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Differentiated Learning Assisted by Student Worksheets with STEM Content on Alternative Energy Materials to Improve Science Process Skills and Creative Problem Solving

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Abstract: The aim of this research is to develop a differentiated learning program assisted by student worksheets containing STEM on Alternative Energy material to improve Science Process Skills and Creative Problem Solving. The method used is research design and development using the ADDIE model stages which consist of five stages, namely analysis, design, development, implementation and evaluation. The instruments used were needs analysis questionnaires, program validation, CPS tests. Data sources for program analysis and design are students and Physics teachers from high schools in Lampung Province. Validators are experts and practitioners of physics education. Questionnaire data were analyzed using percentage techniques. CPS test results data were analyzed statistically using paired sample t-test and one way anova. The results of the research show that a high school physics learning program is needed in schools that can accommodate the different needs of students which include students' initial abilities and learning styles. The product developed, namely a differentiated learning program in the form of teaching modules and student worksheets containing STEM on Alternative Energy material, is valid and effective in increasing CPS. Differentiated learning programs include differentiation of content, processes, products. The learning process and teaching materials are adapted to students' learning styles. Students' learning readiness is accommodated by intensifying student assistance in groups.

Keywords: Creative problem solving; Differentiated learning; STEM; Student worksheets; Teaching module

Introduction

The Independent Curriculum is a new curriculum concept in Indonesia which was introduced by the Ministry of Education and Culture in 2021. This curriculum aims to give schools greater freedom in developing a curriculum that is appropriate to the local context and student needs (Marlina et al., 2022; Indarta et al., 2022). The needs of students or learners are explained in differentiated learning theory which refers to a learning approach that emphasizes individual learning needs in different classes (Iskandar, 2021). This theory recognizes that each student has unique learning needs and characteristics, so different approaches need to be applied to meet their learning needs (Tomlinson, 1999). Apart from that, the Independent Curriculum is also based on the principles of inclusive, holistic, competency-based education and 21st century skills (Sartini & Mulyono, 2022; Cholilah et al., 2023). 21st century skills refer to a set of skills that are considered important for individuals to have in the current digital and global era (Agusti et al., 2019).

One of the 21st century skills is problem solving skills (Jayadi et al., 2020). Problem solving skills include the ability to identify problems, understand and organize information, create and test hypotheses, and develop effective solutions (Gunawan et al., 2018). Creative problem solving (CPS) is an approach to solving problems that combines creativity and logic to produce innovative and effective solutions. CPS requires the ability to think critically and creatively, as well as develop new ideas to solve problems (Treffinger &

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Isaksen, 2005). In the CPS process, creativity plays an important role in generating new ideas that are different and innovative. However, these ideas must be critically evaluated to ensure their effectiveness in solving the problem at hand (Basadur & Gelade, 2016).

Problem solving skills and creative problem solving (CPS) have a close relationship. Individuals who have good problem solving skills tend to have the ability to perform CPS. Problem-solving skills enable individuals to identify problems and develop appropriate solutions, while CPS enables individuals to produce creative and innovative solutions (Khalid et al., 2020). According to Treffinger et al. (2005) there are several indicators of creative thinking skills that can be used in solving problems or creative problem solving (CPS), namely Fact Finding, Fact Interpreting, Idea Finding, Idea Developing, Solution Generating, and Solution Evaluating (Treffinger & Isaksen, 2005).

Science process skills and CPS are related to each other (Ozdemir & Dikici, 2016; Muhali, 2021). Science process skills help individuals to acquire observation, analysis and data interpretation skills, which are required in CPS (Kurniawati & Sukardiyono, 2018). In CPS, individuals need to critically analyze problems, collect data, and evaluate various solution options before selecting the most appropriate solution. Science process skills can help individuals in carrying out these tasks (Papilaya, 2023). Science process skills are the ability to observe, measure, classify, interpret data, and conduct experiments to obtain new knowledge (Ongowo & Indoshi, 2013). This skill is important in the world of education, especially in the field of science, because it helps students to understand scientific concepts in more depth and acquire the skills needed to solve problems (Özgelen, 2012; Juhji & Nuangchalerm, 2020).

Process skills consist of a number of skills which are actually inseparable from each other, but there is a special emphasis on each of these process skills. These process skills include making observations, interpreting observations, classifying, predicting, communicating, hypothesizing, planning experiments/research, applying concepts/principles, asking questions (Tahya et al., 2022) . Skills are also an important component in STEM learning, because students must have skills in observing, analyzing data, reasoning, and solving problems to be successful in learning (Chen et al., 2019).

STEM (Science, Technology, Engineering, and Mathematics) is a learning approach that focuses on developing students' skills and abilities in the fields of science, technology, engineering, and mathematics (Muttaqiin, 2023). Therefore, Student Worksheets can be effective teaching materials for developing students' skills in STEM (Yulanda & Rahmi, 2022). Based on several studies, the use of Student Worksheets in STEM learning can improve students' skills in observation, data analysis and reasoning and can improve students' critical thinking skills in solving problems (Lestari et al., 2018; Safitri & Tanjung, 2023; Mahjatia et al., 2021; Sukmagati et al., 2020). Overall, the use of Student Worksheets in STEM learning can be an effective way to develop students' skills in STEM (Fatmawati et al., 2021). The development of student worksheets must be carried out by integrating STEM learning with an inquiry or problem-based approach, so that students can develop critical thinking skills and creativity in solving problems (Wazni & Fatmawati, 2022).

Based on the background explanation and research that has been carried out previously, there has been a lot of research on Student Worksheets, STEM, Science Process Skills and Creative Problem Solving, but no researchers have conducted research on the development of differentiated learning programs, therefore in this research the problem is formulated, namely how Differentiated learning program assisted by Student Worksheets containing STEM on valid alternative energy material to improve students' science process and CPS skills.

Method

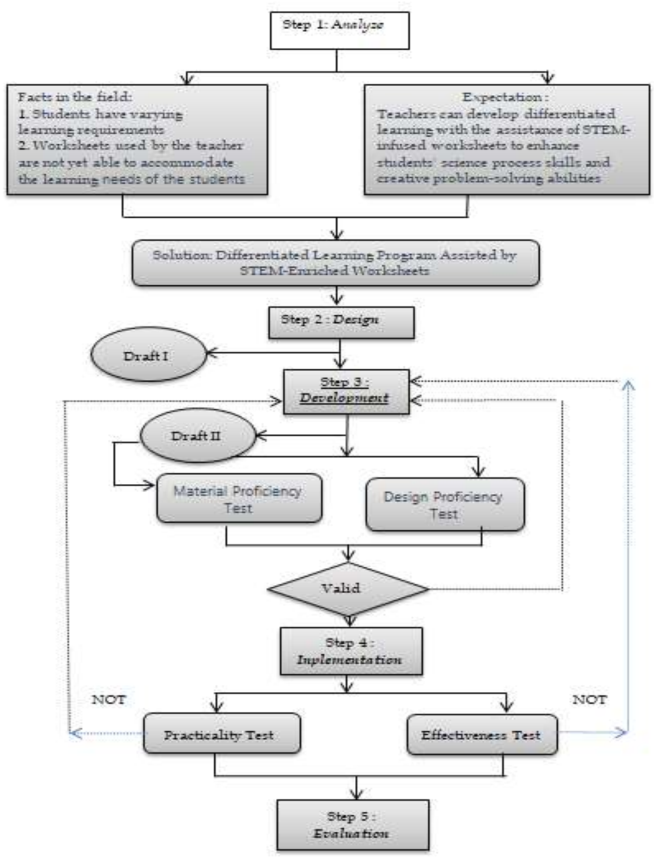

Figure 1. Research procedures

This research is guided by the ADDIE instructional development model (Branch, 2010), namely Analyze, Design, Development, Implementation, and Evaluation. This product development procedure includes 5 stages with a research flow diagram shown in Figure 1.

Analysis

The analysis stage is carried out with the aim of analyzing the needs of educators and students, such as analyzing the needs of student worksheets. As material for conducting analysis, data was collected regarding the physics learning process, as well as the availability of student worksheets used in previous learning. This data collection was carried out on physics teachers and students at the high school level in Lampung Province.

Design

The results of the analysis are used as a reference in preparing differentiated learning programs. At this stage the researcher determines the learning outcomes being developed, determines the material grid and creates a matrix. After all the materials were available, the researcher created a storyboard to provide an overview of the product being developed.

Development

At this development stage, several important things that can influence the success of product development or learning programs include: instructional design (design of learning objectives, design of learning structures and design of learning methods and strategies), media design (graphic design, audio design and multimedia design). , and evaluation design includes (learning assessment and program assessment design). Validation of the product being developed involves content, media and design expert validators. Validators are physics education experts and practitioners. Once the product is declared valid, it is implemented or field trials include effectiveness and practicality tests.

Implementation

At the Implementation stage, researchers apply the product development results in the learning process. Field trials were carried out using a quasi-experimental research design, namely nonequivalent control group design. This design was used to see whether or not there were differences in students' science process skills and CPS scores after using the students' worksheets that were developed.

Evaluation

The evaluation stage is to see the results of the process of implementing differentiated learning with the help of student worksheets containing STEM in the actual classroom learning process.

The research instruments used include: Needs Analysis Questionnaire, Validity Test Scale, Learning Material Implementation Observation Sheet, Pretest and Posttest Instruments. The data analysis technique used is on data for validity and practicality data on students' worksheets using score analysis determined by the researcher, namely a minimum of 2.01 with validity and practicality criteria in the appropriate category (Likert scale), as shown in Table 1.

Table 1. Assessment and Decision Criteria

Range	Criteria
25% < score < 43.75%	not suitable
43.75% < score < 62.5%	quite appropriate
62.5% < score < 81.25%	suitable
81.25%< score < 100%	very suitable

Result and Discussion

Analyze Stage

In the Analyze stage, researchers conducted a needs analysis for educators and students by providing a questionnaire via Google Form about students' learning and use of worksheets so far. The results of the needs analysis can be summarized in table 2.

Table 2. Results of Student Needs Analysis

Statement	Percentage (%)
Learning materials are tailored to students' learning styles	83.4
Learning materials are tailored to students' readiness to learn	71.6
The learning process is adjusted to students' learning styles	59.7
The final assignment/ learning product produced is tailored to students' learning styles	88.9
The final assignment/ learning product is tailored to students' initial abilities	95.4
Teaching materials are more enjoyable with worksheets that contain student activities	59.7
The worksheets used are equipped with Science, Technology, Engineering, and Mathematics activities	85.3

Table 3. Results of Analysis of Educator Needs

Statement	Percentage (%)
In physics class, I always map the needs and learning styles of my students, whether I do it myself or collaborate with the guidance counselor	96.2
In physics teaching, I always use student worksheets	96.6
The student worksheets that I often use are in printed/hard copy format	61.5

Statement	Percentage (%)
In my physics class, I more frequently use a teaching method with the same approach for all students	87.3
The student worksheets that I use in classroom teaching always contain activities related to the science process skills and problem-solving skills of the students.	96.9
In physics class, I always present material of the same level of complexity	89.9
The worksheets used are equipped with Science, Technology, Engineering, and Mathematics activities	79.1

The results of the needs analysis show that students have different learning styles and learning readiness. Students want learning to be adapted to their learning style both in terms of material/content, process and products produced. Everyone has a different learning style and can learn better in different ways (Mardlatillah et al., 2022). Apart from that, the teaching materials used are more fun activities such as student worksheets (Setiadi et al., 2020).

Meanwhile, in the analysis of educators' needs, the learning used by teachers in the learning process has not been able to accommodate various learning styles and students' initial knowledge, resulting in differences in Science Process Skills and CPS between students. Student learning styles are important in the learning process (Mujito, 2014; Handiyani & Muhtar, 2022). Recognizing students' learning styles will make it easier for teachers to choose appropriate learning activities and make it easier for students to receive information (Aprilia et al., 2022). Not all students have good Science Process Skills and CPS, even though they have used student worksheets to practice student activities, because the student worksheets used and even the learning process used are still uniform (Suryaningsih & Nurlita, 2021). Therefore, researchers developed differentiated learning in the form of teaching modules and student worksheets with STEM content to improve students' science process skills and CPS which accommodate various learning styles and levels of students' initial knowledge.

Design Stage

At the design stage, the researcher designs the learning program and student worksheets based on the results of the analysis of the needs of educators and students obtained which are then outlined in the learning program in the table 4.

Based on table 4, the learning program obtained by the researcher designed differentiated learning on content dimensions differentiated by learning resources, level of learning readiness, and learning focus for each student's learning style. In the differentiation dimension, processes are differentiated according to learning styles in the aspects of learning methods and learning strategies. Meanwhile, the learning model for all learning styles is the same, namely using PjBL-STEM. In the product differentiation dimension, the products produced by students are designed to be different according to learning styles, namely in the kinesthetic learning style students produce prototype products for energy producing devices that come from alternative energy sources. In the audio learning style, a video is produced about the energy crisis, the impacts and solutions offered by explaining energy-producing equipment, as well as in the visual learning style, a campaign poster is produced about the energy crisis, the impacts and solutions offered.

Table 4. Differentiated Learning Program

Differentiation Dimension	Aspect	Activity	Learning Style and Readiness to Learn
content	Resources	Textbook	Visual
		Article	Visual
		Video	Auditory
		Presentatation	Auditory
		Local Environment	Kinesthetic
	Level of difficulty	homogeneous teaching materials	High readiness to learn Moderate readiness to learn Low readiness to learn
	Focus of learning	Basic concepts	Low and moderate readiness to learn
		Basic concepts with relevant additional material	High readiness to learn
Process	Learning Method	Lecture	Auditory
		Discussion	Auditory
		Collaboration	Kinesthetic
		Project	Kinesthetic
		Individual problem solving	Auditory/ visual
	Learning Model	PjBL - STEM	Auditory, Visual, Kinesthetic
	Strategy	Individual Guidance	Low (highly intensive) Moderate (intensive) Highly (moderately intensive)

Differentiation Dimension	Aspect	Activity	Learning Style and Readiness to Learn
		Grouping (homogeneous based on initial abilities)	Auditory Visual Kinesthetic
		Use of Technology	Auditory Visual Kinesthetic
		STEM Approach	Auditory Visual Kinesthetic
Product	Choice of Tasks	Presentation	Auditory Visual Kinesthetic
		Essay	Visual
		Poster, Video	Auditory Visual Kinesthetic
		Tangible Product	Kinesthetic
	Product Format	Presentation Slides	Auditory Visual Kinesthetic
		Video	Auditory Visual
		Poster	Visual
		Creative product	Kinesthetic
	Assessment Rubric	Differences in skill level and product quality	Auditory Visual Kinesthetic

After designing differentiated learning, the researchers then conducted a questionnaire to determine students' learning styles and an initial ability test to determine students' learning readiness. After that, students are grouped based on different learning styles. Meanwhile, the results of high, medium and low learning readiness were distributed evenly in the learning style groups. So that in each learning style group there are students with high, medium and low learning readiness. This is in accordance with the analysis of student needs, that students tend to be more comfortable in groups with students who are smarter than themselves. Meanwhile, the differentiation strategy for students based on learning readiness is with different levels of assistance during intensive, moderately intensive and less intensive learning for students with low, medium and high learning readiness.

The next step is to explain the teaching module as a guide in learning and the basis for designing differentiated student worksheets. It is hoped that this student worksheet can accommodate students' needs in learning styles and initial readiness by differentiation in the dimensions of content, process and product. So it is possible that in the learning process in the classroom educators can simultaneously facilitate the diverse needs of students. The process of designing learning programs and worksheets for differentiated students can be depicted in the form of a chart in Figure 2.

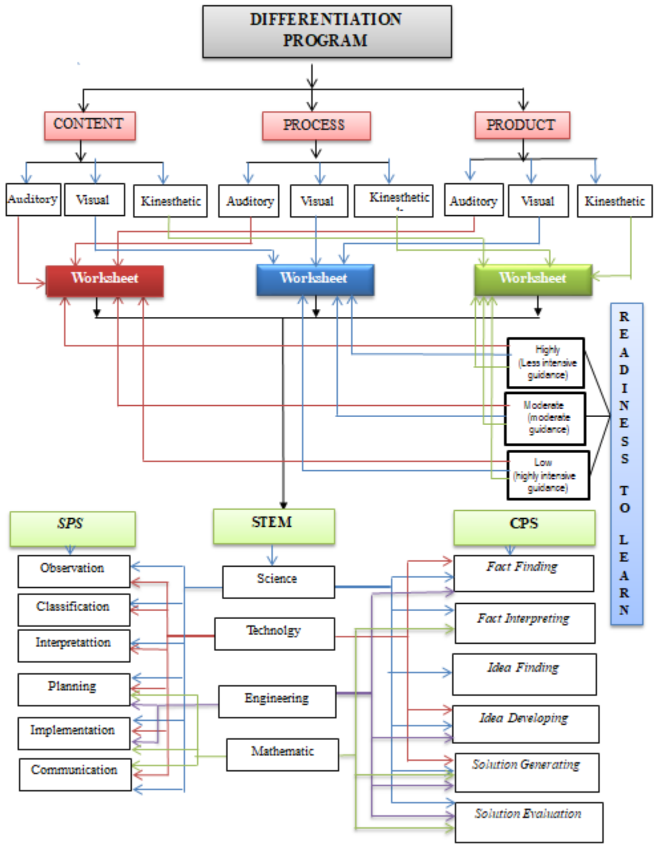

Figure 2. Differentiated learning program chart

Development Stage

In the Development stage, researchers compile teaching modules and develop student worksheets based on the designs that have been created. The learning model applied in the Teaching Module and student worksheets uses PjBL-STEM Laboy-Rush (Stohlmann, 2021) which contains the steps Reflection, Research, Discovery, Application, and Communication.

The validity assessment of the Teaching Modules and student worksheets produced is carried out regarding the suitability of the substance of the design of the teaching modules and student worksheets with instructional design (design of learning objectives, design of learning structures and design of learning methods and strategies), media design (graphic design, audio design , and multimedia design), and evaluation design includes (learning assessment and program assessment design) that integrate STEM to improve Science Process Skills and CPS. The results of the validity assessment are shown in Tables 5 and 6.

Table 5. Teaching Module Assessment Results

Evaluation Aspects	Average Score
Main Components Already includes a minimum of 8 main components	100%
Formulation of CP, TP, IPK Reflects the achievement of competencies in attitude, knowledge, and skills in the processes of science and creative problem-solving as expected.	93%
Learning Contents Already differentiated to accommodate various learning needs of students in learning styles (audio, visual, and kinesthetic) that are in accordance with the coverage of physics understanding CP	96%
Learning Method Illustrates differentiation strategies based on the varying learning abilities of students through individual guidance that differs in intensity, moderate intensity, and low intensity	87%
Media and Learning Resources Supports the achievement of competencies and active learning through differentiated learning that includes various media and learning resources.	96%
Learning Activity Includes introductory activities, core activities, and concluding activities that have been differentiated according to students	95%
Assessment of Learning Outcomes Includes assessment of knowledge, skills, and attitudes that refer to students' abilities in the aspects of scientific process skills and creative problem-solving	93%
Average Percentage	94.30%

The results of the teaching module assessment by physics learning expert validators and practitioners, obtained an average percentage of 94.30%. This represents that the differentiated learning program outlined in the learning teaching module is "very suitable" to accommodate learning styles and learning readiness as well as improving students' science process and CPS skills.

Table 6. Validation Results of the Student Worksheet

Evaluation Aspects	Average Score
Construct	89.00%
Content	89.50%
Language	89.75%
Design	88.50%
Average Percentage	89.19%

The results of the student worksheet validation assessment obtained an average percentage of 89.19%. This value is also above the minimum limit for the suitability criteria for student worksheets, so based on these values it can be concluded that the differentiated student worksheets containing STEM to increase KPS and CPS are "Very suitable" for use in alternative energy learning in the E class X SMA/MA Independent Curriculum. However, expert and practitioner suggestions for improving teaching modules and student worksheets are still being carried out to ensure that differentiated learning programs will be effectively implemented in the field according to the opinion of Wazni et al. (2022).

Implementation Stage

At the Implementation stage, the resulting teaching modules and student worksheets are then implemented to students and educators in the learning process in class X of state high schools in Bandar Lampung. At this implementation stage, it is very necessary to organize the implementation (available facilities, educators, and activity schedule) (Cahyadi, 2019). It is also very necessary to pay attention to supervision to identify problems and obstacles that arise during implementation as well as feedback provided by students and educators. This is a reference for the next stage.

The learning stages are designed so that they can combine activities in the learning model and criteria for science process skills and CPS that will be stimulated as presented in Table 7. The first step in the Reflection activity determines the type of alternative energy content based on auditory, visual and kinesthetic learning styles. The content provided is adapted to various learning styles and is expected to be able to guide students in the problem of energy availability in the student environment (Yulianci & Nurjumiati, 2020). This activity encourages students to look for facts and interpret them, which is an important part of science process skills and creative problem solving skills (Muhali, 2021). Students with a visual learning style are given articles with pictures about energy availability. Students with an auditory learning style are given a video link about the energy crisis that is hitting the world, while students with a kinesthetic learning style are given a series of activities to observe and search for information about energy consumption and organic waste problems in the market environment closest to where the students live.

In research activities, students can provide solutions and identify potential in the surrounding environment to utilize alternative energy sources, this is in accordance with the results of previous research by Lhamdi et al. (2022). In the Discovery activity, students are asked to plan and design products that will be produced as a solution to energy availability based on the potential in their environment, in accordance with the results of previous research by Purwaningsih et al (2020). The resulting products are tailored to students' learning styles. For students with a visual learning style, the form of billing is in the form of videos, posters. Students with an auditory learning style, the form of the bill is in the form of an essay about the energy crisis, its impacts and the solutions provided to overcome the energy crisis. Meanwhile, students with a kinesthetic learning style produce simple energy-producing products using water, wind and biomass energy sources by utilizing waste waste around the students' environment. In the Application activity, students explain the advantages and disadvantages as well as the potential of the product that has been created if implemented on a larger scale, this is in accordance with what Rosyidah et al (2021) suggest. In Communication activities, students present their products and summarize suggestions and input from other students and also teachers, for further product improvements. At each step of the activity and the results of the answers written by the students on the students' worksheets, the researchers were observed to assess science process skills and CPS.

Table 7. Learning Stages

Stages	Description of activities	Science process skills	CPS
Reflection	Guiding students into the context of the problem so that they can understand and generate ideas to solve the problem	Observing, questioning, and predicting	Fact Finding, Fact Interpreting
Research	Providing instruction by facilitating discussions that can enhance students' understanding in problem-solving	Questioning and predicting, Planning and conducting investigations	Fact Finding, Fact Interpreting, Idea Finding, Idea Developing
Discovery	Students, in groups, engage in discussions to process information and present problem-solving solutions	Processing, Analyzing data and information, Creating	Idea Finding, Idea Developing
Applica-tion	Testing the created product; at this stage, students integrate STEM aspects	Evaluate and Reflect	Soluttion Geerating, Solution Evaluation
Communication	Presenting project results and developing communication skills in problem-solving	Communicating the results	Solution Generation, Solution Evaluation

Evaluation Stage

At the Evaluation stage, the aim is to assess the success of the program and the effectiveness of learning. The evaluation stage is very important to ensure that the learning program achieves the desired goals and can be adapted to changing needs or emerging conditions (Cahyadi, 2019). At the evaluation stage, the implementation of science process skills was measured using observation sheets, and the effectiveness of the program using CPS test questions. Data collection was carried out twice, namely at the beginning of the learning activity (pre-test) and at the end of all learning processes (post-test). CPS data is grouped based on student learning styles, namely kinesthetic, visual and auditory. Data on pre-test and post-test results are presented in Table 8.

Table 8. Pre-test, Post-test Data and Results of Paired Sample T-test Analysis for Each Learning Style Group

Learning Style Group	N	Pre-test Average	Post-test Average	Difference	Sig.
Kinesthetic	10	50.1	68.4	18.3	0.000
Auditory	10	49.2	64.5	15.3	0.000
Visual	13	51.5	68.4	16.9	0.000

Based on the results of the analysis summarized in table 8, the average posttest score was greater than the pretest score in each learning style group. The results of the analysis of the Paired Sample T test show a Sig. (2-tailed) value < 0.05 for all learning style groups, this means that after implementing differentiated learning in each learning style there is a significant increase in the value of learning outcomes at the confidence level. 95% in each learning style group.

To ensure that the learning program has the same effectiveness for all learning styles, a one way ANOVA test was carried out. The results are presented in Table 9.

Table 9. Results of One Way ANOVA Analysis for Kinesthetic, Visual and Auditory Groups

Learning Outcomes	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	884.515	2	442.258	1.438	0.253
Within Groups	9229.000	30	307.633		
Total	10113.51	3			

Table 9 shows the results of the One Way Anova Test, obtained sig > 0.05, which means there is no difference in CPS improvement between kinesthetic, auditory and visual learning style groups. This means that the differentiated learning program with the help of student worksheets containing STEM on Alternative Energy material developed in this research can reduce potential differences in CPS caused by differences in student learning styles.

Differentiated learning programs using student worksheets containing STEM can be effective in improving CPS abilities for the following reasons: Differentiated learning programs provide opportunities for students with different levels of understanding to be actively involved. Students with low initial abilities are accompanied more intensively than students with higher initial abilities. The STEM student worksheet has been designed to attract students' attention by stimulating their imagination and curiosity, especially the material or content contained in the STEM student worksheet emphasizes the practical application and relevance of learning material in everyday life. The use of student worksheets containing STEM allows students to relate theoretical concepts to real-world situations, encouraging them to think creatively in solving problems. By working on STEM projects through student worksheets, where each group is given the freedom to choose the product produced through the project, it allows students to hone critical thinking, collaboration, and communication skills. By designing assignments that encourage creative thinking, students will be trained to seek new and innovative solutions, all of which contribute to the development of CPS. Student worksheets that integrate technology can provide a more interesting and in-depth learning experience, and prepare students to face technological challenges in problem solving. By combining differentiated learning programs, STEM-enabled student worksheets, and a focus on CPS, this approach creates a learning environment that supports the development of students' skills that are relevant and applicable in a variety of contexts.

Conclusion

Based on the results of data analysis and discussion, a high school physics learning program in schools is needed that can accommodate differences in student needs which include students' initial abilities and learning styles. The learning program required is a differentiated learning program that includes process, content and product differentiation.The differentiated learning program in the form of teaching modules and student worksheets containing STEM on Alternative Energy material developed in this research is valid and effective for accommodating differences in learning styles and learning readiness as well as for improving students' science process skills and CPS. The effectiveness of the program is shown by the results of the post-test and pre-test difference test using a paired sample t-test, a sig value <0.05 was obtained, indicating that there was a significant increase in CPS for each learning style group. The results of the One Way Anova Test, the gain of the kinesthetic group, visual group and auditory group obtained a sig value > 0.05. This shows that there is no difference in gain between the kinesthetic, auditory and visual learning style groups. This means that the differentiated learning program with the help of student worksheets containing STEM on Alternative Energy material developed in this research can reduce potential differences in CPS caused by differences in student learning styles.

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Author Contributions

Sulistiani collected, analyzed, interpreted data, and wrote the draft article. Undang Rosidin collected and analyzed relevant literature reviews. Agus Suyatna wrote the discussion section and revised the article.

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Conflicts of Interest

No Conflicts of interest.

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