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Development of STEM-Based Dynamic Fluid Material E-Module in the Framework of the Perjaya Dam for Grade XI High School Students

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Abstract: This study aims to develop a STEM-based e-module on dynamic fluid materials contextualized in the Perjaya Dam for grade 11 high school students. Development follows the Rowntree model, which consists of the planning, development, and evaluation stages. Formative evaluations apply the Tessmer model, including expert reviews, one-to-one evaluations, and small groups. Data was collected through guides and questionnaires. The validity of the e-modules is assessed by experts in content, design, and instruction, while its practicality is evaluated based on student responses during one-to-one and small group stages. The results show that the e-module shows a very high level of validity and is considered very practical by users. These findings show that STEM-based e-modules are suitable for use as interactive learning media. Further research is recommended to assess its effectiveness on a larger scale and for different subject matter.

Keywords: Dynamic fluids; Electronic modules; Perjaya Dam; STEM-based

Introduction

Education plays a vital role in supporting national development, particularly in improving the quality of human resources who are intelligent, skilled, and have strong character (Rahman et al., 2022) In this context, physics education at the senior high school level aims to help students master physical concepts and principles while cultivating critical and creative thinking skills (Andila et al., 2021). However, in reality, many students perceive physics as a difficult and abstract subject. This lack of interest often stems from learning materials that are neither contextual nor engaging (Abarang & Delviany, 2022).

One way to address this issue is by developing innovative learning resources, such as STEM-based electronic modules (e-modules). E-modules enable students to study independently, flexibly, and interactively by integrating text, images, videos, and animations (Wiyono et al., 2019). The STEM approach encourages learners to apply interdisciplinary knowledge to real-life problem-solving (Anikarnisia & Wilujeng, 2020).

Unfortunately, many previous e-module developments remain general and have not specifically incorporated local contextual content (Amri et al., 2015). In fact, local potential offers strategic value in transforming abstract physics concepts into more concrete and meaningful learning experiences (Sibarani et al., 2021). One such valuable local context is Perjaya Dam in East OKU Regency, South Sumatra. This dam is not only a critical part of regional irrigation and hydroelectric systems but also serves as a tangible example of fluid dynamics principles applied in everyday life (Lestari, 2015). The novelty of this study lies in the development of a STEM-based e-module contextualized through the local phenomenon of Perjaya Dam to teach fluid dynamics (Ni'mah & Sukartono, 2022). To date, there has been no prior research that specifically integrates local cultural and environmental

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contexts into a STEM-based physics e-module focused on dynamic fluid materials. This study therefore addresses the need for learning materials that are not only innovative and interactive but also locally relevant and contextual.

Researchers conducted a needs analysis in creating e-modules for students who were taking physics subjects with fluid dynamic material (Zahro et al., 2017). So the researchers took class XI high school students by giving a needs analysis questionnaire conducted online via Google Form to 74 students as respondents. Based on the survey results, it is known that 31.1% know or have heard of what e-modules are, but only 21.6% of respondents use e-modules in physics learning at school. Even though the survey shows that the facilities (ICT devices) owned by students already support access to electronic teaching materials such as E-Modules (100% of respondents have ICT devices) and good internet network access (94.6% of respondents have good quality 3G or 4G networks). Seventy-four (98.6) students also believe that the development of STEM-based physics teaching materials is needed. Things that are expected to be in the E-Module to help understand dynamic fluids include: 58.1% contains material related to everyday life, 25.7% contains examples of questions and exercises in the E-Module, 13.5% contains evaluation at the end of the lesson, 12.2% contained descriptions of the material in the form of images, text, video and animation, 43.2% were flexible and could be accessed using ICT devices.

Method

This research is a development research, namely development of STEM-based dynamic liquid materials e-modules in the framework of the Perjaya Dam for high school students in grade XI. The E-Module was developed using the heyzine application software with reference to the rowntree model. This research aims to develop a valid and practical Dynamic Fluid Material E-Module product for Class XI High School Students. The research was conducted in November 2023. The model used in this study is a combination of the Rowntree development model and the Tessmer formative evaluation model.

The research was conducted using the Rowntree Model, which is a product-oriented research model. This model was chosen for several reasons, namely: it includes students, teaching materials and materials in achieving the set goals; procedural and systematic; provide an opportunity to develop an evaluation format to measure components; involving experts. The Rowntree model consists of three stages, namely planning, development, and evaluation. The evaluation stage is carried out according to the Tessmer evaluation procedure starting from self-evaluation, expert review, one-to-one evaluation, and small group evaluation to determine the feasibility of the E-Module that is being developed based on its validity and practicality aspects Figure 1. Meanwhile, the final stage in the Tessmer evaluation, namely the field test, was not carried out because the researchers did not test the effectiveness of the E-Module that was being developed.

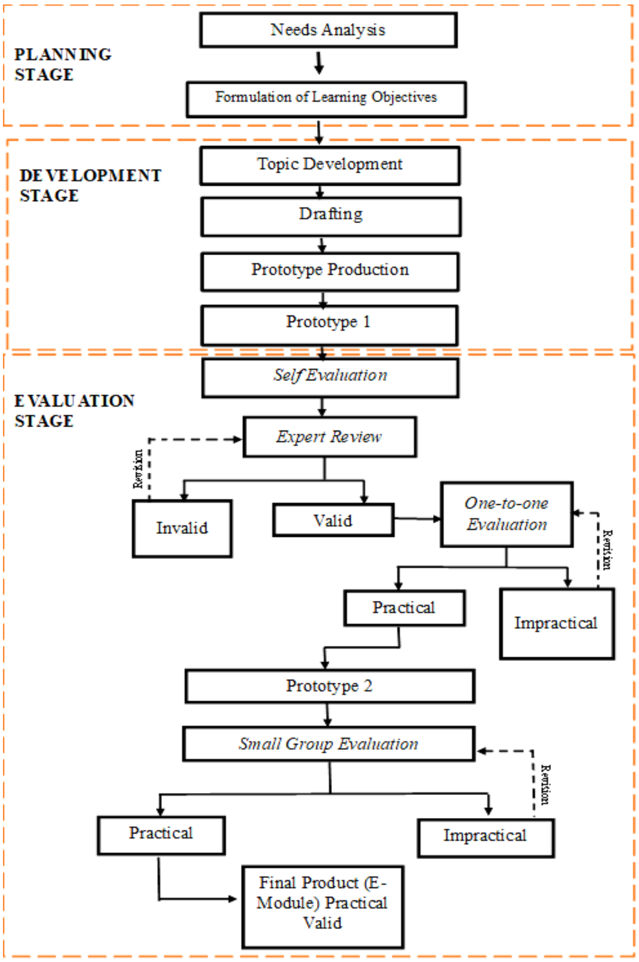


Figure 1. Modification of the research flow for the development of dynamic fluid material e-modules in the context of the Perjaya Dam (Sapitri, 2023)

This research was conducted at SMAN 2 Martapura in the first semester of the 2023/2024 academic year. The main focus of the research is to describe the results of the development of a STEM-based dynamic liquid material e-module in the context of the Perjaya Dam for grade XI high school students, with valid and practical criteria. The research stage includes preparation and implementation, starting from preliminary research which includes the initial observation of the learning process at school, analysis of student characteristics, and the preparation of research instruments. The development procedure is continued through self-evaluation, expert review, one-to-one evaluation, and small group evaluation.

The data collection method includes targets, methods, instruments, and research subjects. The first stage is the product validity test, which is carried out through an expert review sheet with three aspects of assessment, namely the feasibility of the substance of the material, the feasibility of the learning design, and the feasibility of design and language (Plomp & Nieveen, 2013). The instrument used is in the form of an expert validation sheet modified from the assessment instrument for students majoring in high school/MA physics by the National Education Standards Agency (BSNP). Data from expert reviews were collected using the walkthrough technique and analyzed on the Likert scale.

Expert results are obtained from the validation sheet, then the percentage of expert validation results (HVA) and validation indicators are searched using the formula:

$$HVA = \frac{The\ total\ score\ for\ each\ indicator}{Overall\ maximum\ score} \times 100\% \quad (1)$$

The percentage of the score obtained from the results of the calculation based on the results. The analysis of the guide determines the level of validity of the E-Module being developed, as shown in the following table.

Table 1. Categories of Expert Validation Results (Wiyono, 2015)

Percentage %	Classification
86 ≤ WHAT ≤ 100	Highly Valid
70 ≤ HVA < 86	Legitimate
56 ≤ HVA < 70	Less Valid
HVA < 56	Invalid

Questionnaire data analysis was used to determine the practicality of the e-module that is being developed (Rofiyadi et al., 2021). The questionnair data obtained from students will be analyzed using a likert scale to measure students' attitudes, opinions and perceptions regarding the use of the E-Module. The questionnaire value is created in the form of a percentage, according to the criteria in the table.

Table 2. Questionnaire Value Categories

Answer Categories	Statement Score
Strongly agree	5
Agree	4
Enough	3
Disagree	2
Strongly disagree	1

Next, look for the percentage of *one-to-one evaluation* and small group (HEOS) results using the formula:

$$HEOS = \frac{Questionnaire\ score}{maximum\ questionnaire\ score} \times 100\% \quad (2)$$

From the calculation using the formula above, the final value of the product assessment is obtained. Then the final value is adjusted to the category of product practicality presented in Table 3.

Table 3. Categories of One-to-One and Small Group Evaluation Results (Wiyono, 2015)

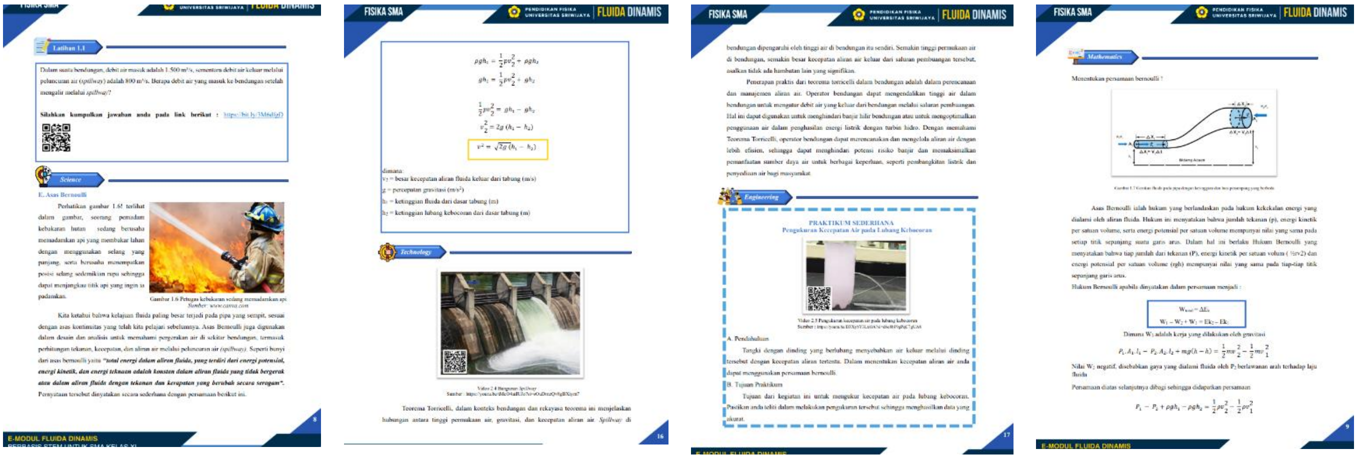
Percentage %	Classification
86 ≤ HEOS ≤ 100	Very Practical
70 ≤ HEOS < 86	Practical
56 ≤ HEOS < 70	Less Practical
HEOS < 56	Practical

Results and Discussion

STEM-based e-modules are the products produced in this study. The STEM-based e-module is designed to understand dynamic fluid materials in the context of the Perjaya Dam. This product comes with a foreword, table of contents, 4) Review of learning materials consisting of: description, use and supporting materials of learning materials; Core Competencies (KI), Basic Competencies (KD), STEM (Science, Technology, Engineering, Mathematics), Instructions for using the E-Module, concept maps, STEM Columns, summaries, formative tests, glossary, biography of the author. The products produced contain dynamic liquid materials in the context of the Perjaya Dam. This research produces STEM-based dynamic fluid materials that are feasible, acceptable, and effective in increasing students' awareness of local wisdom in their fields related to physics concepts. Rowntree product development model and tessmer evaluation. The results and stages of elaboration are described.

In the first production or prototype-1, an E-Module is produced that is adapted to the draft prepared in advance. Standardization in the E-module and display format is considered to make the presentation of the E-Module attractive to readers. The application used in this study is heyzine flipbook, which is used to convert existing PDF files into digital displays adding images, video animations, hyperlinks to make the display more attractive. Figure 2 shows the appearance of prototype I of a dynamic e-module STEM-based liquid.

Research has been conducted on the development of teaching materials, namely the E-Module of STEM-based dynamic fluid materials in the context of a valid and practical high school student in grade XI. This study uses the Rowntree model and the Tessmer evaluation procedure. The following is a description of the results of each stage in this study.



(a) (b) (c) (d)

Figure 2. Prototype 1 e-module display, (a) science-related learning, (b) Dam Context with Spillway Technology on Toricelli's Theorem, (c) Engineering with simple practicum, (d) mathematical equations on Bernoulli's principle

At the preliminary research stage, activities are carried out to obtain information about problems in learning and determine the development that needs to be carried out (Yuliana et al., 2023) This stage includes the results of student analysis using student questionnaire sheets, the results of learning problem analysis using teacher interview sheet instruments, and the results of analysis of learning activities using context analysis sheets (Amaliyah et al., 2024). Based on the results of the initial investigation, the product development of STEM-based dynamic liquid material e-modules in the framework of the Perjaya Dam for high school students in grade XI was carried out. The development of teaching materials based on STEM is proven to improve students' scientific literacy and engagement in learning (Pea et al., 2022). Furthermore, the use of local context such as the Perjaya Dam aligns with previous research emphasizing the importance of integrating ethnoscience into STEM-based modules to make learning more meaningful (Hutomo et al., 2022). The developed modules refer to structured components including: introduction, learning activities (title, description of the material, summary, worksheet, evaluation, and conclusion), as recommended in STEM-based instructional design. Such an approach not only contextualizes science learning but also supports students' 21st-century skills development in line with national curriculum goals.

In the Development or prototyping phase, a formative evaluation of the physics e-module is carried out. First, the self-evaluation was carried out by the researchers themselves, the results of the self-evaluation showed that there were still some spelling and punctuation errors, product shortcomings, no image and video descriptions in the e-module. The physics electronic module is revised to correct errors found during self-evaluation. Second, the revision results are given to expert reviewers for validation. The validity of the physics e-module was assessed by experts, namely two lecturers from Sriwijaya University and one physics teacher. The results of the validity of the STEM integrated physics e-module can be seen in Table 4.

Table 4. Average Results of Expert Review Validation

Validator	Aspect	Score Percentage (%)	Category
Validator 1: Lecturer	Material	96.76	Very Valid
Validator 2: Lecturer	Design	94.71	Very Valid
	Language	93.57	Very Valid
Validator 3: High school teacher	Learning Design	96.91	Very Valid

Based on table 4, it can be explained that validator 1 who is a physics education lecturer gave a percentage score on the material aspect of 96.76%, indicating that the content of the material in the e-module is considered very valid. Validator 2 who is a physics education lecturer gave a very high score on the design aspect 94.71% and language 93.57%, which shows that the design and use of the e-module language is very valid and suitable for use.

While 3, a high school teacher, gave an average learning design score of 96.91%, indicating that the learning design approach in the e-module was considered very valid. Overall, all validators gave a "very valid" category for each aspect they assessed. The validation results in the expert review show that prototype 1 of the e-module belongs to a very valid category and is suitable for testing at a later stage.

The One to One evaluation was carried out on 3 students using an interview instrument. STEM-integrated physics e-modules are given to high, medium, and low-skilled students. Students are required to read the physics e-module without being taught by the teacher first. The researcher asked the students questions after reading the physics e-module provided in the form of an easy concept map, material fluid dynamics, and activity sheets. Students argue that electronic modules arouse curiosity and interest in mastering physics material. This is because physics e-modules can be used anywhere and anytime, and are accompanied by understanding the material through videos, animations, and practical activities. The physics e-module is already graphically valid because its size is appropriate for age and material (Slamet, 2010). Stating that the accuracy of the teaching materials used in the learning process will make it easier to accept the subject matter given (Dismarianti et al., 2020). The results of the students' responses can be seen in Table 5.

Table 5. Results of Student Responses in the One-on-One Evaluation Stage

Indicator	Total Score	Score Maximal	Score Percentage (%)
Ease of Use	109	120	90.83
The Attractiveness of the serving	65	75	86.66
Benefit	75	75	96.00
Average percentage of leaner responses to one-to-one evaluation			91.16
Category			Very practical

Based on Table 5, the results obtained from the students' response to the use of prototype 1 at the one-to-one evaluation stage were 91.16% so that it can be concluded that the use of prototype 1 of a STEM-based dynamic fluid e-module in the context of the Perjaya Dam for high school students in grade XI met very practical criteria. In addition to obtaining data in the form of the level of practicality of prototype 1.

Small Group Evaluation is carried out by practicing valid e-physics modules on students. Small Group Evaluation was carried out on grade XI students Science 1 which comes from medium and low ability in class XI of SMAN 2 Martapura. The material tested is a fluid dynamics material (Scott, 2017). Test the practicality of physics e-modules from small groups using student questionnaires (Tessmer, 1993). The practicality questionnaire includes several indicators, namely usable, easy to use, attractive and cost-effective The results of the practicality of student and teacher responses can be seen in Table 6.

Table 6. Student Response Results in the Small Group Evaluation Stage

Indicator	Total Score	Score Maximal	Score Percentage (%)
Ease of Use	340	360	94.44
The Attractiveness of the serving	214	225	95.11
Benefit	216	225	96.00
Average percentage of leaner responses to small group evaluation			95.18
Category			Very practical

Based on Table 6, the results of students' responses to the use of prototype 2 for each indicator were 94.44% ease of use in the practical category, 95.11% dish attractiveness in the very practical category and 96% benefit in the very practical category. If the percentages of the three indicators are averaged, the result is 95.18% in the very practical category. Thus, based on the results of the trials at the small group evaluation stage, prototype 2 of the E-Module has been declared practical.

Students in small groups still need a long time to understand the physics e-module. The physics lessons of the e-module have been revised and refined in their design so that students can learn them in an optimal time. The highest score is on the color composition statement in the physics e-module, which is interesting to read. Physics e-modules are designed in color so that they appeal to students and ultimately increase motivation in Learn. Thus, revisions are made based on suggestions from teachers and students, so that they can tested in a large group of STEM integrated physics e-module products that can improve students' skills. states that the integration of STEM concepts in physics e-modules can improve learning and innovation skills, which include critical thinking, creativity, innovation, and the ability to communicate and collaborate (Ramli et al., 2020).

Conclusion

This research has produced a STEM-based dynamic fluid material e-module in the context of the Perjaya Dam for high school students in grade XI. The results of the validity test show that this e-module is very valid, with details: material components of 96.76%, learning design of 96.91%, and display and language design of 94.21%. In addition, the results of the practicality test through one-on-one and small group evaluations show that this e-module is practically used in learning. Thus, this STEM-based e-module is declared feasible to be used as a teaching material for dynamic fluid materials in grade XI of high school.

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