Jurnal Penelitian Ilmu Pendidikan Indonesia
Volume 4, Number 4, Year 2025, Page 2361 – 2373
https://jpion.org/index.php/jpi

E-ISSN : 2961 - 9386
P-ISSN : 2963 - 1742

Development of Physics Electronic Modules Using the Trait–Treatment Interaction Model Based on Next Generation Science Standards

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Abstract

This research aims to develop a physics electronic module using the Trait Treatment Interaction (TTI) model based on the Next Generation Science Standards (NGSS) to improve students' ability to Construct Explanations and Design Solutions (CEDs) and to test its effectiveness on the topic of Environmental Pollution for grade X SMA/MA. The study uses a Research and Development (R&D) method with the 4D model (Define, Design, Develop, Disseminate). The Define stage includes front-end, student, task, and concept analysis, while the Design stage involves preparing instruments and selecting media. The Develop stage consists of validation by content, media, and language experts, followed by product trials with educators and students, and the Disseminate stage focuses on distributing the effective product. The research subjects were 34 students of class X.I MAN 2 Pesisir Selatan. The findings show that the developed e-module is of very high quality and highly valid, with an average score of 89.24% from expert validators, while its practicality level reached 88.97% based on evaluations from educators and students. The e-module also proved very effective in improving students' CEDs abilities, indicated by an average test score of 90%. High-ability students (faster learners) experienced significant improvement through self-learning, whereas low-ability students (slower learners) benefited more from regular teaching accompanied by additional tutorials. Based on these results, it is recommended that the e-module be further developed for other physics topics, and future researchers are encouraged to optimize time efficiency to ensure a smoother learning process without disrupting the predetermined duration.

Keywords*: CEDs, Electronic Module, NGSS, TTI*

INTRODUCTION

Science education worldwide is undergoing a fundamental transformation, shifting from a passive knowledge transmission model to a more active, constructivist, and learner-centered approach. This trend is driven by the need to prepare young people for the complex challenges of the 21st century, which demand critical thinking, problem-solving, innovation, and collaboration (OECD, 2018).

This shift has led to the development of new frameworks that emphasize science and engineering practices as an integral part of learning, not just content (National Research Council, 2012). One of the most influential frameworks guiding this shift is the Next Generation Science Standards (NGSS), which emphasize science learning through the integration of three dimensions: Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts. Science and Engineering Practices address how scientific knowledge is acquired and understood, Disciplinary Core Ideas address the content of scientific knowledge, and Crosscutting Concepts address how scientific content is connected through concepts that cross disciplines (Cahyanti et al., 2020).

Within the NGSS framework, one essential practice that is highlighted and highly relevant to future needs is Constructing Explanations and Designing Solutions (CEDs). CEDs go beyond conceptual understanding, but rather foster students' ability to construct coherent, evidence-based scientific explanations for natural phenomena and design innovative solutions to real-world problems (Achmad, 2022).

Despite a strong global trend toward science education that focuses more on students' ability to understand problems, develop, design, explain, test, and refine solutions, real-world

E-ISSN : 2961 - 9386
P-ISSN : 2963 - 1742

conditions indicate that the implementation of physics learning in Indonesia still faces significant challenges. Observations in various schools often reveal learning dominated by lectures, where the teacher serves as the center of information and students tend to be passive (Yulianti & Wati, 2021). Physics material is often presented disconnected from real-life contexts, focusing on memorizing formulas and solving routine algorithmic problems, without providing adequate space for students to develop scientific arguments.

Of the above phenomena, the most prominent specific problem is students' low capacity to understand problems, develop solutions, design solutions, explain solutions, and then test and refine solutions in physics learning. Students often fail to identify relevant evidence from data or observations to support their explanations, connect evidence to physics concepts logically and coherently, and construct structured scientific arguments that include claims, evidence, and reasoning. The above problems are highly relevant to the indicators in the Constructing Explanations and Designing Solutions (CEDs) ability (McNeill, Lizotte, Krajcik, & Marx, 2006).

Furthermore, students experience obstacles in designing solutions due to difficulties defining problems, identifying design criteria and constraints, generating and selecting the best solution based on physics principles, and testing and modifying designs (Bybee, 2014). This low CEDs ability is influenced by learning models that are not adaptive to differences in student characteristics, speed, and learning preferences. The available learning modules are generally static and non-interactive, such as textbooks or printed worksheets, so they are unable to adapt to the individual characteristics of students.

The urgency of improving CEDs skills is very high in the era of the Industrial Revolution 4.0 and Society 5.0, which require individuals to think critically, solve complex problems, innovate, and adapt (Schwab, 2016). Physics learning that still focuses on memorization and routine calculations produces graduates who are ill-prepared to face global challenges. Each student has different learning characteristics, so a uniform approach is ineffective in developing complex skills such as CEDs. Adaptive learning strategies are needed that adapt methods to student characteristics. The Trait Treatment Interaction (TTI) model provides a solution by tailoring learning treatments (treatments) to individual traits or characteristics (traits) such as learning styles, motivation, and cognitive abilities (Cronbach & Snow, 1977).

Research integrating Trait Treatment Interaction (TTI) principles into the development of learning media to improve Constructing Explanations and Designing Solutions (CEDs) skills based on the Next Generation Science Standards (NGSS) is still very limited. Studies such as Aswirna et al. (2024) demonstrate the potential of TTI in designing more personalized learning, but its application in physics e-modules that are adaptive to student characteristics is still rare. Most existing e-modules are still linear and unable to adjust learning paths according to student traits. This gap emphasizes the need to develop more sophisticated and adaptive e-modules to facilitate mastery of 21st-century skills such as CEDs. Various studies also show that students still have difficulty in constructing scientific explanations and designing solutions (Schwarz et al., 2017; McNeill & Krajcik, 2011), with physics learning outcomes still low (OECD, 2019; Kemendikbudristek, 2023) and analytical and problem-solving abilities that are not optimal (Anderson & Siford, 2013; Zangori et al., 2017).

Furthermore, based on observations at MAN 2 Pesisir Selatan and interviews conducted with Nadya Syahdi, S. Pd, students' abilities in Constructing Explanations and Designing Solutions (CEDs) are still relatively low and have not received attention in assessments. Many factors contribute to the poor achievement of this ability. Several studies indicate that the causes of low CEDs abilities in students can originate from educator and student factors as well as several other factors. For example, the availability of learning modules used in schools is still in the form of printed textbooks or static worksheets. These modules do not allow for dynamic interactions or personalized learning that are essential for developing CEDs skills. These facts strongly indicate that there is an urgent need for intervention through the development of

E-ISSN : 2961 - 9386
P-ISSN : 2963 - 1742

innovative and adaptive learning media, which specifically targets improving students' CEDs abilities.

Based on the problems and urgency outlined, this research proposes the development of an innovative physics electronic module (e-module). This e-module will be carefully designed based on the Trait Treatment Interaction (TTI) model, with a primary focus on improving Constructing Explanations and Designing Solutions (CEDs) skills in accordance with the Next Generation Science Standards (NGSS). Through this e-module, it is hoped that students will experience a more personalized and adaptive learning experience, where materials and activities are tailored to their learning characteristics, effectively facilitating the development of CEDs skills.

Based on the aforementioned aspects, the researcher will conduct research in the form of developing a Physics e-module on Environmental Pollution for 10th grade students, entitled "Development of an Electronic Physics Module Using the Trait Treatment Interaction Model Based on Next Generation Science Standards." The proposed solution is expected to help address the problems encountered.

RESEARCH METHODS

This research uses the R&D (Research and Development) method. According to Nana Syaodih (2009), R&D is the process or steps of developing new products or improving existing ones that can be considered. Furthermore, according to Putra (2015), R&D is a system aimed at discovering, improving, developing, creating, and testing the effectiveness of superior, effective, efficient, productive, and intelligent products, models, and new research methods/strategies/methods. With this in mind, R&D is a research method conducted systematically to improve existing products or explore new ones through testing.

The product to be developed in this research is the development of a Physics E-Module using the Trait Treatment Interaction (TTI) Model on Environmental Pollution to improve students' abilities in Constructing Explanations and Designing Solutions (CEDs). This research uses a 2 x 2 x 2 factorial design, considering moderator variables that influence the effect of treatment (independent variables) on outcomes (dependent variables). The initial ability of students is considered as a moderator variable (covariate).

This study used a 4D model with 4 development stages: Define, Design, Develop, and Disseminate (Widiyasari et al., 2020). The define stage is the stage of collecting data from various sources according to the information needed to determine and define development requirements. The design stage is the e-module design stage. At this stage, there are two steps, namely: e-module design and e-module evaluation instrument design. The develop stage is the stage to produce the development product. This stage consists of several steps, including: expert validation, revision based on expert validation results, product revision, and product trials by educators and students (Yuliantari et al., 2023). After revisions are made at the development stage, the learning media that has been produced is disseminated at this stage (Arkadiantika et al., 2020).

E-ISSN : 2961 - 9386
P-ISSN : 2963 - 1742

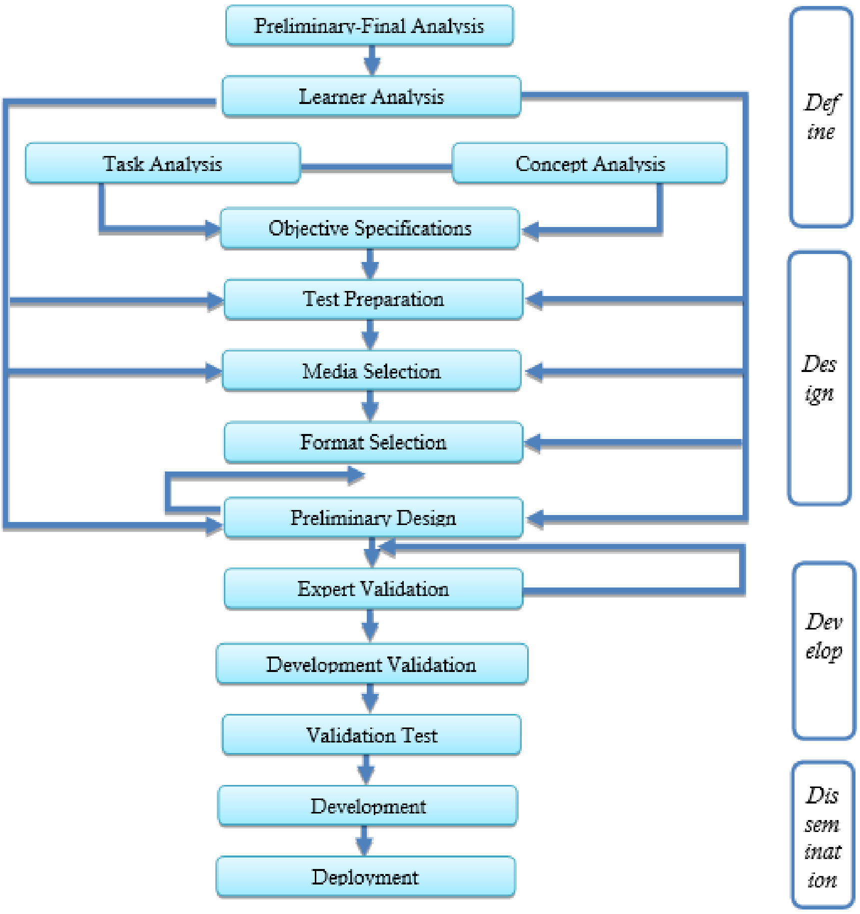


Figure 1. 4D Learning Tool Development Model by Thiagarajan

The population is the entire generalization area consisting of objects/subjects that have certain qualities and characteristics and are determined by the researcher to be studied and drawn conclusions. The population in this study was all 34 students of class XI MAN 2 Pesisir Selatan. The sample is part of the population that is the actual source of data in a study (Amin et al., 2023). The sampling technique used in this study was saturated sampling. Saturated sampling is a sampling technique when the entire population is used as a sample. If the population is less than 100 people, then the entire sample is taken. The sample in this study was all students of class XI MAN 2 Pesisir Selatan. The research procedure was carried out in three stages, namely the preparation, implementation, and final stages. In the preparation stage, the location and schedule of the research were determined, student IQ testing was carried out, and the preparation of teaching modules and research instruments. The implementation stage involved the learning process using e-modules based on the TTI model, while the final stage included administering tests and analyzing student learning outcomes.

Product trials were conducted in three stages: validity, practicality, and effectiveness. Validity testing was conducted by subject matter, media, and language experts to assess the appropriateness of the product's content and presentation. Practicality testing was conducted by teachers and students to assess the e-module's usability in the learning process. Meanwhile, effectiveness testing aimed to determine the extent to which the e-module improved student learning outcomes after use.

The research data included qualitative data in the form of suggestions and comments from validators and student responses, as well as quantitative data in the form of Likert-scale assessment scores. Data sources consisted of primary data obtained from student learning outcomes and secondary data in the form of previous exam scores. The research instruments

E-ISSN : 2961 - 9386
P-ISSN : 2963 - 1742

used included product validation sheets, practicality questionnaires for teachers and students, and effectiveness tests consisting of multiple-choice questions, essays, and student worksheets.

Table 1. Research Instruments

No.	Kriteria	Instrumen
1.	Valid	a. Material/content validity instrument sheet b. Media validity instrument sheet c. Language validity instrument sheet d. Test item validity sheet
2.	Practical	a. Practicality questionnaire for teachers b. Practicality questionnaire for students
3.	Effective	a. Test questions

Data analysis was conducted in several stages. Validity, practicality, and effectiveness were calculated using a Likert scale with a value of 81–100% interpreted as very valid, practical, or effective; while 61–80% was included in the valid, practical, or effective category. The reliability of the questions was tested using SPSS 24 software and obtained a result of 0.84, indicating high reliability. The results of the analysis of discriminant power and the level of difficulty of the questions indicated that the instrument was classified as good and easy to use. The normality test was conducted using the Shapiro-Wilk method with the criteria for normally distributed data if the significance value is greater than 0.05. To test the hypothesis, analysis of covariance (ANACOVA) was used to determine the effect of using the TTI model on learning outcomes by taking into account the covariate of students' initial abilities.

RESULTS AND DISCUSSION

This research obtained results in the form of development that produced an e-module to improve students' CEDs abilities by using the 4D development model as follows:

1. *Define* (Definition Stage)

The definition phase was conducted to gather the necessary information before developing a physics e-module based on the Trait Treatment Interaction (TTI) model. Based on observations and interviews with teachers and students of grade XI MAN 2 Pesisir Selatan, it was found that student learning motivation was still low, with an average first-semester score of 63.97. This low learning outcome was caused by a lack of variety in learning media and teaching methods that focused on formulas without real-life relevance, thus discouraging students from engaging in physics.

A needs analysis was conducted using a SWOT approach to assess the internal and external factors influencing the development of the e-module. The main strengths lie in students' ability to access online learning and the flexibility of the e-module, which can be used anytime. While weaknesses relate to dependence on internet networks and data quotas, the national curriculum encourages students to learn independently. While threats include low technological literacy and limited access to digital devices among both teachers and students.

2. *Design* (Design Stage)

The design stage is a continuation of the definition stage which aims to improve the Physics e-module for grade X SMA/MA by utilizing technological advances. At this stage, research instruments are prepared which include validation sheets, practicality, and effectiveness. The e-module validation sheet is divided into three aspects, namely material, media, and language, each of which is assessed by experts in their respective fields. Meanwhile, the practicality sheet is used to assess the efficiency, implementation, and clarity of the e-module language, with the assessment carried out by physics teachers and grade X.I students of MAN 2

E-ISSN : 2961 - 9386
P-ISSN : 2963 - 1742

Pesisir Selatan. The effectiveness of the e-module is measured through the results of student learning tests after using the developed e-module.

In developing this e-module, the Trait Treatment Interaction (TTI) learning model was chosen, emphasizing the adjustment of learning treatment to student characteristics. The TTI model facilitates differences in individual abilities by grouping students based on IQ test results or Academic Potential Tests (TPA). High-ability students are directed to study independently using the e-module and other resources, while middle- and low-ability groups receive direct guidance from educators. If the learning outcomes of these groups do not meet the Minimum Completion Criteria (KKM), relearning and additional tutorials are provided. At the end of the process, all groups are given an evaluation test to assess understanding and learning achievement.

3. *Develop* (Development Stage)

The development phase aims to produce a valid and practical physics e-module on environmental pollution. At this stage, the previously designed e-module is tested and refined based on input from experts and practitioners to ensure its suitability for use in the learning process.

The development process begins with product validation by three validators from UIN Imam Bonjol Padang, consisting of a construction expert, a content expert, and a language expert. This validation assesses the e-module's suitability in terms of content, language, and presentation. The validators' suggestions and comments are used as the basis for making improvements to the e-module's content and presentation to better suit learning needs.

Next, a practicality test is conducted by educators and students at MAN 2 Pesisir Selatan. Educators assess aspects of ease of use, time efficiency, and content alignment with the curriculum, while students assess the material's appeal and ease of understanding through a questionnaire.

Table 2. Revisions from the validator

Before Revision	After Revision
In this section, the CEDs indicators and the parts that will be achieved in learning are still not neat and structured. They have not been made in table form to make them more neatly structured.	
	
The heavy metal material was removed and the material on global warming, the greenhouse effect, and the thinning of the ozone layer was added, as well as adapting the material to the Merdeka curriculum textbook.	
	
Addition of general information, Pancasila student profiles, learning achievements and objectives that still need to	

E-ISSN : 2961 - 9386
P-ISSN : 2963 - 1742

Before Revision	After Revision
be improved, and made in table form to make it neater and more structured.	
	

4. *Dissemination* (Deployment Stage)

This stage is an activity using the developed e-module. At this stage, a limited trial was conducted using a trial class, namely class XI at MAN 2 Pesisir Selatan. After the product was proven effective based on the test results of students who used the e-module on environmental pollution material at MAN 2 Pesisir Selatan, the final stage of the dissemination process involved packaging. Packaging was carried out to enable the product to be used by others. The e-module was packaged in the form of a PDF link that was distributed so that it could be accessed and utilized by others, especially in the context of physics learning in class XI at MAN 2 Pesisir Selatan.

This study used the Trait Treatment Interaction (TTI) learning model with e-modules as the primary medium. Before the main activity, the educator introduced the e-module, explained the TTI learning steps, and divided students into groups based on ability. The TTI model consists of three stages: initial treatment to identify student abilities through an aptitude test, grouping based on high and low ability levels, and administering appropriate treatment. High-ability students participated in independent learning using the e-module, while low-ability students received guidance through regular learning and tutorials led by peers with higher abilities.

Data for the attitude assessment were obtained based on notes on observation sheets of student attitudes during the learning process at each meeting. This data was collected by researchers during three face-to-face meetings on the topic of environmental pollution. Students' attitudes, including faith, devotion to God Almighty, noble character, independence, critical thinking, global diversity, and creativity, increased by an average of 81% each meeting, achieving very good criteria. This can be seen in Figure 2.

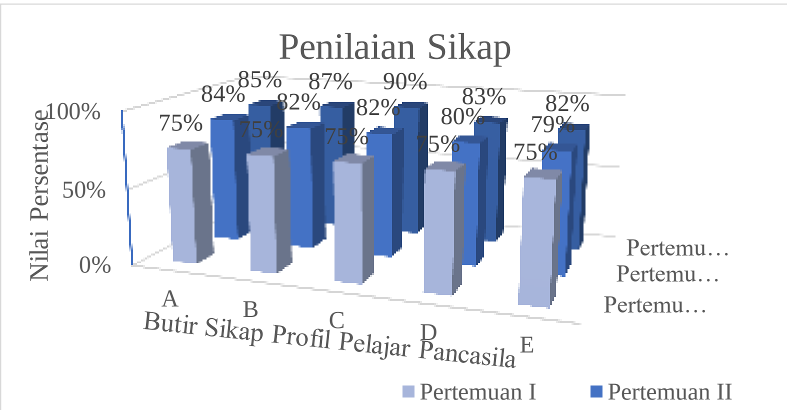


Figure 2. Results of Student Attitude Assessment

The validity test results were obtained from a questionnaire completed by 1 material expert, 1 media expert, and 1 language expert. The final value of the E-Module validity was

E-ISSN : 2961 - 9386
P-ISSN : 2963 - 1742

generated from the average value of the evaluations carried out by the three validators, which is detailed in Table 3. Based on Table 3, the average validity result of the e-module was 89.24, which is classified as very valid, so it is worthy of being continued to the next stage for practicality and effectiveness testing.

Table 3. Average Validity Value of E-Module

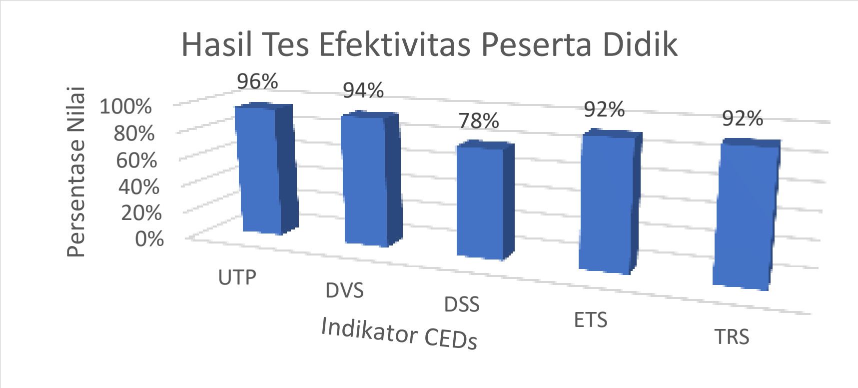
Validator	Average Percentage	Category
Material/Content	90%	Very Valid
Media	85,72%	Very Valid
Language	92%	Very Valid
Average Percentage	89,24%	Very Valid

The practicality test of the e-module was given to educators before being tested on students by providing a practicality assessment questionnaire. The educator practicality sheet consisted of 12 questions. The practicality test was conducted before the effectiveness test was carried out. The practicality sheet was filled out by 34 students of class XI MAN 2 Pesisir Selatan. Based on the analysis carried out by educators and students, the average percentage was 88.97%. Therefore, it was concluded that the e-module can be categorized as very practical.

Table 4. Average Value of E-Module Practicality

Practitioner	Average Percentage	Category
Educators	85%	Very Practical
Students	92,95%	Very Practical
Average Percentage	88,97%	Very Practical

This effectiveness test sheet contains test questions consisting of 10 multiple-choice questions, 5 essay questions, and 6 LKPD questions related to environmental pollution material. Figure 2 clearly shows the difference in the results of student attitude assessments at each meeting from the scores obtained and high. Based on the table above, the percentage of CEDs indicators obtained by students can be seen in Figure 3.



	UTP	DVS	DSS	ETS	TRS
Series1	96%	94%	78%	92%	92%

Figure 3. Per-Indicator Value of CEDs

The figure above shows that students predominantly mastered the CEDs indicator, namely Understand the Problem, with a score of 96%. This is quite different from the other indicator, Design Solutions, with a score of 78%.

Based on this figure, it can be concluded that students' final scores increased from their initial scores, with an average of 90.4%, thus meeting the criteria for very effective learning.

A normality test was conducted using Shapiro-Wilk with SPSS. The following criteria apply: if the Shapiro-Wilk Sig. value is > 0.05, the data is normally distributed, and vice versa. Table 7: Results of the Normality Test Calculation Using Shapiro-Wilk. The Shapiro-Wilk test

E-ISSN : 2961 - 9386
P-ISSN : 2963 - 1742

calculation yielded a significance value of 0.356 > 0.05, indicating a normal distribution of the sample data.

Table 5. Results of Normality Test Calculation Using Shapiro Wilk

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Final score	,176	34	,009	,966	34	,356
a. Lilliefors Significance Correction						

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Hypothesis testing aims to determine whether the researcher's hypothesis is accepted or rejected. This hypothesis test uses the ANACOVA test. The ANACOVA test is an analytical technique useful for increasing the precision of an experiment because it adjusts for the influence of other uncontrolled independent variables. The purpose of the ANACOVA test is to determine/observe the effect of the treatment on the response variable by controlling for other quantitative variables. ANACOVA is used when the independent variables include both quantitative and qualitative variables. The variables in the ANACOVA and the data types in this study can be seen in Table 6.

Table 6. Variables in ANACOVA

No	Variable	Variable	Data Type
1	Y (Response Variable)	CEDs capabilities	Quantitative (*continue*)
2	X (Free Variables)	Initial Value	Quantitative (*covariate*)
		Learning variations (*Self learning* dan *re-teaching + tutorial*)	Quantitative (*Treatment*)

Table 7. Results of Sample Hypothesis Testing Using ANACOVA
Tests of Between-Subjects Effects

Dependent Variable: Y					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	458,347[a]	4	114,587	10,706	,000
Intercept	7873,534	1	7873,534	735,635	,000
X	35,183	1	35,183	3,287	,008
VB_TTI	,645	1	,645	,060	,028
KEMAMPUAN_CEDs	367,117	1	367,117	34,300	,000
VB_TTI * KEMAMPUAN_CEDs	62,039	1	62,039	5,796	,023
Error	310,388	29	10,703		
Total	287993,000	34			
Corrected Total	768,735	33			
a. R Squared = ,596 (Adjusted R Squared = ,541)					

Table 7 shows the influence of learning variations on students' Constructing Explanation and Designing Solutions (CEDs) on environmental pollution material. The table shows that the significance figure for the influence of the Trait Treatment Interaction (TTI) model on Constructing Explanation and Designing Solutions (CEDs) is sig. 0.023 < 0.05, so H_0 is rejected and Ha is accepted. This means that there is an influence of learning variations on the results of Constructing Explanation and Designing Solutions (CEDs). The significance calculation is 0.023 < 0.05, so the group variable of learning variations affects the results of students' Constructing

E-ISSN : 2961 - 9386
P-ISSN : 2963 - 1742

Explanation and Designing Solutions (CEDs) abilities because it is smaller than the sig. 0.05 value.

The influence of IQ tests and learning variations on students' Constructing Explanation and Designing Solutions (CEDs) ability results can also be seen from the significance of the Corrected Model. It can be seen that sig. 0.000 < 0.05 and far below the sig. 0.05 value, so H_0 is rejected and Ha is accepted. So simultaneously there is an influence between IQ tests and learning variations on students' Constructing Explanation and Designing Solutions (CEDs). A comparison of Constructing Explanation and Designing Solutions (CEDs) of students who were given treatment in the form of Self Learning for high-ability students and re-teaching + tutorial for low-ability students can be seen in Figure 4 below.

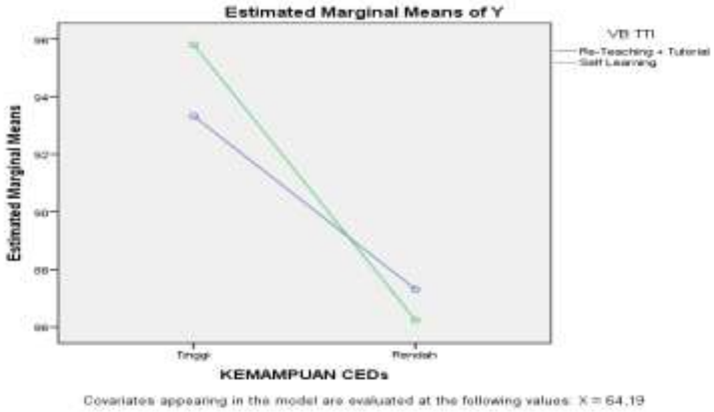

Figure 4. Comparison of the Ability of Constructing Explanations and Designing Solutions (CEDs) Using the TTI Model with Self-Learning and Re-teaching+tutorial Variations

From the image above, we can see that the group of students with high abilities had superior scores in the self-learning variation. Meanwhile, the group of students with low-moderate abilities had superior scores in the re-teaching + tutorial variation.

Table 8. Average CEDs Ability Results of Fast Learner & Slow Learner Class Students Before and After Treatment

	Average Exam Score	
Group	**High Ability**	**Low Ability**
Initial Value	66,91	61,47
Final Value	92,73	91,7

Based on table 8, it can be seen that the semester exam scores of high-ability students initially had an average of 66.91. After being given treatment in the form of independent learning using e-modules, the results of the Constructing Explanation and Designing Solutions (CEDs) ability of students increased to 92.73. Likewise, for low-ability students with an average semester exam score of 61.47 and after being given regular teaching and additional learning (tutorials), the results of the Constructing Explanation and Designing Solutions (CEDs) ability of students increased to 91.7. Furthermore, it can be concluded that research using the Trait Treatment Interaction (TTI) model using e-module learning media can improve the overall Constructing Explanation and Designing Solutions (CEDs) ability of students.

Classroom learning emphasizes active interaction between educators and students with the primary goal of deepening conceptual understanding. Each student has different abilities and learning styles, so learning approaches must accommodate these differences. Student engagement is key to achieving optimal learning outcomes (Logan et al., 2021). Gifted students require a different education than regular students (Galitskaya & Batzaka, 2022).

The Trait Treatment Interaction (TTI) model was implemented because it can tailor learning treatments based on individual student abilities. The TTI (Trait Treatment Interaction) model is an effective learning model used for specific individuals according to their abilities

E-ISSN : 2961 - 9386
P-ISSN : 2963 - 1742

(Aswirna & Harahap, 2020). In this model, students first undergo an IQ test to categorize them into high- and low-ability groups. High-ability students learn independently (self-learning) using an e-module on environmental pollution physics, while low-ability students learn using a regular learning approach and additional tutorials, guided by educators and peers.

The TTI model has been proven effective in improving students' learning outcomes and thinking skills. Several studies (Aswirna, 2018; Fahmi et al., 2020; J. Lee, 2013) show that this model can improve academic abilities, learning independence, and adapt to students' learning styles. The e-modules used in this learning support the Next Generation Science Standards (NGSS) concept, which emphasizes science and engineering skills, particularly in the Constructing Explanation and Designing Solutions (CEDs) aspect. The purpose of the NGSS is to provide guidance in the learning process and develop students' interest in science and scientific practice. This approach trains students to think critically, understand problems, design solutions, and test their results scientifically. Thus, the use of TTI-based e-modules not only improves conceptual understanding but also fosters students' analytical and creative abilities. Independent learning allows students to take responsibility for their own learning process, including defining, planning, and evaluating their abilities (Nacaroğlu & Bektaş, 2023).

The research conducted at MAN 2 Pesisir Selatan showed positive results. After implementing the TTI model with e-modules, both high- and low-ability groups experienced significant improvements in their CEDs abilities. The average score of the high-ability group increased from 66.91 to 92.73 after independent learning using e-modules, while the low-ability group increased from 61.47 to 91.7 through regular learning and tutorials. These results indicate that implementing the TTI model with e-modules can effectively improve students' Constructing Explanation and Designing Solutions abilities. High-ability students are more optimal in learning independently, while low-ability students are more suited to regular learning accompanied by additional guidance. Thus, e-modules based on the TTI model are proven to be able to significantly improve students' learning outcomes, motivation, and scientific skills.

CONCLUSION

Based on the results of the development and discussion, it can be concluded that the e-module development process begins with an analysis of the needs of educators and students, followed by product design, development, and evaluation. The quality of the e-module is assessed as very good with a validity level of 89.24%, practicality of 88.97%, and effectiveness of 90.4%. The application of the Trait Treatment Interaction (TTI) model shows that high-ability students (faster learners) learn more optimally independently (self-learning) with an average score of 92.73, while low-ability students (slower learners) are more effective through regular learning with additional tutorials, which increases their average score from 61.47 to 91.7. Thus, the TTI-based e-module is proven to be valid, practical, effective, and able to improve students' Constructing Explanation and Designing Solutions (CEDs) abilities according to the characteristics of each ability.

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E-ISSN : 2961 - 9386
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