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Development of Project-Based Learning Oriented Student Worksheets to Improve Students' Creative Thinking Skills on Class X High School Nanotechnology Material

Nabiilah Rihhadatul Aisy[1*], Kusumawati Dwiningsih[1]

[1] Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Surabaya, Indonesia.

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Corresponding Author:
Nabiilah Rihhadatul Aisy
kusumawatidwiningsih@unesa.ac.id

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Abstract: The purpose of this study is to determine: the feasibility of project-based learning-oriented student worksheets in terms of content validity and construct validity, and the effectiveness of project-based learning-oriented student worksheets in terms of increasing students' creative thinking skills. Development of Project-Based Learning oriented student worksheets to improve students' creative thinking skills on class X high school nanotechnology material using the Research and Development (R&D) method with a 4D development model (Define, Design, Develop, and Disseminate). However, this research was carried out only until the third stage, namely Develop. The results of data analysis and discussion are as follows: the worksheets of project-based learning-oriented students developed are declared to have met the eligibility requirements in terms of content validity and construct validity with mode (Mo) values ≥ 4 and R ≥ 75%, and student worksheets project-oriented based learning developed was declared effective in terms of increasing students' creative thinking ability with a percentage of N-Gain of 79% moderate category (0.30-0.70) and 21% high category (0.7-1). Thus, Project Based Learning Oriented Student Worksheets can be used to improve students' creative thinking skills on Nanotechnology material.

Keywords: Creative thinking skills; Nanotechnology; Project based learning; Student worksheets; 4D Development

Introduction

The 21st century shows a rapid change in science and technology (IPTEK), thus requiring every country to create and have human resources (HR) that have integrated quality in various scientific disciplines in life (Habibillah et al., 2024). Learning systems in the 21st century emphasize creativity, critical thinking, cooperation, communication skills, sociability and character skills (Daulay et al., 2021). There are four abilities that students must have in the 21st century, namely the ability to think critically and solve problems, the ability to communicate, creativity and innovation, and collaboration (Bahtiar et al., 2023). Based on the Decree of the Head of the Education Standard, Curriculum, and Assessment Agency of the Ministry of Education, Culture, Research, and Technology Number 033/H/KR/2022 concerning Learning Outcomes in Early Childhood Education, Primary Education Level, and Secondary Education Level in the Independent Curriculum (2022) emphasizes students to have and apply creative thinking skills in the learning process (Khalil et al., 2023).

In addition, in the Decree of the Head of the Education Standard, Curriculum, and Assessment Agency Number 009/H/KR/2022 concerning Dimensions, Elements, and Sub-Elements of the Pancasila Student Profile in the Independent Curriculum (2022), students are expected to master the creative dimension which includes producing original ideas, works, and actions, and have the flexibility to think to find alternative solutions to a problem. So it can

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be known that students are required to master creative thinking skills (Handayani et al., 2021). Creative thinking is a thought process to express new relationships, see things from a new perspective, and form new combinations of two or more concepts that have been mastered before (Purwaningrum, 2016). The thought process involves elements of fluency, flexibility, originality, and elaboration (Guilford, 1950). To be able to develop students' creative thinking, a learning model is needed that is in accordance with classroom conditions and student-centered, so that students become more interested in following the learning process. One of the things that can be done is to develop a Project Based Learning model according to 21st century learning (Markula et al., 2022).

Project-Based as learning that uses Projects as a medium in the learning process to achieve competence in attitudes, knowledge and skills (Chounta et al., 2017). The emphasis of learning lies in the activities of students to produce products by applying the skills of researching, analyzing, creating, to presenting learning products based on real experiences (Zamiri et al., 2024). The product in question is the result of a project in the form of goods or services in the form of designs, schemes, written works, works of art, works of technology, and others. Through the application of Project-Based Learning, learners will practice planning, carrying out activities according to plan and displaying or reporting the results of activities (Logan et al., 2021). With project-based learning, students can explore their knowledge by being directly involved in learning (Potvin et al., 2021). Previous research findings stated that the project-based learning model can improve the learning atmosphere in the classroom (Nurtanto et al., 2020).

Other research findings also state that the project-based learning model can make it easier for students to learn so that it can improve student learning outcomes (Ratnawati et al., 2020). Research states that the development of project-based learning tools is very valid for improving students' science process skills. There is a lack of availability (Fatmawati et al., 2022) and the low ability of teachers to compile Project-Based Learning Tools as a source of student learning causing students' willingness to learn to decrease (Zen et al., 2022). According to the Buck Institute for education (BIE), Project Based Learning is a lesson model that requires students to be able to solve problems and produce a real product. The resulting product or work can be in the form of observations, videos, and works of art. The syntax of *Project Based Learning* is as follows: Start with the Essential Question; Design a Plan For the Project; Create a Schedule; Monitor the Students and the Progress of the Project; Assess the Outcome, and Evaluate the Experience (Setyowati et al., 2018).

Research conducted by Triantoro (2022), states that project-based learning modules can help improve students' creative thinking. Generally, research on the development of teaching materials for student worksheets either in electronic form, or in printed form has been widely carried out. Research conducted by Badriyah et al. (2021), states that student worksheets with mind mapping strategies can train students' creative thinking skills in terms of fluency, flexibility, and originality in redox material declared effective. It can be concluded that the development of worksheets for Project-Based Learning oriented students can improve creative thinking skills. There has been no study of the project-based learning model on nanotechnology materials in chemistry subjects.

The purpose of this study is to determine the feasibility of project-based learning-oriented student worksheets in terms of content validity and construct validity, and the effectiveness of project-based learning-oriented student worksheets in terms of increasing students' creative thinking skills. It is hoped that this student worksheet can help students improve their creative thinking skills.

Method

The method to be used in this study is the 4D development model. The stages in the 4D model are Define, Design, Develop, and Disseminate (Roswanti et al., 2023). However, this research was carried out only until the 3rd stage, namely Develop. The subjects of this study were 38 students and were conducted in class X odd semester at State High School 4 Sidoarjo (Hl et al., 2023)In the first stage, namely definition, 5 main steps are taken, including: front-end analysis, to analyze the problems underlying the development of student worksheets; learner analysis, to analyze student characteristics such as learning abilities and skills; concept analysis, by compiling worksheet designs for nanotechnology material learners; task analysis, determining the learning indicators used in accordance with the applicable basic competencies; analysis of learning objectives (specifying instructional objectives), to summarize the results of concept analysis and task analysis used to compile tests and design student worksheets (Lawhon, 1976).

In the second stage is design. The activities carried out are test preparation, media selection, format selection, and initial design. The first step begins with the preparation of tests based on learning objectives and student analysis. Then the selection of learning media in accordance with the stages set, namely student worksheets on nanotechnology material, then the selection of student worksheet formats by designing the product design to be developed (Afni et al., 2021). The final stage is development. This stage aims to produce a product in the form of student worksheets that are valid and suitable for use as learning media through trials, studies, validation, and development. The validation process begins by creating an instrument that contains content validation and construct validation (Elangovan et al., 2021).

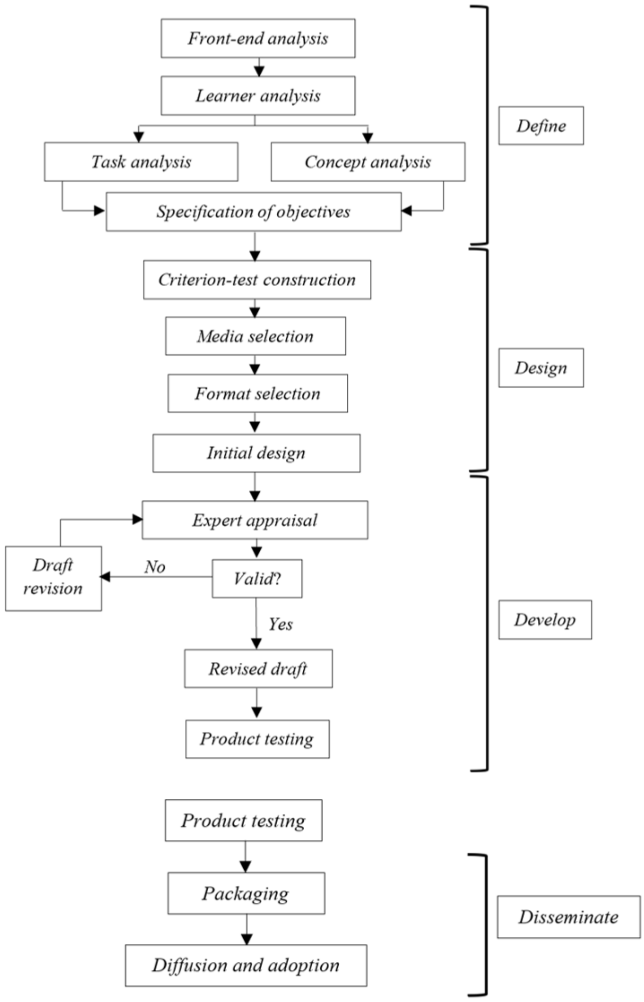

Figure 1. 4-D model by Thiagarajan

This study produces quantitative data that includes validity (content and construct) and effectiveness. Validity data is obtained by filling out validation sheets by three validators (two validators are lecturers majoring in chemistry, Faculty of Mathematics and Natural Sciences, State University of Surabaya), and one other validator is a chemistry teacher at State High School 4 Sidoarjo. Effectiveness data were obtained by filling in pre-test and post-test sheets arranged based on indicators of creative thinking skills. The validated data were analyzed using quantitative descriptive methods using Likert scale calculations presented in Table 1.

Table 1. Likert Scale

Statement	Score
Very Valid	5
Valid	4
Valid Enough	3
Invalid	2
Very Invalid	1

Based on these criteria, the validity data (content and construct) of the student worksheets are analysed in a quantitative descriptive manner using frequently appearing scores (Mode/Mo) obtained from expert assessments on the validation sheet is at least 4 (valid). Furthermore, to find out whether there is a disagreement from the answers of the three validators, an analysis is carried out using the Borich method known as Percentage Agreement (R) with equation 1:

$$\text{Percentage Agreement (R)} = 1 - \frac{A-B}{A+B} \times 100\% \quad (1)$$

Percentage Agreement (R) is used to determine the understanding between validators so that the answers between validators are declared valid and have understanding. The percentage result can be said to be reliable for the validity of the content and construct if the R value is ≥ 75% (Afni et al., 2021). Student worksheets are declared valid if the expert assessment on the validation sheet is obtained in at least 4 (valid) modes and has an understanding between validators. Pre-test and post-test score data are obtained from creative thinking skills given to students. *N-Gain* is a comparison of the gain score obtained by students with the highest gain score that student may get. The *N-Gain* formula is in equation 2.

$$G = \frac{Skor\ Posttest - Skor\ Pretest}{100 - Skor\ Pretest} \times 100 \quad (2)$$

The processing of N-Gain results is interpreted in the categories shown in Table 2. Interpretation is used as a benchmark for the effectiveness of student worksheets used by students.

Table 2. N-Gain Value Classification

Value	Criterion
G < 0.3	Low
0.3 ≤ G ≤ 0.7	Moderate
G ≥ 0.7	High

Based on the N-Gain score criteria, student worksheets are said to be effective if the average student gain score obtained is more than or equal to 0.3 ($G \geq 0.3$) or reaches the criteria of "Moderate" or "High" (Vanzal et al., 2023).

Results and Discussion

The research done by adapting the 4D development model is enough to develop a limited trial in the third stage. The following is a detailed explanation of the research steps carried out.

Define

The define stage is a stage that is useful for determining, explaining, and analysing the needs, as well as the development requirements of a product. In other words, this stage aims to get a product that suits the needs of the target user (Dwivedi et al., 2021). In this study, the product in question is the Student Worksheet. This defining stage is divided into five parts, namely initial final analysis, student analysis, concept analysis, task analysis, and goal specifications.

Initial Final Analysis

Early-final analysis is carried out in order to determine basic problems that then lead to instructional solutions, so that they can be used as a foundation in the process of developing student worksheets. In the early-final analysis, facts related to problems related to students' creative thinking skills on nanotechnology material will be obtained (Khamhaengpol et al., 2021).

Student Analysis

Student analysis that aims to determine student profiles that include initial creative thinking skills (pre-test), learning motivation, learning experience towards nanotechnology materials, and preferences in the use of student worksheets (Coman et al., 2020; Juliana et al., 2024; Sarwar et al., 2024).

Concept Analysis

In concept analysis, the content of the material from the learners' worksheets will be determined. So that the process of drafting concepts from student worksheets becomes systematic, which can be obtained by identifying, collecting, and selecting material relevant to the existing curriculum (Darling-Hammond et al., 2020).

Task Analysis

Task analysis has the aim of identifying the stages of task completion to be carried out by students so that learning outcomes can be achieved. Task analysis includes analysis of learning outcomes and the flow of learning objectives related to nanotechnology materials (Ray, 2023).

Destination Specification

The specification of objectives is based on the analysis of the concept and the analysis of the tasks that have been performed. In the specification of objectives, the learning objectives that you want to expect after the learning process will be formulated. So that through the specification of objectives, the content of student worksheets will be clearer and can also be used as a reference in developing pre-test and post-test questions that will be used in the next stage (Syahfitri, 2023).

Design

The second stage of the 4D model is the *design stage*. The purpose of this stage is to design the learners' worksheets. This stage can be started with the creation of feasibility instruments from the learner worksheets the learner worksheets developed. The selection of media, the format for the material, and the production of the initial version are the main aspects of the design stage.

Figure 2. Nanotechnology student worksheet cover design

IDENTITAS

Penyusun : Nabiilah Rihhadatul Aisy
Bidang Studi : Kimia
Materi : Struktur Atom dan Aplikasinya dalam Nanoteknologi
Jenjang Pendidikan : Sekolah Menengah Atas (SMA)
Kelas/Semester : X/Ganjil
Kurikulum : Kurikulum Merdeka

Capaian pembelajaran dan Tujuan Pembelajaran

Pada akhir fase E, peserta didik memliki kemampuan untuk merespon isu-isu global dan berperan aktif dalam memberikan penyelesaian masalah. Kemampuan tersebut antara lain mengidentifikasi, mengajukan gagasan, merancang solusi, mengambil keputusan, dan mengkomunikasikan dalam bentuk projek sederhana atau simulasi visual menggunakan aplikasi teknologi yang tersedia terkait dengan nanoteknologi. Semua upaya tersebut diarahkan pada pencapaian tujuan pembangunan yang berkelanjutan (Sustainable Development Goals/SDGs). Melalui pengembangan sejumlah pengetahuan tersebut dibangun pula akhlak mulia dan sikap ilmiah yaitu kreatif.

Elemen	Capaian Pembelajaran
Pemahaman Kimia	Peserta didik mampu memahami struktur atom dan aplikasinya dalam nanoteknologi.
Keterampilan Proses	Peserta didik mampu merencanakan pembuatan produk nanoteknologi yaitu bio-baterai.

Tujuan Pembelajaran

a. Peserta didik mampu merespon isu-isu global dengan menganalisis data nanoteknologi dengan tepat.
b. Peserta didik mampu merencanakan pembuatan produk nanoteknologi yaitu bio-baterai dengan benar.

1

Figure 3. Student worksheet identity

Tahap 1
PERTANYAAN MENDASAR

Menyajikan Permasalahan

Link 1: https://www.youtube.com/watch?v=Oyoud99LfRs
Ironi Pabrik Nikel, Merusak Alam Sendiri Demi Hijaukan Kota-Kota di China
Link 2: https://www.youtube.com/watch?v=gk41QHbtluY
Kulit Pisang Bisa Jadi Baterai?

Link 1	Link 2
SCAN ME	SCAN ME

Pertanyaan Mendasar

1. Dari video yang telah kalian tonton tuliskan dampak negatif yang diperoleh dari penambangan nikel?

Jawaban:

2

Figure 4. Stage 1: Fundamental questions

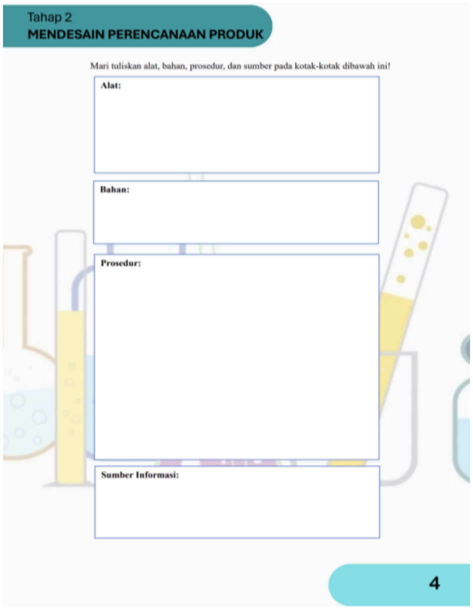

Figure 5. Stage 2: designing product planning

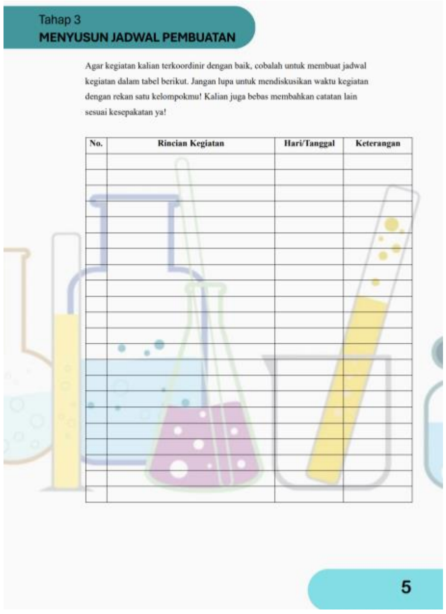

Figure 6. Stage 3: establishing a creation schedule

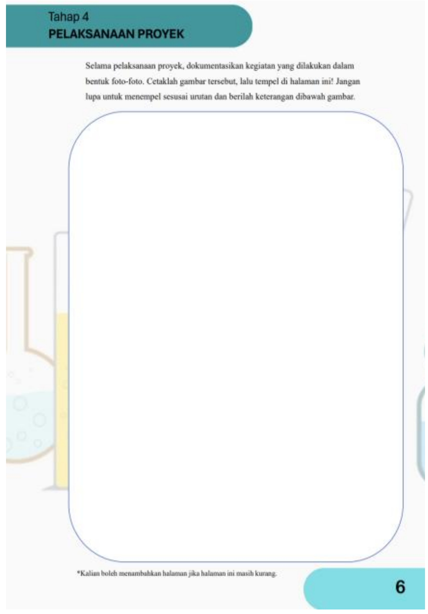

Figure 7. Phase 4: Project implementation

Figure 8. Stage 5: testing results

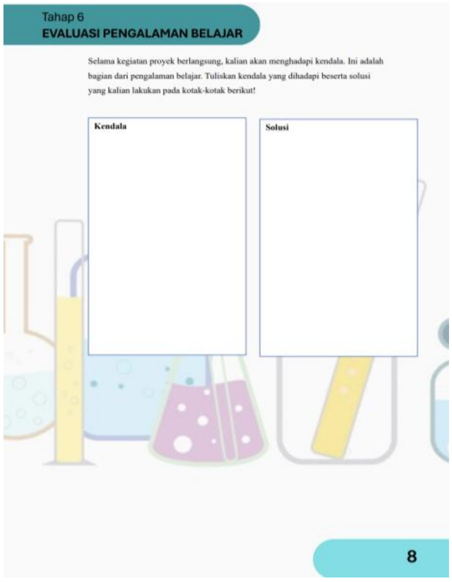

Figure 9. Stage 6: learning experience evaluation

Figure 10. Bibliography

Development

The third stage of the 4D model is the *development stage*. The purpose of the *develop* stage is to produce student worksheets that have been revised based on expert input and continued with student worksheet trials. There are two steps in this stage, namely:

Expert Appraisal

Expert validation aims to validate learners' worksheets before testing, and validation results will be used to revise the initial product. The work embar of students that has been developed will then be assessed by material experts and media experts in terms of the validity of the content and the validity of the construct until it is declared valid. Validation is used as a corrective material for the perfection of the worksheets of the learners developed. Validators are asked to provide an assessment of student worksheets that have been developed based on the items on the assessment sheet and provide criticism and suggestions. Validation is carried out until the student worksheets are declared valid to be implemented in learning activities. The validation results are analyzed and followed up by revising student worksheets according to validator criticism and suggestions. This is done to get the validity value of the student worksheet.

Table 3. Content Validation Results

Question Number	Score				Criterion
	V_1	V_2	V_3	Mo	
1	3	4	5	5	Very Valid
2	4	3	4	4	Valid
3	4	4	5	4	Valid
4	3	4	5	5	Very Valid
5	4	4	5	4	Valid
6	4	3	5	5	Very Valid
7	4	5	5	5	Very Valid

The content validation results of the three validators in table 3 obtained mode values (Mo) 4 and 5. The validation score is obtained from three validators so that each R is calculated as a percentage, which is $(R)_{1,2}$; $(R)_{1,3}$; and $(R)_{2,3}$. The following is the result of the calculation of understanding or percentage of agreement (R).

Table 4. Results of Recapitulation of Understanding Content Validation Score

Question Number	Score			Percentage of Agreement (R)		
	V_1	V_2	V_3	$R_{1.2}$	$R_{1.3}$	$R_{2.3}$
1	3	4	5	85.70	75	88.90
2	4	3	4	85.70	100	85.70
3	4	4	5	100	88.90	88.90
4	3	4	5	85.70	75	88.90
5	4	4	5	100	88.90	88.90
6	4	3	5	85.70	88.90	75
7	4	5	5	88.90	88.90	100

The Percentage Agreement (R) result from content validation in table 4 is in the range of 75%-100% so that it can be stated that the student worksheet is valid.

Table 5. Construct Validation Results

Question Number	Score				Criterion
	V_1	V_2	V_3	Mo	
1	4	4	5	4	Valid
2	4	4	4	4	Valid
3	5	4	4	4	Valid
4	4	5	5	5	Very Valid
5	3	5	5	5	Very Valid
6	4	4	5	4	Valid
7	4	4	5	4	Valid
8	3	5	5	5	Very Valid
9	5	5	5	5	Very Valid
10	4	4	5	4	Valid
11	4	4	5	4	Valid
12	5	5	5	5	Very Valid
13	4	5	5	5	Very Valid
14	5	4	5	5	Very Valid

The results of construct validation from the three validators in table 5 obtained mode values (Mo) 4 and 5. The validation score is obtained from three validators so that each R is calculated as a percentage, which is $(R)_{1,2}$; $(R)_{1,3}$; and $(R)_{2,3}$. The following is the result of the calculation of understanding or percentage of agreement (R).

Table 6. Results of Recapitulation of Understanding Construct Validation Score

Question Number	Score			Percentage of Agreement (R)		
	V_1	V_2	V_3	$R_{1.2}$	$R_{1.3}$	$R_{2.3}$
1	4	4	5	100	88.90	88.90
2	4	4	4	100	100	100
3	5	4	4	88.90	88.90	100
4	4	5	5	88.90	88.90	100
5	3	5	5	75	75	100
6	4	4	5	100	88.90	88.90
7	4	4	5	100	88.90	88.90
8	3	5	5	75	75	100
9	5	5	5	100	100	100
10	4	4	5	100	88.90	88.90
11	4	4	5	100	88.90	88.90
12	5	5	5	100	100	100
13	4	5	5	88.90	88.90	100
14	5	4	5	88.90	100	88.90

The Percentage Agreement (R) result from construct validation in table 6 is in the range of 75%-100% so that it can be stated that the student worksheet is valid.

Testing of Developed Student Worksheets (Product Testing)

After the student worksheets were declared valid, a limited trial was conducted on 38 Class X-G students at State High School 4 Sidoarjo to get an effectiveness score. The effectiveness value is obtained from increasing the creative thinking ability of students where a pre-test is carried out before being given student worksheets and post-test after being given student worksheets. There are five description questions for the pre-test and post-test that have been adjusted to the indicators of creative thinking skills.

Of the five questions in table 7, they meet the characteristics of indicators of creative thinking skills according to Daryanes et al. (2022), Anggorowati et al. (2024), and Sugiyanto et al. (2018) that is:

Fluency

In this fluency indicator, there are several characteristics as follows: Triggering ideas or answers or solving problems or questions that are many in number; Provide various ways or suggestions in order to do various things, and always think of more than one answer.

Flexibility

In this flexibility indicator there are several characteristics as follows: creating ideas or answers or solving various problems or questions, looking for many and different alternatives, changing the way of approach or thinking that exists, and classifying certain things based on different categories (Akbari et al., 2024; Dotzauer et al., 2019; Luo et al., 2020).

Originality

In this indicator of originality there are several characteristics as follows: Creating new expressions that are unique, so that the intention is to be able to provide ideas that are not thought of by others or do not fully refer to the book, and Able to create unusual combinations or combinations of certain parts or elements.

Elaboration

In this Elaboration indicator there are several characteristics as follows: Enriching or developing an idea that already exists or is created by others, Detailing the details of an object or idea so that it becomes more interesting, and seeking a deeper meaning of an answer or problem solving through the implementation of detailed steps.

Table 7. Pre-test and Post-test Questions for Creative Thinking Skills

Question Number	Indicators of Creative Thinking Skills	Question
1	Flexibility	Explain the working principle of a bio battery. What is the main difference between bio batteries and conventional batteries?
2	Fluency	How can nanotechnology be used to design more environmentally friendly bio batteries?
3	Originality	In your opinion, to what extent can bio batteries overcome the environmental problems caused by conventional batteries? Explain using scientific arguments!
4	Originality	What do you think about the potential for bio batteries to replace conventional batteries in the future? Give reasons to support your opinion!
5	Elaboration	Find or design a simple experiment to test the bio performance of batteries using different biological materials. Explain the steps of the experiment, the expected results, and the interpretation of those results!

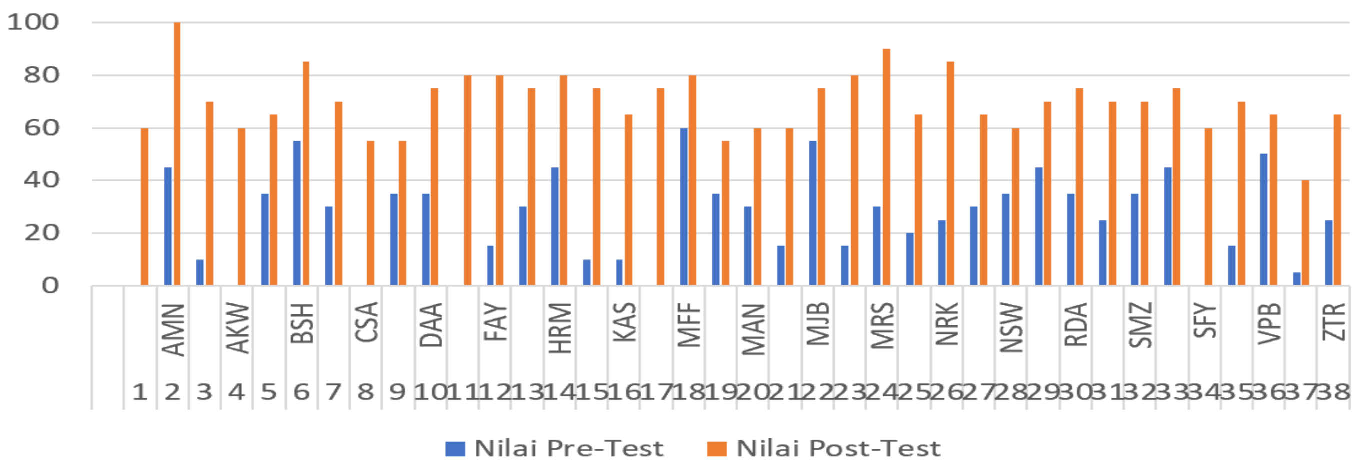

Figure 11. Graph of improvement in student learning outcomes

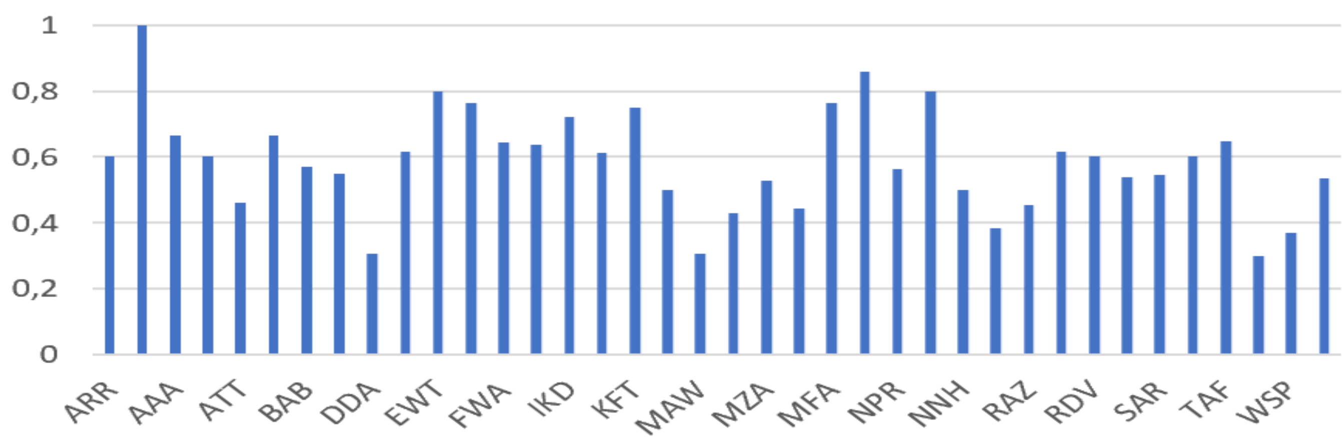

Figure 12. N-gain

The results of the pre-test and post-test are presented in figure 11 graph of increasing creative thinking ability that after being given worksheets students there is a significant improvement. Based on the results of the pre-test and post-test scores, a comparison of gain scores is obtained according to the calculation of equation 2.

The results of the pretest and posttest creative thinking skills in figure 12 showed a significant improvement. This is evident from the N-Gain percentage of 79% of the moderate category (0.3-0.7) and 21% of the high category (0.7-1) presented in the pie chart in figure 13.

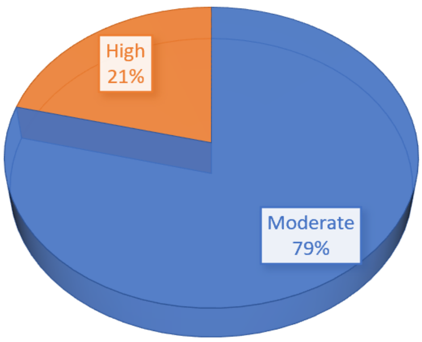

Figure 13. N-gain percentage

Conclusion

The conclusions obtained from the results of data analysis and discussion are as follows: the worksheets of project-based learning-oriented students developed are declared to have met the eligibility requirements in terms of content validity and construct validity with mode values (Mo) ≥ 4 and R ≥ 75%, and student worksheets project-oriented based learning developed was declared effective in terms of increasing students' creative thinking ability with a percentage of N-Gain of 79% moderate category (0.30-0.70) and 21% high category (0.7-1).

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Author Contributions

Creating ideas and concepts, developing, designing and translating as well as managing the entire research and data analysis process, N. R. A; Review, K. D; Validation; N. R. A., and K. D.

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Conflicts of Interest

Authors declare no conflict of interest.

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