.89

The results of the task analysis showed that the average score of students' problem-solving skills was

88.89. Referring to the minimum completeness criteria for physics, the score is already above 75. Physics practicum activities referring to the engineering design process stage are alternative learning strategies that teachers can use to improve students' problem-solving abilities through practical activities (Wind et al., 2019). For learning purposes that involve students to actively develop cognitive abilities, student worksheets are needed (Mumtaza & Zulfiani, 2023; Piawi et al., 2018). One of the characteristics of learning physics in vocational schools is that the learning process and learning materials are adapted to the character and competency skills of students (Hidayatullah et al., 2020). Electrical materials are one of the materials that are not compatible with vocational materials (Khoeriah et al., 2020).

The stages of the EDP model of identifying problems, seeking information, identifying solutions, and making products can train students to develop cognitive abilities in the form of problem-solving skills (Vistara et al., 2022). Students use physics concepts and equations to solve problems by making certain products (Berland et al., 2014). How to learn physics by applying physics concepts to everyday problems can improve students' abilities according to competency skills (Lisanti et al., 2022a; Wheelahan, 2015). In addition, practice-based physics (science) learning activities increase students' motivation and activeness, which in turn can improve their cognitive abilities and problem-solving abilities (Gillies & Nichols, 2015; Sithole et al., 2017). Learning that is centered on student has a significant role on students' problem solving abilities.

Figure 3. Product effectiveness test of replica motorcycle turn signals

Students in groups carry out learning activities, namely identifying problems encountered during designing and making products (Yu et al., 2020). Learning activities like this provide opportunities for students to develop problem-solving skills effectively (Jaenudin et al., 2020). Students gain direct learning experience in solving problems through practical activities (Chiang & Lee, 2016). Understanding gained through direct experience (practice) provides better retention compared to only understanding through seeing or reading (Nurtanto et al., 2020). Physics learning activities using various types of learning resources make it easier for students to understand the material and improve problem solving abilities (Setyarini et al., 2021). It is easier for students to understand the material through practical activities compared to using the lecture method (Mumtaza & Zulfiani, 2023).

Learning activities using group practice methods make the learning atmosphere fun (Asma et al., 2020). The physics material for practice is adapted to the automotive theme and is designed in a systematic and structured manner. Students apply electrical physics material to make replicas of motorcycle turn signals. Technique-based learning or skill competencies make students more enthusiastic about learning. Fun physics learning makes students active in learning so that learning is not boring (Nurtanto et al., 2018). During product manufacturing activities, students actively build their knowledge and understanding (Hjalmarson & Parsons, 2021). Learning activities through science, technology, and engineering practices can stimulate students' problem-solving abilities (Norlaili et al., 2022). Problem-solving abilities can gradually develop through a series of product manufacturing stages (Vijaya et al., 2017; Yu et al., 2020).

Practice-based science learning activities are student-centered and have a significant impact on students' problem-solving abilities (Ginting et al., 2023). In the learning process, the function of the teacher in practical learning is to act as a guide and facilitator during the learning process and provide various learning resources (Hairida & Setyaningrum, 2020; Salinas et al., 2023). Through engineering design process activities, students learn independently to find their understanding through the problem-solving mechanisms they encounter (Faozi et al., 2020; Jaenudin et al., 2020). Students seek solutions from various reference sources. In addition, group discussion activities facilitate students' collaboration and exchange of ideas (Sagita et al., 2023). Practical activities and group discussions can stimulate the development of students' cognitive abilities, including problem-solving abilities (Susbiyanto et al., 2019; Wahyuni et al., 2019).

Electrical study material is applied to the automotive department, one of which is the motorcycle light electrical system. Physics learning that facilitates students to practice applying physics concepts through making certain products can develop students' cognitive abilities (Umamah & Andi, 2019). One of the physics materials that students consider difficult is electricity, so problem-solving abilities need to be developed in physics learning (Ibnusaputra et al., 2023). The ability to solve physics problems in electrical materials is a very fundamental ability for vocational students (Anggraini et al., 2022). Learning physics according to the context that students are interested in can train students' problem-solving skills (Sari et al., 2023). Students' solving skills are more easily improved using learning methods that put theory into practice directly (Astriani et al., 2023; Gunawan et al., 2018).

Measuring the ability to solve problems in the physics of dynamic electricity material is carried out before learning to determine students' initial abilities. After students follow a series of stages of the learning process, they are given a post-test. Based on the results of the pre-test and post-test, the increase in students' solving abilities in electricity material can be measured.

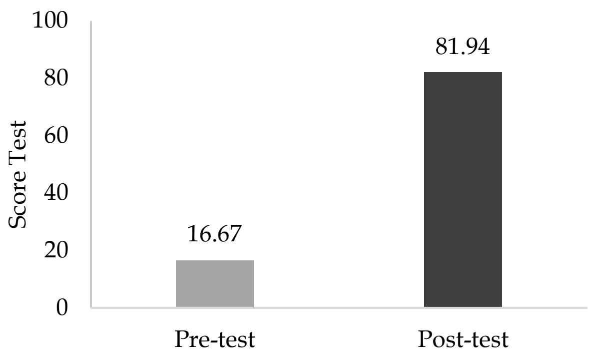

Figure 4. Comparison of pre-test and post-test scores in physics problem solving ability

Based on the data in Figure 4, it is known that the average pre-test value is 16.67. The average value of the pre-test is still very low and below the minimum standard value. The average score of the students' post-test increased after learning to 81.94. This value is higher than 75, which is the minimum standard score for physics at the school. The test results showed that students experienced an increase in problem-solving abilities after being given learning treatment using engineering design process-based student worksheets. Increasing students' physics problem-solving abilities, then analyzing each indicator of problem-solving ability. Based on the results of the analysis of test scores, it can be seen that the increase in students' problem-solving abilities increased in all indicators.

Table 10. N-Gain Problem-Solving Ability

Indicator	N-Gain	Criteria
Identify the problem	0.92	High
Devise a strategy	0.92	High
Apply strategy	0.82	High
Evaluate solutions	0.56	Moderate
Average	0.80	High

Data in Table 10 shows that the highest increase occurred in the indicators of identifying problems and designing strategies. Both of these indicators have an N-Gain value of 0.92 and are included in the High improvement criteria. The lowest increase occurred in evaluating indicators. On the indicator evaluating the solution, the N-Gain value is 0.56. Students experience an increase in ability on indicators evaluating solutions in the Moderate category. The stage of evaluating solutions is the last stage of the problem-solving ability indicator and is included in cognitive level 6. An analysis of increasing physics problem-solving abilities in each student is carried out to determine the achievement of research and learning objectives.

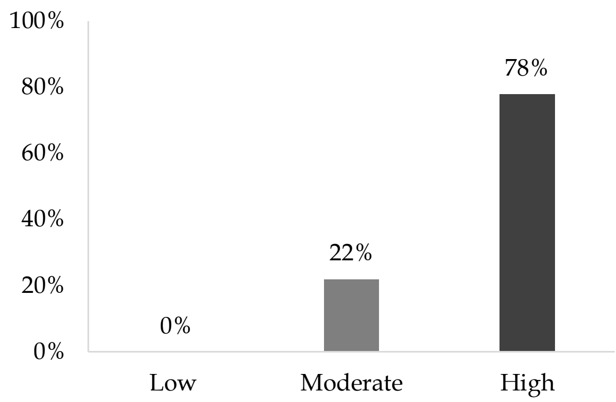

Figure 5. Comparison of the percentage of criteria for ability to solve physics problems

Based on the data in Figure 5, it is known that students who experienced an increase in their ability in the Moderate category were 22%, and there were no students in the Low category of improvement. The test results showed that as many as 78% of students experienced an increase in their ability to solve physics problems in the high improvement category. Most of the students experienced an increase in their ability to solve problems in dynamic electricity physics after learning physics using engineering design process-based student worksheets. Physics learning in vocational high school does not only cover concept mastery but also its application (Amalia et al., 2024; Hidayatullah et al., 2020). Physics learning must be developed on the basis of the application of theory (Roemintoyo & Budiarto, 2023).

After implementing the student worksheets, the fifth stage is evaluation. At this stage, an analysis of the achievement of learning objectives and product development objectives is carried out. The results of the assessment and implementation show that the level of feasibility and practicality of student worksheets using the stages of the Engineering Design Process (EDP) learning model is included in the category of very

Feasible and very Practical. Students experience an increase in their ability to solve physics problems in the High category. However, there are still some students whose improvement category is Moderate. Learning activities using student worksheets based on the engineering design process help students understand the material. Students are required to think critically to solve problems (Wind et al., 2019). Such learning can stimulate students to improve their problem solving skills (Mohd Abeden & Siew, 2022).

Based on learning that implements student worksheets using the stages of the Engineering Design Process (EDP) learning model, there are several findings that become notes. These findings include that there are factors that influence the results of product implementation, namely that students are not used to doing practice-based physics learning to make products. Even though students look enthusiastic about participating in learning, the teacher takes more time to provide explanations and guidance during the learning process. In addition, because learning is carried out after the pandemic, teachers and students need more time to adjust to learning rhythms, learning patterns, and learning styles and to recall basic material about electricity presented at the previous level.

Conclusion

The student worksheets produced have met the eligibility requirements in the very eligible category and the practical requirements in the very practical category to be implemented in physics learning at vocational high school, especially for class X competence in automotive (motorcycle) engineering expertise in dynamic electricity material. Student worksheets using the stages of the Engineering Design Process (EDP) learning model are used to train students in improving their physics problem-solving skills during the physics learning process. The results of the research and the results of the discussion, it can be concluded that student worksheets using the stages of the Engineering Design Process (EDP) learning model can be used in vocational physics learning to train and improve students' physics problem-solving skills of students.

Acknowledgments
The researcher would like to thank the reviewers and the team at the JPPIPA Journal who have provided constructive suggestions for articles up to the publication of this article. The researcher also thank Prof. Dr. Insih Wilujeng, M.Pd., who has guided and provided suggestions and comments during the implementation of research and writing until the completion of this article. The researcher is also grateful to all the lecturers who have provided feasibility assessments, to the physics teacher and class X automotive engineering students who have provided product practicality assessments and constructive input, as well as provided assistance and facilities during the research. Recommendations for further research that student worksheets developed are not only for automotive engineering majors.

Author Contributions
T.R wrote the article draft, revised, and edited the draft article. I.W as a supervision of the research contributed to the guidance in writing articles and provided critical feedback on the manuscript.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest.

References

Ali, M., & Tse, A. W. C. (2023). Research Trends and Issues of Engineering Design Process for STEM Education in K-12: A Bibliometric Analysis. *International Journal of Education in Mathematics, Science and Technology*, *11*(3), 695–727. https://doi.org/10.46328/ijemst.2794

Amalia, S. I. Y., Degeng, P. D. D., & Razali, K. A. (2024). EFL Students' Perspectives toward Project-Based Learning in Vocational High Schools. *Journal of Languages and Language Teaching*, *12*(1), 226. https://doi.org/10.33394/jollt.v12i1.9740

Anggraini, R. D., Prastowo, T., & Sudibyo, E. (2022). Analysis of Problem Solving Skills in the Vocational High School Using Direct Current Electricity as A Case Study. *IJORER: International Journal of Recent Educational Research, 3*(3), 301-311. https://doi.org/10.46245/ijorer.v3i3.219

Aristawati, I. V., Marwoto, P., & Ellianawati, E. (2023). Analysis of the Need for Electronic Module IPAS Development to Improve Independence, Creativity and Critical Thinking. *Physics Communication*, *7*(1), 14–21. https://doi.org/10.15294/physcomm.v7i1.36685

Asma, R., Asrial, A., & Maison, M. (2020). Development of Interactive Electronic Student Worksheets on Electromagnetic Induction Based on Scientific Approaches. *Jurnal Penelitian Pendidikan IPA*, *6*(2), 136–142. https://doi.org/10.29303/jppipa.v6i2.387

Astriani, D., Martini, Rosdiana, L., Fauziah, A. N. M., & Purnomo, A. R. (2023). STEAM-Project Based Learning (PjBL): Efforts to Train Critical Thinking Skills for Prospective Science Teacher. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 7909–7915. https://doi.org/10.29303/jppipa.v9i10.3823

Berland, L., Steingut, R., & Ko, P. (2014). High School Student Perceptions of the Utility of the

Engineering Design Process: Creating Opportunities to Engage in Engineering Practices and Apply Math and Science Content. *Journal of Science Education and Technology*, *23*(6), 705–720. https://doi.org/10.1007/s10956-014-9498-4

Chiang, C. L., & Lee, H. (2016). The Effect of Project-Based Learning on Learning Motivation and Problem-Solving Ability of Vocational High School Students. *International Journal of Information and Education Technology*, *6*(9), 709–712. https://doi.org/10.7763/ijiet.2016.v6.779

Deininger, M., Daly, S. R., Sienko, K. H., & Lee, J. C. (2017). Novice designers' use of prototypes in engineering design. *Design Studies*, *51*, 25–65. https://doi.org/10.1016/j.destud.2017.04.002

Docktor, J. L., Dornfeld, J., Frodermann, E., Heller, K., Hsu, L., Jackson, K. A., Mason, A., Ryan, Q. X., & Yang, J. (2016). Assessing student written problem solutions: A problem-solving rubric with application to introductory physics. *Physical Review Physics Education Research*, *12*(1), 010130. https://doi.org/10.1103/PhysRevPhysEducRes.12.010130

Ekantini, A., & Wilujeng, I. (2018). The development of science student worksheet based on education for environmental sustainable development to enhance scientific literacy. *Universal Journal of Educational Research*, *6*(6), 1339–1347. https://doi.org/10.13189/ujer.2018.060625

Faozi, A. K. A., Hobri, Fatekurohman, M., Aini, K., & Yuniar, D. (2020). Student's problem solving abilities in Project Based Learning (PjBL) based on Learning Community (LC). *Journal of Physics: Conference Series*, *1538*(1), 012070. https://doi.org/10.1088/1742-6596/1538/1/012070

Fatimah, S., & Rohani, R. (2022). Development Of (Lkpd) Discovery Learning-Based For Class X Science Students Of Environmental Pollution Material. *Jurnal Penelitian Pendidikan IPA*, *8*(4), 2101–2108. https://doi.org/10.29303/jppipa.v8i4.2093

Gillies, R. M., & Nichols, K. (2015). How to Support Primary Teachers' Implementation of Inquiry: Teachers' Reflections on Teaching Cooperative Inquiry-Based Science. *Research in Science Education*, *45*(2), 171–191. https://doi.org/10.1007/s11165-014-9418-x

Ginting, F. W., Mellyzar, M., & Lukman, I. R. (2023). Analysis of Student Environmental Literacy: PjBL-Based Learning that is Integrated STEM. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 242–248. https://doi.org/10.29303/jppipa.v9i1.2599

Gunawan, G., Suranti, N. M. Y., Nisrina, N., & Herayanti, L. (2018). Students' Problem-Solving Skill in Physics Teaching with Virtual Labs. *International Journal of Pedagogy and Teacher Education*, *2*, 10. https://doi.org/10.20961/ijpte.v2i0.24952

Haerani, H., Arsyad, M., & Khaeruddin, K. (2023). Development of Experiment-Based Physics Worksheets in Science in Developing Students' Science Process Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 292–298. https://doi.org/10.29303/jppipa.v9i1.2609

Hairida, H., & Setyaningrum, V. (2020). The Development of Students Worksheets Based on Local Wisdom in Substances and Their Characteristics. *Journal of Educational Science and Technology (EST)*, 106–116. https://doi.org/10.26858/est.v6i2.12358

Hartini, S., Mariani, I., Misbah, & Sulaeman, N. F. (2020). Developing of students worksheets through STEM approach to train critical thinking skills. *Journal of Physics: Conference Series*, *1567*(4), 042029. https://doi.org/10.1088/1742-6596/1567/4/042029

Hidayatullah, R. S., Ariyanto, S. R., Mubarok, H., & Yohannes, A. (2020). Collaborative problem-based Learning: An analysis of problem-solving skills in vocational schools. *IJORER: International Journal of Recent Educational Research, 1*(3), 209-217. https://doi.org/10.46245/ijorer.v1i3.62

Hjalmarson, M. A., & Parsons, A. W. (2021). Conjectures, Cycles and Contexts: A Systematic Review of Design-based Research in Engineering Education. *Studies in Engineering Education*, *1*(2), 142. https://doi.org/10.21061/see.35

Ibnusaputra, M., Wilujeng, I., & Kuswanto, H. (2023b). Development of Electronic Worksheet Guided Inquiry to Reduce Misconceptions and Improve High School Students' Concept Mastery on Straight Motion Material. *Jurnal Penelitian Pendidikan IPA*, *9*(5), 2653–2663. https://doi.org/10.29303/jppipa.v9i5.2738

Ince, E. (2018). An Overview of Problem Solving Studies in Physics Education. *Journal of Education and Learning*, *7*(4), 191. https://doi.org/10.5539/jel.v7n4p191

Jaenudin, D., Kurniasih, S., & Amalia, G. R. (2020). Improving Students Ability in Problem Solving and Creativity Through Project-Based Learning. In *Proceedings of the 4th Asian Education Symposium (AES 2019)*. https://doi.org/10.2991/assehr.k.200513.058

Khoeriah, I. H., Abdullah, A. G., & Mulyanti, B. (2020). Reconstruction of vocational high school physics instructional materials. *Momentum: Physics*

Education Journal, 85–93. https://doi.org/10.21067/mpej.v4i2.4572

Koenig, K. (2019). *Physics education research for 21st century learning*.

Lin, K.-Y., Wu, Y.-T., Hsu, Y.-T., & Williams, P. J. (2021). Effects of infusing the engineering design process into STEM project-based learning to develop preservice technology teachers' engineering design thinking. *International Journal of STEM Education*, *8*(1). https://doi.org/10.1186/s40594-020-00258-9

Lisanti, R., Yusrizal, Y., Evendi, E., Elisa, E., & Ilyas, S. (2022). Pengembangan Lembar Kerja Peserta Didik Untuk Meningkatkan Penguasaan Konsep dan Keterampilan Pemecahan Masalah Peserta Didik. *Jurnal Penelitian Pendidikan IPA*, *8*(4), 1947–1953. https://doi.org/10.29303/jppipa.v8i4.1263

Maknun, J. (2020). Implementation of Guided Inquiry Learning Model to Improve Understanding Physics Concepts and Critical Thinking Skill of Vocational High School Students. *International Education Studies*, *13*(6), 117. https://doi.org/10.5539/ies.v13n6p117

Manalu, E. N. B., Hendri, M., & Rasmi, D. P. (2022). Analysis of STEM-Based Student Worksheet Development with Scaffolding using the Web. *Jurnal Penelitian Pendidikan IPA*, *8*(2), 573–578. https://doi.org/10.29303/jppipa.v8i2.1145

Mohd Abeden, N. A., & Siew, N. M. (2022). Assessing Students' Critical Thinking and Physics Problem-Solving Skills in Secondary Schools. *Malaysian Journal of Social Sciences and Humanities (MJSSH)*, *7*(6), e001584. https://doi.org/10.47405/mjssh.v7i6.1584

Mumtaza, M. F., & Zulfiani, Z. (2023). Development of Student Worksheets Based on Science Process Skills on Excretory System Concepts. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 265–272. https://doi.org/10.29303/jppipa.v9i1.1474

Nasrullah, A., Marlina, M., & Dwiyanti, W. (2018). Development of Student Worksheet-Based College E-Learning Through Edmodo to Maximize the Results of Learning and Motivation in Economic Mathematics Learning. *International Journal of Emerging Technologies in Learning*, *13*(12). https://doi.org/10.3991/ijet.v13i12.8636

Nisa, W. L., Ismet, I., & Andriani, N. (2020). Development of E-Modules Based on Multi-representations in Solid-State Physics Introductory Subject. *Berkala Ilmiah Pendidikan Fisika*, *8*(2), 73. https://doi.org/10.20527/bipf.v8i1.7690

Norlaili, N., Al Huda, A. M., Yuliani, H., & Azizah, N. (2022). Literature Research: The Use of Science, Technology, Engineering and Math (STEM) In Physics Learning. *Jurnal Ilmiah Pendidikan Fisika*, *6*(1), 45. https://doi.org/10.20527/jipf.v6i1.4153

Nurtanto, M., Nurhaji, S., Baser, J. A., & Yadin, Y. (2018). Problem-Based Learning Implementation: Improvement in Learning Process and Results in Vocational Higher Education. *Jurnal Pendidikan Teknologi Dan Kejuruan*, *24*(2), 203–212. https://doi.org/10.21831/jptk.v24i2.19519

Nurtanto, M., Pardjono, P., W., & Ramdani̇, S. D. (2020). The Effect of STEM-EDP in Professional Learning on Automotive Engineering Competence in Vocational High School. *Journal for the Education of Gifted Young Scientists*, *8*(2), 633–649. https://doi.org/10.17478/jegys.645047

Nuryadin, A., Sulaeman, N., Subagiyo, L., Sholeh, M., & Andrianto, E. (2023). Developing Worksheets Using Engineering Design Process to Promote Sustainable Development Goals for Pre-service Physics Teacher. *Jurnal Ilmiah Pendidikan Fisika*, *7*(1), 183. https://doi.org/10.20527/jipf.v7i1.7775

Piawi, K., Kalmar Nizar, U., & Mawardi, M. (2018). Development of student worksheet based on guided inquiry with class activity and laboratory in thermochemistry material. *Proceedings of the International Conferences on Educational, Social Sciences and Technology - ICESST 2018*, 679–683. https://doi.org/10.29210/20181100

Precharattana, M., Sanium, S., Pongsanon, K., Ritthipravat, P., Chuechote, S., & Kusakunniran, W. (2023). Blended Engineering Design Process Learning Activities for Secondary School Students during COVID-19 Epidemic: Students' Learning Activities and Perception. *Education Sciences*, *13*(2), 159. https://doi.org/10.3390/educsci13020159

Ridlo, Z. R., Supeno, S., Wahyuni, S., Wicaksono, I., & Ulfa, E. M. (2022). Analysis of Implementation Project-Based Learning Model of Teaching Integrated with Computer Programming in Improving Computational Thinking Skills in a Classical Mechanics Course. *Jurnal Penelitian Pendidikan IPA*, *8*(4), 2029–2035. https://doi.org/10.29303/jppipa.v8i4.1789

Roemintoyo, & Budiarto, M. K. (2023). Project-based Learning Model to Support 21st Century Learning: Case Studies in Vocational High Schools. *Journal of Education Research and Evaluation*, *7*(4), 662–670. https://doi.org/10.23887/jere.v7i4.63806

Safarati, N., & Zuhra, F. (2023). Use of Problem-Solving Based Physics Comic Media on Global Warming Material in Increasing Learning Motivation and Students' Understanding Concept. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 9193–9199. https://doi.org/10.29303/jppipa.v9i11.4828

Sagita, S., Rahmat, A., Priyandoko, D., & Sriyati, S. (2023). Sustainability of Project-Based Learning: Challenge and Obstacles from Students Perception Point of View. *Jurnal Penelitian Pendidikan IPA, 9*(2), 810-816. https://doi.org/10.29303/jppipa.v9i2.3044

Sakdiah, H., Ginting, F. W., Rejeki, N. S., & Miranda, A. (2022). Pembelajaran STEAM Terhadap Keterampilan Proses Sains Ditinjau dari Sikap Ilmiah Mahasiswa pada Mata Kuliah Kajian Fisika Kejuruan. *Jurnal Penelitian Pendidikan IPA*, *8*(5), 2531–2536. https://doi.org/10.29303/jppipa.v8i5.2313

Salam, A. A. K., Abdullah, H., & Amin, B. D. (2023). Development of REACT-Oriented Student Worksheets to Improve Physics Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 462–471. https://doi.org/10.29303/jppipa.v9i1.2497

Salinas, J. C., Broberg, M. R., Wagner, D. N., & Carpenter, J. (n.d.). *Evaluation of a High School Engineering Short Course Integrating the Engineering Design Process, Creativity, and Innovation (Evaluation)*.

Sari, E., Syamsurizal, S., & Asrial, A. (2016). Pengembangan Lembar Kegiatan Peserta Didik (LKPD) Berbasis Karakter Pada Mata Pelajaran Kimia SMA. *Edu-Sains: Jurnal Pendidikan Matematika dan Ilmu Pengetahuan Alam*, *5*(2). https://doi.org/10.22437/jmpmipa.v5i2.3388

Sari, I. P. M., Jatmiko, B., & Suprapto, N. (2023). Students' Physics Problem-Solving Skills in Daily Life Context: Between Confession and Fact. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 231–241. https://doi.org/10.29303/jppipa.v9i1.2561

Setyarini, D. A., Imam Supardi, Z. A., & Elok Sudibyo. (2021). Improving Senior High School Students' Physics Problem-solving Skills Through Investigated Based Multiple Representation (IBMR) Learning Model. *IJORER : International Journal of Recent Educational Research*, *2*(1), 42–53. https://doi.org/10.46245/ijorer.v2i1.74

Siregar, A. N., Prasetyo, Z. K., Jumadi, J., & Paramitha, D. (2023). Effectiveness of Using Guided Inquiry-Based E-LKPD on Global Warming Material to Increasing Students' Understanding of Concepts. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 9156–9161. https://doi.org/10.29303/jppipa.v9i11.5166

Sithole, A., Chiyaka, E. T., McCarthy, P., Mupinga, D. M., & Bucklein, B. K. (2017). Student Attraction, Persistence and Retention in STEM Programs: Successes and Continuing Challenges. *Higher Education Studies*, *7*(1). http://dx.doi.org/10.5539/hes.v7n1p46

Soe, M. T. M., Shultz, R., Muscarella, J., Ward, J., & Fontecchio, A. (2018). Board 127: A Project-Based Approach to Develop Engineering Design Process Skills Among High School Students (Work in Progress). *2018 ASEE Annual Conference & Exposition Proceedings*, 29911. https://doi.org/10.18260/1-2--29911

Stehle, S. M., & Peters-Burton, E. E. (2019). Developing student 21st Century skills in selected exemplary inclusive STEM high schools. *International Journal of STEM education*, *6*(1), 1-15. https://doi.org/10.1186/s40594-019-0192-1

Supriyadi, E., Zamtinah, Z., Soenarto, S., & Hatmojo, Y. I. (2019). A Character-Based Assessment Model For Vocational High Schools. *Jurnal Cakrawala Pendidikan*, *38*(2), 269–280. https://doi.org/10.21831/cp.v38i2.24099

Susbiyanto, S., Kurniawan, D. A., Perdana, R., & Riantoni, C. (2019). Identifying the mastery of research statistical concept by using problem-based learning. *International Journal of Evaluation and Research in Education (IJERE)*, *8*(3), 461. https://doi.org/10.11591/ijere.v8i3.20252

Tapilouw, M. C., Dewi, L., & Hastuti, S. P. (2021). Entering 21st century skills: Teacher and junior high school student's perspective about science learning media' scope. *Journal of Physics: Conference Series*, *1957*(1), 012035. https://doi.org/10.1088/1742-6596/1957/1/012035

Umamah, C., & Andi, H. J. (2019). Pengaruh model Project Based Learning terhadap keterampilan berpikir kreatif dalam pembelajaran fisika terapan. *Jurnal Pendidikan Fisika dan Keilmuan (JPFK)*, *5*(1). https://doi.org/10.25273/jpfk.v5i1.3033

Vijaya, M., Reddy, B., & Panacharoensawad, B. (2017). Students Problem-Solving Difficulties and Implications in Physics: An Empirical Study on Influencing Factors. *Journal of Education and Practice*, *8*(14), 59–62. Retrieved from https://files.eric.ed.gov/fulltext/EJ1143924.pdf

Vistara, M. F., Rochmad, R., & Wijayanti, K. (2022). Systematic Literature Review: STEM Approach through Engineering Design Process with Project Based Learning Model to Improve Mathematical Creative Thinking Skills. *Mathematics Education Journal*, *6*(2), 140–156. https://doi.org/10.22219/mej.v6i2.21150

Wahyuni, S., Kosim, Gunawan, & Husein, S. (2019). Physics Learning Devices based on Guided Inquiry with Experiment to Improve Students' Creativity. *Journal of Physics: Conference Series*, *1233*(1), 012034. https://doi.org/10.1088/1742-6596/1233/1/012034

Wheelahan, L. (2015). Not just skills: What a focus on knowledge means for vocational education. *Journal of Curriculum Studies*, *47*(6), 750–762. https://doi.org/10.1080/00220272.2015.1089942

Wind, S. A., Alemdar, M., Lingle, J. A., Moore, R., & Asilkalkan, A. (2019). Exploring student understanding of the engineering design process using distractor analysis. *International Journal of STEM Education*, *6*(1), 4. https://doi.org/10.1186/s40594-018-0156-x

Yu, K.-C., Wu, P.-H., & Fan, S.-C. (2020). Structural Relationships among High School Students' Scientific Knowledge, Critical Thinking, Engineering Design Process, and Design Product. *International Journal of Science and Mathematics Education*, *18*(6), 1001–1022. https://doi.org/10.1007/s10763-019-10007-2