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Development of Karst Environment-Based Teaching Modules to Improve Learning Outcomes in Terms of Learning Motivation

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Abstract: This Research and Development (R&D) study aims to develop a Physics Teaching Module based on the Karst Environment using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) and evaluate its effectiveness on learning outcomes regarding student motivation. Content validity was assessed by two experts, while practicality was tested by a physics teacher. The module was trialed with 36 students in class XI F2 at SMAN 4 Maros. Data collection instruments included validation sheets, practitioner questionnaires, motivation scales, and learning achievement tests (pretest and posttest). Data analysis techniques involved the Aiken's V index for validity, descriptive statistics, the Paired Sample T-Test for effectiveness, and a One-Way ANOVA to analyze learning improvements based on motivation levels. Results indicate that the module is valid with an average Aiken's V index of 0.81 and is categorized as practical based on practitioner responses of 82.20%. Furthermore, the module proved effective in improving learning outcomes, as evidenced by a significant difference between pretest and posttest scores (Sig. 0.00 < 0.05), with significant differences also observed among students with varying levels of motivation (Sig. 0.00 < 0.05). In conclusion, this Karst environment-based physics module is declared valid, practical, and effective for use in school physics learning processes.

Keywords: ADDIE model; Karst environment; Learning motivation; Learning outcomes; Teaching module

Introduction

Education is the primary foundation for building a quality nation as mandated by Law No. 20 of 2003, which in science must actively develop cognitive, affective, and psychomotor potential (Fatmawati et al., 2021; Arham, 2020). Physics learning outcomes, as an indicator of success, require the support of appropriate instructional instruments. Destari et al. (2022) emphasize that the development of learning tools is crucial as a primary stimulus to optimize students' academic achievement.

Learning outcomes are also significantly influenced by motivation as the driver of student learning (Aprily, 2020). Alimuddin et al. (2022) state that strong motivation reinforces the effectiveness of the learning process, while Syamsinar et al. (2023) mention that achievement motivation contributes significantly to physics learning results. The interaction between instructional design and internal drive determines the extent of improvement in learning outcomes (Hajar et al., 2020), where active student involvement in concept discovery has a greater impact than conventional methods (Doyan et al., 2023).

The effectiveness of learning also depends on the relevance of the material to real life through the local environment (Rasyid et al., 2024). According to Dwisetyaningrum et al. (2019) explain that environmental experiences make students more active, which is proven effective in increasing cognitive abilities

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(Umi et al., 2025). By utilizing local potential, students can understand the reality of ecosystems in a more profound and applicable manner.

Karst areas are natural laboratories rich in physical phenomena, such as water flow systems related to Bernoulli's principle and continuity (Karongi et al., 2023; Arsyad et al., 2021). Zulfaniar et al. (2024) suggest developing environment-based teaching materials to increase creativity. In this study, the material developed to achieve this goal is a structured independent learning module (Satria et al., 2020; Ramli et al., 2024). Structured independent modules (Fatmawati et al., 2021) are chosen because they focus more on student needs than standard textbooks (Marta & Ramli, 2021; Jannah et al., 2018) and effectively improve analytical thinking skills (Ndoa & Jumadi, 2022; Aris et al., 2024).

The condition at SMAN 4 Maros shows that physics learning outcomes are still moderate due to reliance on standard textbooks and abstract mathematical analysis without utilizing the potential of the Bantimurung Bulusaraung National Park. The lack of contextual learning resources leads to low student interest. A module innovation is needed that can bridge fluid dynamics concepts with the Bantimurung waterfall phenomena so that students understand physics applications directly within their ecosystem.

Karst environment-based modules serve to integrate the reality of physics into daily life (Badawi & Qaddafi, 2015). Integrating real-world problems effectively improves learning quality and fosters environmental awareness (Umi et al., 2025). The use of contextual modules provides opportunities for flexible independent learning for students with varying levels of motivation, making the transfer of knowledge more meaningful.

This research develops a teaching module that integrates the principles of discharge and pressure of the Bantimurung karst waterfall as the primary intervention, differing from the focus of Arsyad et al. (2021). The quality of this module will be tested through validity, practicality, and effectiveness standards. Aligned with the findings of Badawi et al. (2015), environment-based modules significantly improve outcomes by presenting familiar contexts. This study aims to develop a karst-based module and examine its influence on learning outcomes while considering student motivation levels.

Method

Type of Research

This research is a type of Research and Development (R&D) study using the ADDIE development model method. The ADDIE stages include Analyze, Design, Development, Implementation, and Evaluation.

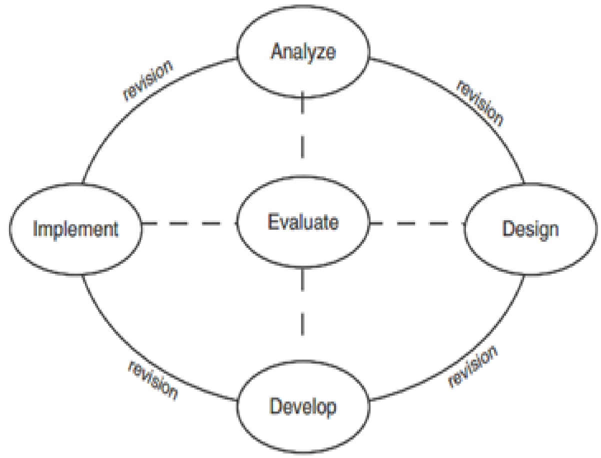


Figure 1. Stages of the ADDIE model development (Branch, 2009)

Analyze Stage

Spatioti et al. (2022) explain that the ADDIE model serves as a systematic guide in the instructional design process to achieve specific learning outcomes through continuous evaluation at every phase. A needs analysis is conducted to identify the problems faced in the physics learning process and to determine appropriate solutions to make learning more effective. Furthermore, this analysis aims to identify student competencies, which will serve as the foundation for developing a physics teaching module based on the karst environment.

Initial-Final Analysis

The analysis at SMAN 4 Maros indicates that developing a karst-environment-based teaching module is essential to translate students' actual needs into effective product requirements (Miranda et al., 2023). Observations conducted at the school revealed a significant gap where learning resources are limited to a single textbook that is rarely used independently, and despite having complete laboratory facilities, they remain underutilized for exploratory activities or environmental experiments. These conditions, coupled with monotonous teaching methods and external factors such as high classroom temperatures at midday, lead to a decline in student motivation and concentration. Given that outdoor-based learning has a proven positive impact on science learning outcomes (Pulido et al., 2025), developing this karst-based physics module serves as an innovative solution to make the learning process more interactive and applicative. By leveraging the school's adequate infrastructure, this module is expected to facilitate students in observing natural phenomena directly and connecting physics concepts to the reality of their surrounding environment.

Analysis of Student Characteristics

The analysis of learner characteristics at SMAN 4 Maros shows that Grade XI students are in the formal operational stage, where they are capable of abstract thinking, developing hypotheses, and collaborating on logical problem-solving. These abilities can be optimized through a karst-environment-based physics module designed to foster independent and contextual learning. However, diagnostic results and teacher interviews reveal that most students still require guidance to grasp abstract concepts. Consequently, the module's development must account for individual learning styles, as these are significant factors influencing educational success (Pebrianti et al., 2025). Specifically, the module aims to accommodate the three primary learning groups : visual, auditory, and kinesthetic (Kirschner, 2017), ensuring that students can achieve optimal learning outcomes through methods that align with how they effectively absorb knowledge. The following are the results of the student learning style analysis:

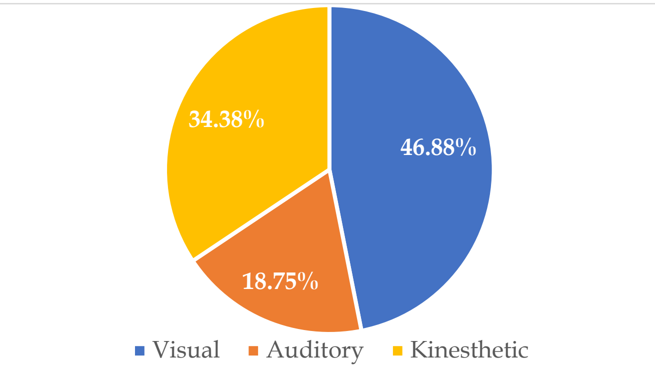


Figure 2. Learning styles of class XI students at SMAN 4 Maros

Each student has a unique way of understanding learning materials, depending on their individual learning style. Based on the data analysis of Grade XI students at SMAN 4 Maros, various learning styles were identified: visual, auditory, and kinesthetic. The data distribution revealed that 46.88% of students possess a visual learning style, 18.75% are auditory, and 34.38% are kinesthetic.

The results indicate that the majority of students understand material more easily through images, diagrams, and visual illustrations. However, existing resources are limited to printed textbooks with minimal imagery, leaving visual learners without optimal support. To address this, the module is designed with an engaging layout featuring photographs and videos of physics phenomena in the karst environment, such as waterfalls, underground water flows, and cave water droplets. These visuals are expected to help students grasp concepts more effectively and improve learning outcomes. Additionally, the module includes interactive and contextual Student Worksheets (LKPD) that support kinesthetic learners through observation activities, simple experiments, and group discussions.

Environmental Analysis

The environmental analysis identifies SMAN 4 Maros as a school with a highly strategic geographical location in the Pakalu area, part of the Maros–Pangkep Karst landscape one of the largest karst regions in Indonesia. Specifically, the Bantimurung-Bulusaraung National Park (TN Babul), with its rich geological heritage and biodiversity, serves as an ideal natural instructional medium for physics, particularly regarding fluid dynamics. Real-world phenomena such as waterfalls and karst river systems allow students to directly observe the application of Bernoulli's Principle and the Continuity Equation through changes in water flow velocity between narrow and wide river sections. By integrating these phenomena into the teaching module, students are no longer dependent solely on theoretical explanations but can instead grasp concepts through direct observation of the physical realities surrounding them.

The urgency of developing local potential based modules is evident because despite this extraordinary environmental potential, interviews with teachers and students at SMAN 4 Maros reveal that these natural resources have not been optimally utilized, as physics instruction remains heavily focused on general textbooks. Consequently, developing a karst-environment-based physics module is crucial because an adequate learning environment including physical aspects and a conducive academic atmosphere is proven to increase student motivation and comfort (Susilo et al., 2025). Furthermore, utilizing high-quality local karst potential is capable of significantly improving learning outcomes (Muresan et al., 2019). This approach is supported by research indicating that teaching materials based on local wisdom are effective in enhancing educational achievement because they relate science directly to the students' living environment while simultaneously fostering a sense of responsibility for environmental conservation (Sari et al., 2021).

Concept/Material Analysis

Concept Analysis and Systematic Organization Concept analysis aims to identify and systematically organize essential physics materials to ensure they align with specific learning outcomes. Through this stage, researchers select and structure core concepts into a learning map that serves as a primary reference for designing classroom activities. Presenting information based on similarities in profiles or characteristics that are already recognized by student can significantly accelerate the process of synchronizing understanding (Levy et al., 2019). This stage is a vital foundation because the results determine the appropriate instructional forms and approaches to improve student outcomes, acknowledging that the school environment is a major factor influencing educational success (Murtopo et al., 2023).

Relevance of Fluid Dynamics to Karst Phenomena Fluid Dynamics was specifically chosen for Grade XI because students frequently face difficulties in understanding the abstract relationships between pressure, velocity, and flow rates. Concepts such as Bernoulli's Law and the Continuity Equation are often perceived as difficult due to overly theoretical instruction and limited laboratory facilities for direct observation. To overcome this, the module links these theories to real phenomena within the karst environment, such as underground river flows, the mechanisms of the Bantimurung waterfall, and water seepage through limestone crevices. These natural occurrences provide a tangible context for how fluids flow from high-pressure to low-pressure areas, allowing students to validate physics theories through direct observation of their surroundings.

Integration of Contextual and Interactive Strategies To support independent learning, this karst-environment-based physics module is equipped with interactive Student Worksheets (LKPD), contextual practice questions, and access to digital learning resources. This innovation is designed to accommodate various learning styles visual, auditory, and kinesthetic, ensuring that every individual can absorb knowledge in the manner most comfortable for them. Through this contextual approach that is closely linked to daily life, students are expected not only to understand physics concepts deeply and improve their learning outcomes but also to develop a stronger sense of curiosity and concern for the conservation of the karst environment in their region.

Design Stage

The design stage is the planning phase for the physics teaching module based on the karst environment that will be developed. According to Saputra et al. (2020), the design stage is the phase of planning and creating the product design. This is a crucial stage in the research because the karst environment-based physics teaching module will be developed during this phase. Activities in the design stage include the selection of learning media and the selection of formats.

The main steps in the design are preparing the necessary assets such as the design of teaching materials, images, videos, content, questions, and other elements that must be prepared before development. The initial design of this teaching module includes the following: the teaching module cover is designed in accordance with the material to be developed. The content section contains teaching material structured in a factual form, aligned with what is happening and what students experience. This is done to make it easier for students to understand the presented subject matter. Exercises and evaluation are prepared in the form of questions included in the karst environment-based physics teaching module. The evaluation questions are placed at the end of the chapter and aim to measure student learning outcomes in physics instruction.

After the initial design is completed, the resulting asset components are then compiled into the karst environment-based physics teaching module with the appropriate format. The karst environment-based physics teaching module that has been designed by the researcher becomes the researcher's initial design (Prototype 1).

Development Stage

The development stage is focused on the process of producing the developed module (Miftahatuljannah et al., 2021; Susilawati et al., 2023). The development of the karst environment-based physics teaching module is the stage of realizing what has been prepared during the design phase. In this development stage, product validation is conducted to assess whether the design of the karst environment-based physics teaching module is effective and practical. Several aspects of expert assessment for the karst environment-based physics teaching module include 1) material/content feasibility, 2) presentation feasibility, 3) language feasibility, and 4) graphic feasibility. At this stage, data from expert assessments are used to measure the feasibility of the compiled teaching module, while suggestions and input are used to revise the karst environment-based physics teaching module. The revised karst environment-based physics teaching module becomes the final product used in the implementation stage.

Implementation Stage

This implementation stage aims to determine student responses and the feasibility of learning (Qomariyah & Maftukhin, 2017). Implementation is the testing phase on research subjects, namely physics subject teachers/learning practitioners as well as students of SMAN 4 Maros. The trial was conducted using a one-group pretest-posttest design, with the trial being carried out twice, specifically before and after the experiment. The one-group pretest-posttest design can be illustrated as follows (Arikunto, 2013):

Pretest	Treatment	Posttest
O_1	X	O_2

Figure 3. One group pretest-posttest design

Description:
O_1 = Pre-test (initial test before treatment is given)
X = Provision of treatment
O_2 = Post-test (final test after treatment is given)

Evaluation Stage

The evaluation stage is carried out at each stage to improve the product based on input from material experts, media experts, and educational practitioners (Pradana et al., 2021). The evaluation stage is conducted to provide feedback to product users, so that the product results can be achieved can be seen to determine the improvement and feasibility of the developed material. Evaluation is performed to measure the achievement of the development goals.

Data Analysis

Descriptive Analysis

Descriptive analysis is conducted to describe or illustrate the collected data, including the mean score, variance, and standard deviation of the variables in the study.

Quantitative Data Analysis

Prerequisites Test

Prior to conducting hypothesis testing, the learning outcomes and student motivation data at SMAN 4 Maros underwent prerequisite testing. A normality test was performed to ensure the validity of using parametric statistics. Furthermore, a homogeneity test was conducted to verify that the variance across student motivation groups was equal, thereby ensuring that the ANOVA results remained unbiased.

Normality Test

Normality testing is performed using the SPSS 26 software with a significance level of 5%. The method for testing the residual distribution is done by observing the significance value in the Kolmogorov-Smirnov table. If the significance value is greater than 0.05, it means the data is normally distributed.

The results of the normality test using the SPSS version 26 program show that the Sig. value in the One-Sample Kolmogorov-Smirnov test for learning motivation is 0.16, for the learning outcome pretest score is 0.14, and for the learning outcome posttest score is 0.08. It can thus be concluded that the distribution of the obtained data variance is normal because the significance value is greater than 0.05, or Learning Motivation 0.16 > 0.05, Learning Outcome Pretest 0.14 > 0.05, and Learning Outcome Posttest 0.08 > 0.05.

Homogeneity Test

Homogeneity testing is performed using the SPSS 26 software with a significance level of 5%. The method for testing the residual distribution is done by observing the significance value in the Based on Mean table. If the significance value is greater than 0.05, it means the data is homogeneous.

The results of the homogeneity test using the SPSS version 26 program show that the Sig. Based on Mean value is 0.28. Thus, it can be concluded that the data variance is homogeneous (the homogeneity test is fulfilled) because the significance value is greater than 0.05, namely, 0.28 > 0.05.

Analysis Teaching Module Validation Data

The analysis to determine the level of relevance by experts used the content validity coefficient (Aiken's V). The Aiken's V formula is used to calculate the content validity coefficient based on the assessment results from each expert regarding the developed product (Azwar, 2012).

$$V = \frac{\Sigma s}{n(c-1)} \tag{1}$$

Description:
V : Expert agreement index regarding item validity
s : The difference between the score assigned by each expert and the lowest score in the category used
s : $s = r - l_0$
r : Score assigned by the rater
L_0 : Lowest assessment score.
n : Number of experts.
c : Highest assessment score.

Aiken test requirements: After calculation, if $v \geq 0{,}4$ then the expert agreement index is considered valid (Azwar, 2012).

Analysis of Practicality Test Results

Practicality data were obtained by analyzing the assessment questionnaires completed by subject teachers. This analysis was conducted to measure the level of usability and ease of implementation of the developed physics module within the classroom setting. In line with Hasanudin et al. (2024), practicality assessment is conducted to determine the ease of use of the module by users during learning activities Furthermore, Sere et al. (2022), state that practicality is a vital dimension that indicates the extent to which instructional tools can be implemented by teachers and understood by students without significant technical obstacles. The calculation formula for the practicality analysis follows the standards established by Akbar (2013), as follows:

$$Practitioner\ Score = \frac{Obtained\ score}{Maximum\ score} \times 100\% \quad (2)$$

According to Riduwan (2010), the percentage of responses from teachers and students for each statement uses the criteria according to Table 1.

Table 1. Practitioner Assessment Scoring Criteria

Percentage (%)	Category
76-100	Very practical
56-75	Practical
26-55	Less practical
0-25	Not practical

Effectiveness Analysis of the Karst Environment-Based Physics Teaching Module

The effectiveness of learning module development refers to the success rate of the developed module in achieving predefined learning objectives, as demonstrated by improvements in learning outcomes, conceptual understanding, and student engagement following the implementation of the module (Behrendt & Smallfield, 2024; Adelowo et al., 2024). The effectiveness of the karst environment-based physics module can be determined by testing student learning outcomes. The paired sample t-test was employed to examine the mean differences between pre-treatment and post-treatment scores. The paired sample t-test is applicable when the data follows a normal distribution. To facilitate the data analysis, this study utilized SPSS version 26 software with a significance level of 5%.

The decision-making guidelines for the paired sample t-test are based on the significance (Sig.) value. Based on the SPSS output, the criteria for hypothesis testing are as follows: if the Sig. value > 0.05, H1 is rejected; if the Sig. value < 0.05 , H1 is accepted.

Statistical Hypothesis:

H_0: $\mu 1 = \mu 2$

H_1 : $\mu 1 \neq \mu 2$

H_0: There is no difference in the improvement of learning outcomes between the pre-test and post-test after using the karst environment-based teaching module.

H_1 : There is a difference in the improvement of learning outcomes between the pre-test and post-test after using the karst environment-based teaching module.

Analysis of Learning Outcome Improvement Based on Learning Motivation After Using the Karst Environment-Based Teaching Module

The analysis employed is the One-Way ANOVA, which is used to determine whether there are significant differences in learning outcomes among groups of students based on their levels of learning motivation (Mishra et al., 2019). The One-Way ANOVA is applicable provided that the data are normally distributed and meet the criteria for homogeneity. To facilitate the data analysis process, this research utilized IBM SPSS Statistics version 26 software with a significance level of 5%.

The decision-making guidelines for the One-Way ANOVA are based on the significance (Sig.) value. Based on the SPSS output, the criteria for hypothesis testing are as follows: if the Sig. value > 0.05, H1 is rejected; if the Sig. value < 0.05 , H1 is accepted.

Statistical Hypothesis:

H_0: $\mu 1 = \mu 2$

H_1 : $\mu 1 \neq \mu 2$

H_0 : There is no difference in post-test learning outcomes among students based on their level of learning motivation after using the karst environment-based teaching module.

H_1 : There is a difference in post-test learning outcomes among students based on their level of learning motivation after using the karst environment-based teaching module.

After conducting the One-Way ANOVA test and obtaining a significant result, a follow-up Post Hoc Test is performed to identify which specific groups show significant and non-significant differences.

Result and Discussion

Development of Karst Environment-Based Physics Teaching Modules to Improve Learning Outcomes Viewed from Learning Motivation

Descriptive Analysis

Descriptive analysis was conducted to describe or illustrate the collected data, including the mean score, variance, and standard deviation.

Table 2. Descriptive Analysis of Variables

Indicator	Mean score	Variance	Standard deviation
Learning motivation	97.11	77.07	8.78
Learning outcome pre-test	11.59	6.25	2.50
Learning outcome post-test	23.06	10.44	3.23

Table 2 above presents the descriptive statistics for students in class XI F2. The learning motivation achieved a mean score of 97.11 with a standard deviation of 8.78 and a variance of 77.07. For the learning outcome pre-test, the mean score was 11.59 with a standard deviation of 2.50 and a variance of 6.25. Meanwhile, the learning outcome post-test achieved a mean score of 23.06 with a standard deviation of 3.23 and a variance of 10.44.

Content Validity Results of the Karst Environment-Based Physics Teaching Module using Aiken's V Index

The validity assessment of the developed karst environment-based physics teaching material was conducted by two experts who provided evaluations and feedback on four feasibility aspects: content feasibility, presentation feasibility, language feasibility, and graphic feasibility. The scores obtained from the expert agreement index analysis using the Aiken's V coefficient are presented in Table 3 below:

Table 3. Analysis of the Karst Environment-Based Physics Teaching Module using Aiken's V Index

Feasibility aspect	Total item validity score	Validation index	Category
Content	13.17	0.82	Valid
Presentation	12.83	0.80	Valid
Language	12.83	0.80	Valid
Graphics	4.83	0.81	Valid
Average		0.81	Valid

)

Table 3 above shows that the content feasibility aspect obtained a total validity item score of 13.17 with an average validity index (V) of 0.82, placing it in the valid category. The presentation feasibility aspect obtained a total validity item score of 12.83 with an average validity index (V) of 0.80, also categorized as valid. Furthermore, the language feasibility aspect yielded a total validity item score of 12.83 with an average validity index (V) of 0.80, falling into the valid category. Finally, the graphic feasibility aspect obtained a total validity item score of 4.83 with an average validity index (V) of 0.81, which is categorized as valid. This means the analysed V index is ≥ 0.4, indicating that the expert agreement index is considered valid.

Validation Results of the Teacher/Practitioner Assessment Questionnaire for the Karst Environment-Based Physics Teaching Module

The expert validation data for the teacher assessment questionnaire, consisting of 25 statements, were analyzed using the Aiken's V expert agreement index. The analysis results for the instrument's validity yielded an expert agreement index of 0.81, which is in the valid category. Based on these results, the teacher/practitioner assessment questionnaire for the Karst Environment-Based Physics Teaching Module is declared feasible for field use without revision.

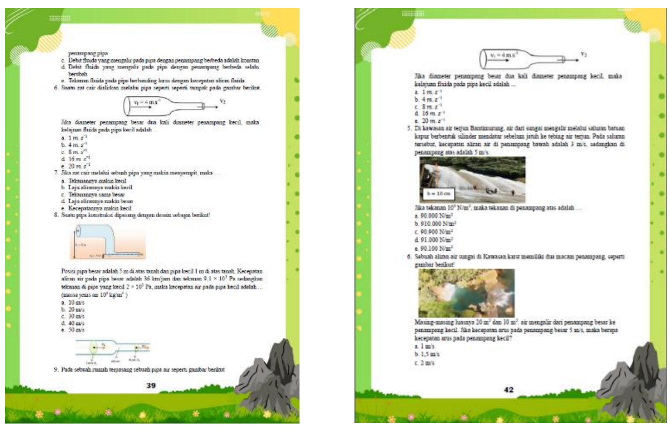
Validation Results of the Learning Motivation Questionnaire

The instrument was validated by two experts to determine the feasibility of each statement item. There are 32 statement items consisting of six indicators: the desire and wish to succeed, the drive and need for learning, interesting activities in learning, future hopes and aspirations, appreciation in learning, and a conducive learning environment. The validity analysis for the learning motivation questionnaire yielded an average validity index (V) of 0.77, placing it in the valid category.

Validation Results of the Learning Outcome Test Instrument

The instrument was validated by two experts to determine the feasibility of each test item. Instruments declared feasible will be used to measure the improvement in student learning outcomes, consisting of 30 multiple-choice questions on the topic of Dynamic Fluids. The validity analysis yielded an average validity index (V) of 0.81, which is in the valid category.

The expert validation analysis for the learning outcome test instrument was declared valid and feasible for use with revisions. The corrections and suggestions from the experts were: adding images to the questions presented, and using lowercase letters for answer options. After revising the learning outcome test instrument based on the corrections and suggestions from the two validators, the instrument was declared feasible for use in the trial phase.



Before revision After revision

Figure 4. Comparison of the learning outcome test instrument before and after revision based on expert validation

Practitioner Assessment of the Karst Environment-Based Physics Teaching Module

The practitioner assessment of the karst environment-based physics teaching module was obtained through assessment questionnaires filled out by several teachers/practitioners. The practitioners in this study were high school physics teachers. The results of the data analysis for the practitioner assessment regarding the quality of the karst environment-based physics teaching module showed an average score of 82.2% (above 50%), which means it is practical and that practitioners gave a positive response to the developed module.

Effectiveness of the Karst Environment-Based Physics Teaching Module

The effectiveness of the developed karst environment-based physics teaching module can be seen from the students' learning outcome test results. The measurement of learning outcomes for class XI F2 students at SMAN 4 Maros was conducted using a test consisting of 30 multiple-choice items. Both the pre-test (before learning) and the post-test (after learning with the karst environment-based module) consisted of 30 items. The analysis of student test scores for both the pre-test and post-test can be seen in Table 4.

Table 4. Results of Learning Outcome Test Score Analysis

Parameter	Pre-test score	Post-test score
Theoretical min score	0	0
Theoretical max score	30	30
Empirical min score	7	17
Empirical max score	17	28
Mean score	11.59	23.06

Table 4 above presents the statistical overview of the physics learning outcome scores for 36 students in class XI F2. Before using the karst environment-based teaching module, the mean pre-test score was 11.59, while the mean post-test score after using the module was 23.06. Based on these data, it is evident that the average physics learning outcome score after being taught using the karst environment-based module is higher than the score obtained before using the module. The chart showing the pre-test and post-test results can be seen in Figure 5.

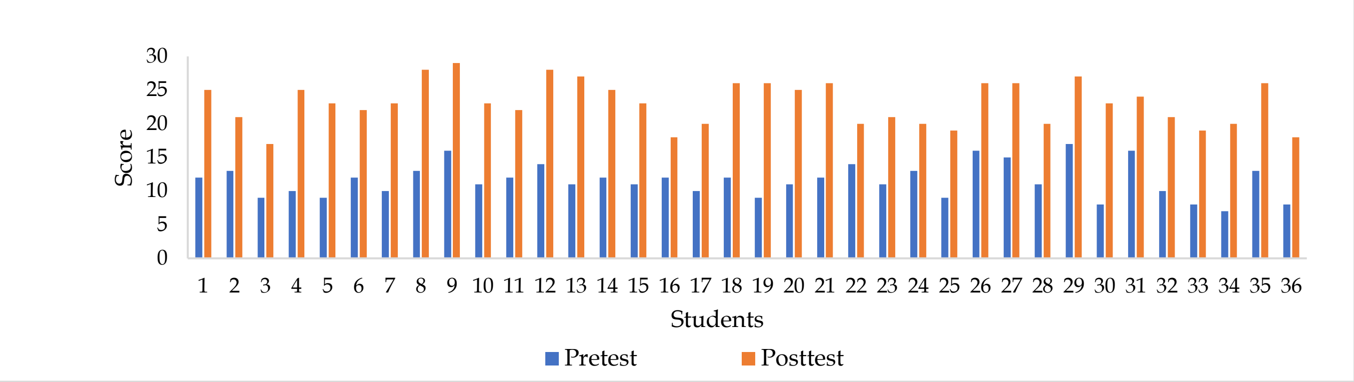


Figure 5. Pretest and posttest learning outcomes

The pre-test results indicate that student learning outcomes were still relatively low. This is because the material previously studied was presented in a general manner and had not been linked to the students' surrounding environment. Consequently, students tended to receive information passively and were less encouraged to analyze or evaluate physics concepts in their vicinity. In contrast, the post-test scores show an improvement in student learning outcomes after using the karst environment-based teaching module. Statistically, this effectiveness is frequently evidenced by the increase in scores between the pre-treatment and post-treatment phases (Pratama & Syahputra, 2025).

This teaching module integrates physics concepts with the local environment, specifically the Bantimurung Bulusaraung National Park (TN.Bantimurung) karst area, making learning more contextual and relevant for students. This environment-based approach not only strengthens material comprehension but also boosts student motivation in connecting physics concepts with phenomena encountered in their daily surroundings, thereby enhancing learning outcomes. This is in line with the research conducted by Sere et al., (2022), which states that the application of modules based on environmental potential is effective in improving student learning outcomes. This effectiveness is attributed to the provision of more meaningful learning experiences and the stimulation of students' curiosity regarding physical phenomena occurring in their immediate surroundings.

Furthermore, the pre-test and post-test scores were analyzed to determine the effectiveness of using the karst environment-based physics teaching module using the paired sample t-test. The results of the paired sample t-test analysis can be seen in the following Table 5.

Table 5. Results of the Paired Samples T-Test Analysis for Pre-test and Post-test Learning Outcomes

	Paired samples test							
	Paired differences							
				95% confidence interval of the difference				
	Mean	Std. deviation	Std. error mean	Lower	Upper	T	Df	Sig. (2-tailed)
pretest – posttest	-11.53	4.37	0.73	-13.01	-10.05	-15.84	35	0.00

Based on the analysis above using SPSS version 26, the Sig. (2-tailed) value obtained is 0.00. Therefore, it can be concluded that there is a significant difference in learning outcomes between the pre-test and post-test after using the karst environment-based teaching module because the significance value is less than 0.05 (0.00 < 0.05). In other words, H0 is rejected and H1 is accepted. This indicates that the developed karst environment-based physics teaching module is effective in improving student learning outcomes.

The results of this study are in line with the research by Kusumawati et al. (2023), which state that environment-based teaching materials have the potential to increase student engagement and learning outcomes because they link academic concepts with real-world environmental phenomena. Similarly, research by Dahniar et al. (2018), states that the effectiveness of using learning tools is measured by students' learning outcome test scores, where 18 out of 32 students were in the very high category. Thus, it was found that the use of karst ecosystem-based learning tools for grade VII students at SMP Negeri 4 Bantimurung is valid and effective.

Analysis of Post-test Learning Outcomes Based on Learning Motivation Categories

The analysis of post-test learning outcomes based on learning motivation categories was conducted to determine whether students' learning outcomes after using the karst environment-based physics teaching module show the same levels relative to their learning motivation. The frequency distribution of post-test learning outcomes in relation to student learning motivation can be seen in the following table:

Table 6. Frequency Distribution of Post-test Learning Outcome Scores Based on Learning Motivation Categories for Class XI F2 Students

Post-test	Means post-test	Motivation	Category
11	26.82	5	Very high
20	22.30	20	High
5	18.20	11	Moderate
0	0	0	Low
0	0	0	Very low
36		36	

Based on Table 6, it is found that student post-test learning outcomes after using the karst environment-based teaching module range from the moderate to very high categories. Out of 36 students, 11 are in the very high category with a mean score of 26.82, 20 are in the high category with a mean score of 22.30, and 5 are in the moderate category with a mean score of 18.20. In terms of learning motivation, students also show a trend toward high categories. Specifically, 5 students are in the very high motivation category, 20 students are in the high category, and 11 students are in the moderate category. The total proportion of students in the high and very high categories reaches 25 students. The chart showing the mean post-test scores of students' learning outcomes based on learning motivation levels can be seen in Figure 6 below:

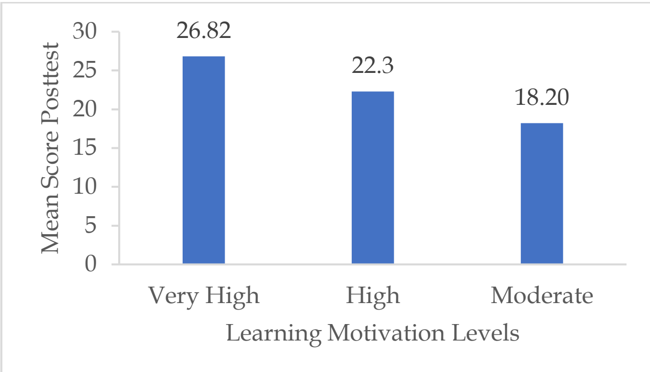


Figure 6. Mean post-test scores of students' learning outcomes based on learning motivation levels

Furthermore, the post-test learning outcome scores and learning motivation scores were analyzed to determine whether student learning outcomes differ when grouped by learning motivation levels after being taught with the karst environment-based teaching module using the One-Way ANOVA test. This hypothesis testing calculation utilizes the ANOVA test with a 95% confidence level.

Table 7. One-Way ANOVA Results of Post-test Learning Outcomes Based on Learning Motivation Categories

	Sum of squares	Df	Mean square	F	Sig.
Between groups	17.92	2	85.96	14.65	0.00
Within groups	193.64	33	5.89		
Total	365.56	35			

Based on Table 7 above, it can be concluded from the ANOVA test results using SPSS version 26 that the obtained Sig. value is 0.00. Therefore, it is concluded that there is a significant difference in post-test learning outcomes among students based on their levels of learning motivation after using the karst environment-based teaching module, as the significance value is less than 0.05 (0.00 < 0.05). This means that H0 is rejected and H1 is accepted. This confirms that learning motivation influences the variations in student learning outcome achievement. These results are in line with the research by Arafah et al. (2020), which states that learning motivation has a direct positive effect on physics learning outcomes. It is recommended that physics teachers understand students' self-efficacy well and investigate and analyze students' basic learning needs to achieve physics learning objectives. Similarly, research by Imran et al. (2024) states that the relationship between learning motivation and physics learning outcomes is positive; that is, as learning motivation increases, physics learning outcomes also tend to increase.

The results of the post hoc test analysis using SPSS version 26 show the following: the comparison between the moderate motivation and high motivation groups yielded a Sig. value of 0.01, meaning there is a significant difference between the two, the comparison between the moderate motivation and very high motivation groups yielded a Sig. value of 0.00, indicating a significant difference. For the high motivation and moderate motivation groups, a Sig. value of 0.00 was obtained, indicating a significant difference, the comparison between the high motivation and very high motivation groups yielded a Sig. value of 0.06, meaning there is no significant difference between the high and very high motivation groups. Similarly, the comparison between the very high motivation and moderate motivation groups yielded a Sig. value of 0.00, indicating a significant difference. Finally, the comparison between the very high motivation and high motivation groups yielded a Sig. value of 0.06, which means there is no significant difference between these two categories.

Conclusion

Based on the research results and the trials of the karst environment-based physics teaching module on the learning outcomes and motivation of class XI F2 students at SMAN 4 Maros, the following conclusions are drawn: The physics teaching module based on the karst environment developed in this study was declared valid in terms of content, presentation, graphics, and language, with a mean score of 0.81. In addition to its validity, practitioners provided positive feedback, categorizing the module as a practical medium for classroom instruction with a score of 82.20%. The module proved effective in improving learning outcomes for fluid dynamics, as indicated by a significance value of 0.00 (0.00 < 0.05), showing a significant difference between students' achievement before and after instruction in class XI F2 at SMAN 4 Maros. Furthermore, a significant difference in learning outcomes was observed among students with different learning motivation levels following the use of this module, as evidenced by a Sig. value of 0.00 (0.00 < 0.05).

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Author Contributions

S.M.R.M.: Conceptualization, methodology, original draft preparation, formal analysis, investigation, visualization, and writing—review and editing. P.P. & A.H.: Validation, supervision, and resources. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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