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# Atomic Structure Teaching Module with PhET Simulation to Increase Student Motivation and Learning Outcomes

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**Abstract**
This study aims to obtain the feasibility of teaching modules with PhET simulations to increase student motivation and learning outcomes in atomic structure content as a learning tool. The eligibility of teaching modules consists of valid, practical, and effective criteria. This development research uses the ADDIE research model which consists of five stages which include analysis, design, development, implementation, and evaluation. The trial design used was the One Group Pretest-Posttest Design. The subjects in this study were students of class X SMA Intensif Taruna Pembangunan Surabaya with a total of 30 students. The research instruments used included validation sheets, student response sheets, student activity observation sheets, learning motivation sheets and pretest-posttest sheets. Analysis of the data used using the validity test, analysis of the percentage of practicality and the percentage of effectiveness. The results of the validity test obtained a validation mode score of 4 so can be stated that the teaching modules developed are included in the good category. The results of the practicality test obtained the percentage of students' response results of 82.3% so can be stated that the teaching modules developed are categorized as very practical. Then the percentage of the effectiveness of motivation to learn before treatment obtained results of 50.6% and after treatment of 85.7%. Based on these percentages, it can be stated that the teaching modules created can increase students' learning motivation. The learning outcomes of students obtained an N-Gain score of 0.71 which means that the teaching module is in the high category.

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## INTRODUCTION

The curriculum in Indonesia has changed eleven times from 1947 with a simple curriculum to the 2013 curriculum. The replacement of the curriculum was intended to improve the quality of education and improve the previous curriculum (Khoirurrijal et al., 2022).

Permendikbud Number 033/H/KR/2022 explains the changes in the curriculum from the 2013 curriculum to an independent curriculum. Implementation of the independent curriculum is found at every level of school. The Merdeka curriculum includes several phases. There are two phases at the high school education level, namely phase E in class X and phase F in classes XI and XII.

One characteristic of the changes that have occurred is the existence of teaching modules. In the 2013 curriculum, there are terms of learning devices such as lesson plans and assessment

instruments. but in the independent curriculum, the learning devices change to teaching modules. The teaching module applies to each subject.

At the high school education level, students are taught various fields of science, one of which is chemistry (Sariwati et al., 2023). Chemistry is a science that has an important role in life, this is because through chemistry various kinds of life phenomena can be explained logically. Chemistry learning has complex concepts that require mental activity to carry out high scientific thinking, this has the potential to cause learning difficulties for students (Purwandani et al., 2019).

Atomic structure content is part of the learning outcomes in Phase E of class X SMA/MA. Atomic structure content is considered quite abstract because students tend to only know how atomic structure is through explanations from the teacher. Based on the results of the pre-research, it was found that 69% of students considered the atomic structure content difficult.

Another factor that causes students' learning difficulties is that the learning methods they get are not by the characteristics of students. The abilities that students have are different, so this is what makes teachers still look for ways that are suitable for teaching (Desi et al., 2020).

The learning method is the steps, procedures, sequences, and methods used by a teacher in achieving learning objectives. A good learning method is a method that can make students comfortable with the learning process. So that in using the method the teacher must choose a method according to the scope of the material and the characteristics of the students (Kartiani, 2015). In addition to teaching methods, there are teaching materials that support meaningful learning for students (Lidra et al., 2022). Good teaching materials will be able to help educators feel comfortable with learning and will be able to carry out learning by the applicable curriculum. The combination of appropriate teaching methods and materials will make students better understand the learning provided.

The results of pre-research conducted on students from a high school in Surabaya found that 79.3% of chemistry learning in the field mostly used the Teacher Center Learning (TCL) learning model. Teachers play an active role when compared to students so students tend to only accept the material provided, this makes students' motivation and activeness in participating in lessons low (Viani, 2017). Based on the results in the field, it was found that 69% of students stated that they were less motivated in participating in chemistry learning.

The interaction between teachers and students is an important factor in learning (Aprilia et al., 2023). The use of learning devices can improve student learning outcomes. PhET (Physics Education Technology) is a project at the University of Colorado that develops a series of simulations that utilize computer power to deal with problems that other tools cannot solve (Finkelstein et al., 2005).

PhET Simulations were developed to help students achieve three learning objectives, namely:

1. Used as connecting procedural knowledge in the form of chemical formulas with existing (original) reality;
2. Used as a tool to help students develop procedural skills and knowledge so that students not only learn about carrying out experimental sequences but can also know when the right time is so that the procedures made can be carried out;
3. It is used as a tool to help students understand how to apply their knowledge in the real world (Muzana et al., 2017).

Based on the description above, it is necessary to develop a teaching module that can increase student motivation and learning outcomes in chemicals. This research has a difference from previous research, namely that in the learning module section learning activities are used that are tailored to the needs of students and also in LAPD containing atomic structure material that

uses PhET simulations as a learning medium. The purpose of developing this teaching module is to obtain teaching modules with PhET simulations that are suitable for use, with the formulation of the research problem "How is the feasibility of teaching modules with PhET simulations as learning tools in terms of eligibility criteria with valid, practical, and effective categories in increasing student motivation and learning outcomes in chemistry material?"

## METHOD

The type of research used is development research using the ADDIE development model from Dick and Carry in 1996 (Mulyatiningsih, 2016). The ADDIE model has five stages consisting of Analysis, Design, Development, Implementation, and Evaluation. There are five steps to carrying out research and development of the ADDIE model, which are as follows:

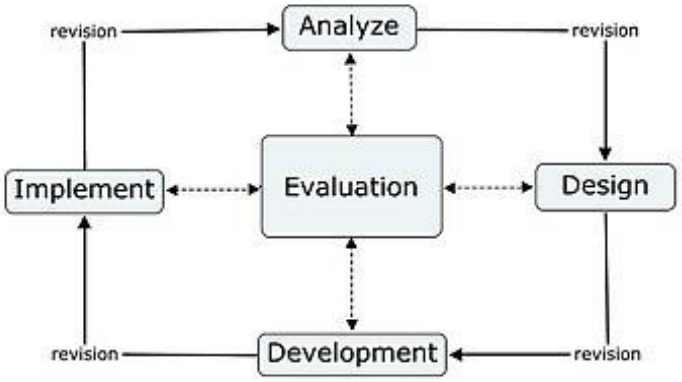


Figure 1. The ADDIE model

The trials in this study used the One-Group Pre-test Post-test Design.

O1…. X1…. O2

Description :
O1 – Motivation and learning outcomes (before being given treatment)
O2 – Motivation and learning outcomes (after being given treatment)
X1 – Learning using teaching modules with PhET simulations (Cresswell et al., 2018).

The trial was conducted on 30 class X students of the Taruna Pembangunan Surabaya Intensive High School in the 2022/2023 academic year. The instruments used in this study were validation sheets, student response sheets, student learning motivation sheets, and pretest-posttest sheets. Response sheets are used to measure the practicality of teaching modules in the learning process. Student motivation sheets are used to determine the effectiveness of teaching modules as learning tools.

The validity test was carried out by two chemistry education lecturers and one high school teacher. The validity test is obtained from the analysis of the validation sheet which will then be analyzed descriptively quantitatively. Data is taken using a Likert scale.

Table 1. Likert Scale

| Category | Score |
|---|---|
| Very less | 1 |
| Not enough | 2 |
| Enough | 3 |
| Good | 4 |
| Very good | 5 |

(Riduwan, 2012).

Validation data analysis is obtained by looking for the mode obtained from the assessment of the three validators. The results of the validity test will determine the feasibility of the teaching modules made (Lutfi, 2021).

The practicality test is used to determine the practicality of the teaching module as a learning tool. Practicality data was obtained by distributing response sheets to students. The response sheet contains two main objectives, namely to find out interest in learning and ease in understanding the material through learning. Practicality test using the Guttman scale.

Table 2. Guttman Scale

| Category | Positif Statement | Negative Statement |
|---|---|---|
| Yes | 1 | 0 |
| Not | 0 | 1 |

(Riduwan, 2012).

The results of the practicality test are analyzed by practicality percent, namely by:

$$\text{practicality percentage}(\%) = \frac{\text{number of events occurred}}{\text{total number}} \times 100\%$$

Effectiveness data is divided into two, namely data on motivation and data on student learning outcomes. Motivational data comes from motivational sheets given before and after learning with teaching modules. Then this data was analyzed with the effectiveness percentage test. Teaching modules with PhET simulations are declared effective if the practicality percentage is ≥61%. The following are the criteria for the effectiveness of learning motivation using the Guttman scale.

Table 3. Percentage of Practicality Criteria

| Category | Percentage |
|---|---|
| Very less effective | 0% - 20% |
| Less effective | 21% - 40% |
| Moderately effective | 41% - 60% |
| Effective | 61% - 80% |
| Very effective | 81% - 100% |

(Riduwan, 2012).

Learning outcomes can be seen from the pretest and posttest scores of students. The following are the steps for analyzing student learning outcomes using the N-Gain test. Analysis of improvement between the pretest and posttest using the N-Gain test to test the effectiveness between the pretest and posttest. The formula for the effectiveness of the N-Gain score is as follows:

$$N - Gain = \frac{Posttest\ score - pretest\ score}{maximum\ score - pretest\ score}$$

The categorization of the acquisition of the N-Gain score can be determined based on the N-Gain value or from the N-Gain value in the form of a percent (%). We can see the division of categories for the acquisition of N-Gain values in the following table:

Table 4. N-Gain Score Category

| *N-Gain Score* | Categories |
|---|---|
| (g) > 0,7 | Tall |
| 0,3 ≤ (g) ≤ 0,7 | Currently |
| (g) < 0,3 | Low |

(Hake, 1998)

## RESULTS AND DISCUSSION

### Analysis Stage

The analysis phase consists of several topics, namely the analysis of student characteristics, material characteristics and student learning styles. At this stage, data was obtained from students and chemistry teachers. The analysis phase can be said to be the initial stage of research or pre-research. Students are given a questionnaire containing questions related to learning and the atomic structure material that has been obtained.

In the analysis, preliminary research (pre-research) will be conducted on tenth grade students at Taruna Pembangunan Surabaya Internsive High School. This stage is carried out to find out existing learning problems as material for finding solutions, in accordance with the objectives of the analysis stage, namely to identify possible causes of a learning performance gap (F. Hidayat et al., 2021).

The results of the analysis phase are that students have difficulty understanding atomic structure material because the content of atomic structures is abstract and the application of teaching methods used by teachers is more dominant using the lecture method. This effects on the low motivation of students on atomic structure content.

This has an impact on the low motivation of students in the atomic structure material. Basically the atomic structure material is material that is considered quite abstract because students will learn not only theory but how to get a clear picture of the parts of an atom. Atomic structure material is material that is abstract, conceptual understanding and applicable (Harahap, 2016). The fact is that students learn more from the teacher's explanation, so students will tend to have difficulty learning atomic structure.

### Design Stage

In the design or design stage. At this stage, the researcher formulates the objectives of the results of the analysis phase. These objectives will later be stated in the teaching modules that are made. Making teaching modules is based on the rules for compiling teaching modules that have been given by the Ministry of Education and Culture. The preparation of teaching modules is a teacher's pedagogic competence that needs to be developed, this is so that teacher teaching techniques in the classroom are more effective, efficient, and do not leave the discussion of achievement indicators (Maulida, 2022). The following is an overview of the teaching modules created.

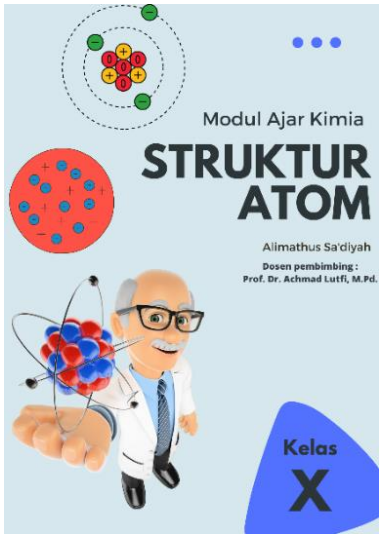


Figure 2. Teaching Module Cover

The teaching module is designed to contain several sections, namely:

1. General information containing the identity of the module author, initial competencies, Profil Pelajar Pancasila, facilities and infrastructure, and student targets
2. The core component consists of learning outcomes, learning objectives, triggering questions, lesson preparation, learning activities, assessment, enrichment and remedial, student and educator reflections, reading materials, and a glossary
3. Attachment containing LAPD (Student Activity Sheet).

The material contained in the teaching module is adjusted to the results at the analysis stage. From the results obtained, a teaching module design was created which included learning objectives related to atomic modeling theory, atomic number analysis, and analysis of isotones, isotopes, and isobars. The designed teaching modules are teaching modules that have not been validated or tested for feasibility.

**Development Stage**

The development stage is the stage of realizing the previous one (design stage). At this stage, a validity test was carried out to determine the feasibility of the teaching modules made. The validation test consists of three categories namely validity, practicality, and effectiveness. The validity test was carried out by two chemistry education lecturers and one high school teacher by the Develop Stage which included an assessment of the level of fulfillment of the requirements carried out by experts, namely media and chemical materials/IPA experts (Lutfi, 2021). The validity test is obtained from the analysis of the validation sheet which will then be analyzed descriptively quantitatively. Data was taken using a Likert scale.

Validation data analysis is obtained by looking for the mode obtained from the assessment of the three validators. Data from validation is ordinal data which is equivalent or in other words, mathematical operations cannot be performed (Lutfi, 2021). The results of the validity test will determine the feasibility of the teaching modules made.

***Validity Test***

Validation is divided into two parts, namely content validation and construct validation. Content validation in this study includes aspects of the correctness of the content in the teaching modules made. This is by content validity which is the latest and correctness of the concept of knowledge including correctness of content and suitability of goals (Lutfi, 2021). The results of this validation obtained a score of 4 or it can be said that the teaching module is suitable for use according to the content criteria. Whereas construct validation includes several aspects including language, graphics, and the suitability of the teaching module structure with the existing curriculum.

Construct validation based on the language includes the ease of the language used, the appropriateness of the EYD, and the effectiveness of the language used. Each of these aspects gets a score of 4 or it can be said that the teaching module is made feasible according to linguistic criteria.

The graphics assessed in the teaching module are related to the appearance of the teaching module. In this aspect, a score of 4 is obtained so that in terms of the appearance of the teaching modules that are developed, they are feasible and interesting. This is closely related to the suitability of the teaching module structure with the components contained in the teaching module by the rules of the Ministry of Education and Culture. These components include essential, interesting, relevant and contextual, and sustainable (Maulida, 2021). Each component is contained in construct validation and gets a score of 4 on each aspect. Based on the acquisition of scores on each aspect, it can be said that the teaching modules developed belong to the good category.

### *Practical Test*

There are two objectives in the practicality test in this study, namely to find out how much interest students have in learning and how easy it is for students to work on LAPD with the help of PhET simulations. Practical includes easy-to-use or flexible-to-use (Lutfi, 2021). Student response sheets aim to determine student interest in learning and find out the ease of understanding material through LAPD and PhET simulations. The following are the results of student response questionnaires:

Table 5. of Student Interest Response Results

| No. | Question | Percentage (%) |
|---|---|---|
| 1. | PhET simulations increased my passion for atomic structure. | 86,6 |
| 2. | Learning becomes more interesting with LAPD with PhET simulations. | 83,3 |
| 3. | I feel more motivated to participate in learning because I use PhET simulations. | 90 |
| 4. | I want to relearn atomic structure using PhET simulations. | 73,3 |
| 5. | I feel bored learning with PhET simulation. | 76,6 |

Table 4.5 is a response questionnaire table to determine students' interest in learning with the atomic structure teaching module. The PhET simulation used in LAPD in teaching modules acts as a stimulus to increase students' interest in atomic structure material. This is in line with the contents of the PhET simulation in which there are various file options that you can choose yourself, the animation you want to display, as well as theoretical and experimental simulations that actively involve users (Ekawati et al., 2015).

Table 6. LAPD Ease of Use Response Results

| No. | Question | Percentage (%) |
|---|---|---|
| 1. | LAPD with PhET simulation helped me understand the concept of atomic structure. | 86,6 |
| 2. | I can easily do the posttest questions after learning with PhET simulations. | 76,6 |
| 3. | PhET Simulations make me want to learn more. | 86,6 |
| 4. | The instructions in LAPD made it easier for me to operate the PhET simulation. | 86,6 |
| 5. | The PhET simulation made it difficult for me to understand the material. | 76,6 |

Tabel 4.6 is a student response questionnaire regarding the ease of using LAPD and PhET simulations. The results of the practicality test obtained a percentage of 82.3% so it can be said that the teaching modules developed are included in the very good category. This is in line with research conducted by (Ilma et al., 2020) which states that the application of PhET as a medium in learning atomic structure and the periodic system of elements can improve student learning outcomes in good categories, student learning activities when learning is very active and the response of students is also quite good.

The teaching modules created show that the use of teaching modules can make learning more practical and interesting for students. The teaching modules created contain learning activities that can condition students in a pleasant learning atmosphere. One of the things that can be used to increase student motivation is to create a fun learning atmosphere (Lutfi et al., 2021).

### *Effectiveness Test*

The effectiveness test was carried out to determine the effectiveness of the teaching modules made. The expected results of this effectiveness can be in the form of impacts due to the

products being developed which can be in the form of learning outcomes, activities during use, motivation, interest, retention, and other special skills (Lutfi, 2021). In this study, the effectiveness of teaching modules was measured based on learning motivation and learning outcomes.

The effectiveness test for learning motivation before the treatment was carried out obtained a percentage of 50.6% while the percentage of effectiveness after the treatment using teaching modules with PhET simulation obtained a result of 85.7%. The PhET simulation used in LAPD in teaching modules acts as a stimulus to increase students' interest in atomic structure material. This is in line with the contents of the PhET simulation in which there are various file options that you can choose yourself, the animation you want to display, as well as theoretical and experimental simulations that actively involve users (Ekawati et al., 2015).

Based on data analysis, it can be said that the teaching modules that have been made meet the criteria for effectiveness. Teaching modules with PhET simulations are proven to be able to increase students' learning motivation in atomic structure content. This is in line with the use of PhET simulation media to increase students' learning motivation (Yusuf, 2016).

The following are the results of the N-Gain test based on existing data:

Table 7. N-Gain Test Results

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Pretest | 30 | 6.67 | 53.33 | 35.1111 | 12.85741 |
| Posttest | 30 | 40.00 | 100.00 | 80.2222 | 15.31116 |
| Gain | 30 | .25 | 1.00 | .7169 | .19548 |
| Valid N (listwise) | 30 | | | | |

Based on Table 7., the N-gain value is 0.71, which means it is in the high category. This value indicates that the use of teaching modules with PhET simulations in class X students of SMA Intensive Taruna Pembangunan Surabaya on atomic structure content is in the high category or can be said to be used quite effectively.

Students at the time before doing the pretest have been given directions to study atomic structure, but these low scores can occur due to the learning difficulties of students caused by themselves or from outside students. Learning constraints experienced by students tend to come from internal factors, including from the learner himself (Jamal, 2014). These constraints are related to the use of teacher teaching methods applied in schools. Learners will have difficulty in placing themselves when the learning they get does not match their characteristics. In addition to this, the lack of desire to seek additional information related to the material being taught can also be a factor in the low learning outcomes of students.

There is a relationship between motivation and student learning outcomes, which can be seen in the increase in student learning outcomes. Based on table 7., it can be seen that the increase in learning outcomes obtained from the pretest and posttest scores. Motivation to succeed increases after experiencing failure, so students who have previously experienced failure try to succeed(Lutfi et al., 2023). Less pretest scores make students more motivated in completing the posttest in order to get a better score.

There was an increase between the pretest and post-test scores, which indicated that the teaching module with the PhET simulation effect improving student learning outcomes. This is consistent with the use of PhET simulation media which affects increasing student learning outcomes (Haerana et al., 2020). In conclusion, teaching module has high effectiveness. Later, the teaching modules created can be a reference for teachers to create learning tools for the Implementation of the Independent Curriculum.

## CONCLUSION

Based on the results and discussion that has been described, it can be concluded that the learning module with PhET simulation is suitable for use as a learning tool to increase student motivation and learning outcomes in atomic structure material. The feasibility of teaching modules is reviewed from the results of validity, practicality, and effectiveness. This is reflected in the score obtained from the validity test 4, the practicality percentage of the teaching module is 82.3%, and the effectiveness in increasing learning motivation which was originally 50.6% to 85.7% and the N-Gain score obtained is 0.71 or in other words this teaching module has high effectiveness. The teaching modules created can be a reference for teachers to create learning tools for the Implementation of the Independent Curriculum.

## RECOMMENDATIONS

For future researchers who conduct similar research, they can add remedial and enrichment stages as a form of testing the entire teaching module made, and researchers can add to the relationship between increased motivation and student learning outcomes.

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