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Developing teaching materials on elasticity and hooke's law oriented towards learner autonomy to train science process skills

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Abstract: Low science process skills contribute to a lack of learner autonomy among students. This research aims to develop teaching materials on elasticity and Hooke's law oriented towards learner autonomy to enhance science process skills suitable for the learning process. The study follows the ADDIE development model (analyze, design, develop, implement, and evaluate). The research subjects were 32 students from class XI MPA 1 at SMA Negeri 6 Banjarmasin. Data were collected through validation sheets, observation sheets on the implementation of lesson plans, observation sheets on science process skills, and learning outcome tests. Quantitative data analysis methods were employed. The results indicate that: 1) the teaching materials are highly valid according to validator assessments, 2) the materials are highly practical based on lesson plan implementation, 3) the effectiveness of the teaching materials is moderate, and 4) students' science process skills are categorized as good based on student activity sheets. In conclusion, learner-autonomy-oriented teaching materials are suitable for training science process skills in the topics of elasticity and Hooke's law.

Keywords: teaching materials; learner autonomy; instructional material feasibility; science process skills

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Introduction

Education in Indonesia plays a crucial role in developing students' potential for self-directed learning (Siswanto, Yusiran, & Fajarudin, 2016). Learning processes should position students as active learners who construct their own knowledge with guidance from teachers. This is especially emphasized in physics education, where students are encouraged to engage in experiments to understand physics concepts, principles, and laws (Salam & Miriam, 2016). Physics is a subject that can enhance students' science process skills (SPS) (Zakiati, Mastuang, & Suyidno, 2019).

SPS can increase students' autonomy in constructing meaningful knowledge (Siswanto, Yusiran, & Fajarudin, 2016). Developing SPS is crucial for increasing student autonomy, and teachers play a significant role in choosing appropriate teaching models, which affect not only learning outcomes but also students' SPS (Juhji, 2016).

Based on preliminary studies at SMA Negeri 6 Banjarmasin, the average SPS scores for formulating hypotheses, identifying variables, analyzing data, and drawing conclusions were found to be low. This necessitates the development of teaching materials tailored to students' characteristics and the subject matter. The current teaching materials at the school do not incorporate learner

autonomy, and students rely solely on workbooks/ worksheets, which do not address individual learning needs.

The characteristics of the students in class XI, with an average age of 16-17 years, fall into the formal operational category according to Piaget's cognitive theory, indicating that they possess abstract and logical thinking. However, students still need guidance in knowledge construction, and they tend to be less active in the learning process.

The characteristics of the learning material are relevant to the elements applied in teaching, such as the selection of models, methods, strategies, or media to support the learning process in the classroom (Zakiati, Mastuang, & Suyidno, 2019). SMA Negeri 6 Banjarmasin implements the revised 2013 curriculum, and the topics of elasticity and Hooke's law are taught in class XI. The concepts, principles, and laws covered in this material are relatively easy to relate to everyday life.

Considering the research objectives and the characteristics of students and teaching materials, a suitable strategy is needed to gradually develop SPS, namely learner autonomy. Balcikanli (2010) explains that learner autonomy helps students make decisions, making them more enthusiastic about the learning process. Learner autonomy is a learning strategy that begins with the teacher's guidance and then shifts to the students, encouraging them to be more active and independent. Learner autonomy involves transferring most of the learning responsibilities to students (Salam, Prabowo, & Supardi, 2015) and has the potential to significantly impact students' personal growth and achievements (Dang, 2010). Teaching materials that focus on learner autonomy are appropriate for the learning process to train students' SPS (Salam & Miriam, 2016; Zakiati, Mastuang, & Suyidno, 2019; Fatmah, Mastuang, & Salam, 2018).

An alternative solution to train students' SPS is to develop physics teaching materials oriented towards learner autonomy, selecting teaching models based on students' characteristics and the subject matter. Learner autonomy-oriented learning allows educators to choose teaching models based on students' developmental levels. Each meeting uses a different teaching model, including direct instruction, guided inquiry, and cooperative group investigation. The topics of elasticity and Hooke's law are well-suited for this approach, as each session involves experiments that can enhance students' SPS (Salam & Miriam, 2016). Based on this background, the research aims to describe the feasibility of learner-autonomy-oriented teaching materials to train students' SPS, considering aspects of validity, practicality, effectiveness, and SPS achievement.

Method

The research conducted is a developmental study using the ADDIE development model, as illustrated in Figure 1.

Figure 1. Model ADDIE

The research took place from November 2019 with 32 students from class XI MIPA at SMA Negeri 6 Banjarmasin. Research instruments included teaching material validation sheets, observation sheets on the implementation of lesson plans, observation sheets on students' science process skills (SPS), and the learning outcome test as assessment instruments.

Data analysis techniques involved quantitative methods, evaluating the validity of teaching materials through the validation of lesson plans (Lesson Plan), student activity sheets (student worksheets), teaching material, and the learning outcome test instrument. The practicality of teaching materials was assessed through observation sheets on the implementation of lesson plans. The effectiveness of teaching materials was determined through learning outcome tests (Selvia, Arifuddin, & Mahardika, 2017).

Validation of the developed teaching material product aimed to determine its validity, comparing the average scores from validator assessments using validation sheets with the validity criteria

established by Widoyoko (2016). Observations were made to assess the implementation of lesson plans, using observation sheets, and to observe SPS achievement, using observation sheets on SPS achievement. The average scores from two observers were compared with the practicality criteria and SPS achievement criteria by Widoyoko (2016). Learning outcome tests, measuring students' cognitive abilities before (pretest) and after (posttest) using the teaching materials, served as a reference for the effectiveness of the developed teaching materials, determined using the Normalized Gain (N-gain) and compared with effectiveness criteria by Hake (1998).

Results and Discussion

In the analyze phase, the teacher analyzed the needs in the school, namely identifying the teaching materials used in the form of worksheets that do not support the 2013 revised edition of the curriculum, analyzing the characteristics of XI MIPA 1 Negeri 6 Banjarmasin students aged 16-17 years, included in the formal operational category, namely students Class XI can carry out practical activities to test hypotheses originating from a problem, students can also carry out abstractions to find the physics equations being studied. Analysis of the characteristics of teaching materials, broadly discussing the three materials taught. First, students were introduced to the elasticity of solids, apart from being explained directly, students can also read individually through teaching materials that have been distributed before the learning process, students were also guided intensively starting from filling in worksheets to carrying out Young's modulus experiments. At the second meeting, students were taught and carried out experiments on Hooke's law, and at the last meeting, students were taught about spring arrangement experiments.

In the design phase, designing learning activities began with describing basic competencies, namely analyzing the elastic properties of materials in everyday life and conducting experiments on the elastic properties of a material along with presenting the results and their physical meaning to the learning objectives, determining the number of meetings, namely 3 times. Each meeting was always held with a different model. In the first meeting with the direct teaching model discussing the elasticity of solids, the second meeting with the guided inquiry model discussing Hooke's Law, the third meeting with the investigative group type cooperative model discussing the law of spring arrangement. This stage of designing assessment instruments served to collect research data, several assessment instruments required, namely assessment instruments (Lesson Plan, student worksheets, teaching materials, and learning outcome test) and instruments for observing Lesson Plan implementation, as well as SPS observation instruments.

In the develop phase, the products developed are teaching materials consisting of Lesson Plan, student worksheets, teaching materials, and learning outcome test. The learner autonomy-oriented teaching materials developed consist of Lesson Plan, student worksheets, teaching materials, and learning outcome test to train students' SPS. The Lesson Plan format refers to the revised edition of K13 consisting of Core Competence; Basic Competence.; Indicators of Competence Achievement; learning objectives; learning materials; learning strategies; learning activities in accordance with the model learning steps; learning tools, materials and resources; form of learning assessment; and bibliography. Lesson Plan is a learning procedure or teacher activity guide in learning activities that is adapted to the syntax of the learning model (Anisah, Wati & Mahardika, 2016). The results of the development of the lesson plans consist of three lesson plans for three meetings with time allocation (3×45 minutes) for one meeting which includes (1) lesson plans for the first meeting regarding the material on the elasticity of solids using a direct teaching model; (2) The lesson plan for the second meeting regarding Hooke's legal material uses a guided inquiry model; and (3) the lesson plan for the third meeting regarding spring arrangement material with an investigative group type cooperative model.

Student Worksheets are printed teaching materials consisting of sheets of paper that provide instructions for learning tasks to be carried out by students (Juhji, 2016). The developed student worksheets consists of three sets: the first student worksheets uses direct instruction where students still receive assistance from the teacher; the second student worksheets, using guided inquiry, contains

reduced instructions as the teacher's role diminishes to further train students' science process skills (SPS); the third student worksheets uses cooperative group investigation, providing technical instructions such as experiment objectives, materials and equipment, hypothesis formulation, variable identification, experimental steps, observation data, and data analysis results and conclusions.

The developed teaching material serves as a learning source for students, systematically organized to capture the interest of students as part of the learning media (Zakiati, Mastuang, & Suyidno, 2019). The elasticity and Hooke's law teaching material is structured into three sessions: solid material elasticity, Hooke's law, and spring arrangements. This teaching material comprises components such as a cover, introduction, table of contents, basic competencies and indicators, concept map and keywords, learning objectives for each session, supporting images, example questions, summaries, exercises, glossary, and references.

Learning Outcome Test is a test developed to measure students' learning outcomes and assess their understanding of the material studied. The learning outcome test is based on the item writing grid and developed according to the targeted basic competencies (Anisah, Wati, & Mahardika, 2016). The developed learning outcome test consisted of 6 items: 3 items on knowledge with cognitive domain and 3 items on SPS, covering aspects that have been trained. The developed learning outcome test is then pilot tested on students during pretests and posttests. The learning outcome test also included instructions for answering questions and a space to provide correct answers below each question. The teaching material produced is subsequently validated by experts, and any necessary revisions are made based on their suggestions.

The validity of the instructional tools is assessed based on the validation of lesson plans, Student Worksheets, Learning Outcome Tests, and Teaching Materials (Hartini, Zainuddin, and Miriam, 2018). Instructional materials are considered valid if they fall into the valid category (Noor, Zainuddin, & Miriam, 2017). The validity test for the lesson plan includes several assessment aspects such as the formulation of learning objectives, language, presented content, and timing. The results of the validity test for the lesson plan are presented in Table 1.

Table 1. Results of Lesson Plan Validity

Aspect	Average	Category
Purpose	3.73	Highly Valid
Language	3.39	Valid
Content	3.22	Valid
Time	3.58	Highly Valid
Validity	**3.48**	**Highly Valid**
Reliability	**0.71**	**High**

The results of the lesson plan validity in Table 1 show that the developed lesson plan is valid based on aspects such as the formulation of objectives, language, presented content, and timing, indicating an overall valid category. This suggests that the developed lesson plan aligns with the components of a good and correct Indonesian language, is well-organized, clear, coherent, and suitable for the instructional model used, and adheres to appropriate time allocation (Zakiati, Mastuang, & Suyidno, 2019).

The validity test for students' worksheets consist of several assessment aspects, including format, language, and content. The results of the validity test for students' worksheets are presented in Table 2.

Table 2. Results of Students' Worksheets Validity

Aspect	Average	Category
Format	3.76	Highly Valid
Language	3.83	Highly Valid
Content	3.33	Valid
Validity	**3.64**	**Highly Valid**
Reliability	**0.74**	**High**

The results of the student worksheets validity in Table 2 indicate that student worksheets demonstrate validity in the highly valid category, making it suitable for use by teachers during experiments in the classroom. Student worksheets serve as a teaching material that can facilitate students in the learning process, providing guidance and direction. The developed student worksheets are considered valid, allowing it to be used as a guide for students in implementing the learning process (Zakiati, Mastuang, & Suyidno, 2019).

The validity test for teaching materials involves several assessment aspects, including the appropriateness of content, presentation, language, and graphics. The results of the validity test for teaching materials are presented in Table 3.

Table 3. Results of Teaching Material Validity

Validity Aspect	Average	Category
Content	3.73	Highly Valid
Presentation	3.69	Highly Valid
Language	3.18	Valid
Graphs	3.36	Valid
Validity	**3.65**	**Highly Valid**
Reliability	**0.83**	**High**

The results of the validity of teaching materials in Table 3 indicate that the developed teaching material content is valid, as the validation results provided by the validator show that the components of the teaching material have been well-fulfilled. It can be concluded that the developed teaching material is suitable for use in the classroom learning process (Anisah, Wati, & Mahardika, 2016).

The validity test for learning outcome test consists of several assessment aspects, including general construction, language, and timing for each item. The results of the validity test for learning outcome test are presented in Table 4.

Table 4. Results of Learning Outcome Test Validity

Scoring Aspect	Average	Category
Item 1	3.55	Highly Valid
Item 2	3.58	Highly Valid
Item 3	3.58	Highly Valid
Item 4	3.25	Valid
Item 5	3.50	Highly Valid
Item 6	3.65	Highly Valid
Validity	**3.52**	**Highly Valid**
Reliability	**0.78**	**High**

The results of THB validity in Table 4 show that the validation results provided by the validator indicate that the components of the learning outcome test have been well-fulfilled. It can be concluded that the developed teaching material is suitable for use in the classroom learning process (Anisah, Wati, & Mahardika, 2016).

The use of valid teaching materials, such as lesson plans, students' worksheets, teaching materials, and learning outcome test, which have been meticulously arranged, can facilitate teachers in conducting more structured learning. Furthermore, the use of teaching materials were simulated by the researchers with fellow students to obtain feedback so that teaching materials can be improved if necessary, resulting in optimal improvements. The results of this improvement phase would be used for field testing to collect research data.

In the implementation phase, the application of the developed teaching material to determine its feasibility was carried out. The implementation of the learner autonomy-oriented teaching material was conducted during the field trial, directly involving students of grade XI MIPA 1 Banjarmasin in three

sessions, each lasting 2×45 minutes. Students were asked to answer questions at the beginning of the learning session before the teacher uses the developed teaching material.

In the evaluation phase, both formative and summative evaluations were conducted. Formative evaluation is carried out during the design and development stages to refine the teaching material. In the design stage, improvements have been made to the application learning objectives, with all objectives using C3 changed to C4 for three learning objectives and C3 for three learning objectives. In the development stage, improvements to the lesson plan include a modification to the first meeting using direct instruction with additional excerpts. Students' worksheets for the first meeting addressed problems related to the discussion of Young's modulus, teaching material for the second learning objective regarding Hooke's law involves only one application question, and learning outcome test with a question analyzing the arrangement of springs in series and parallel is better combined into a single question. Summative evaluation was conducted to determine the feasibility of the developed teaching material based on validity, practicality, and effectiveness, as well as the achievement of students' science process skills. Further adjustments would be made if necessary.

Practicality of Teaching Material Results

The practicality of teaching material is measured by assessing the implementation of lesson plan. The assessment of Lesson Plan implementation is carried out by two observers to determine the completeness of Lesson Plan implementation (Noor, Zainuddin, & Miriam, 2017). The instructional models used include direct instruction, guided inquiry, and cooperative group investigation. The results of the lesson plan implementation observation are presented in Table 5.

Table 5. Results of Lesson Plan Implementation Observation

Meeting	Lesson Plan Implementation		Reliability	
	Average	Category	Average	Category
1	3.28	Practical	0.77	High
2	3.61	Very Practical	0.86	Very High
3	3.72	Very Practical	0.81	Very High

Results of the implementation of Lesson Plan for the three sessions are presented in Table 5. The first meeting, using direct instruction, is categorized as practical, while the second and third meetings, using guided inquiry and cooperative group investigation models, are categorized as very practical. Teaching materials are considered practical if they are practical and easy to administer (Widoyoko, 2016). From the average observations of lesson plan implementation for the three sessions, it can be concluded that lesson plan is highly practical, indicating that the use of this learner autonomy-oriented lesson plan is practical and easy to implement

Effectiveness of Teaching Materials

The effectiveness of teaching materials is assessed based on students' learning outcomes, specifically the cognitive learning effectiveness measured by the N-gain (Selvia, Arifuddin, & Mahardika, 2017). Teaching materials are considered effective if they yield results in line with the set objectives (Anisah, Wati, & Mahardika, 2016). The N-gain calculations obtained are presented in Table 6.

Table 6. Learning Outcome Test

Average		Effectiveness	
		N-gain	Category
Pretest	8.78	0.59	Medium
Posttest	47.16		

The N-gain results indicate a moderate category, meaning that the teaching materials are effective in improving students' cognitive abilities. However, the overall learning outcomes of all students are below the minimum completeness criteria at the school.

The posttest results show that there are several factors and challenges affecting the completeness of student learning outcomes. For example, in solving analytical problems, only a few students completed them according to the procedure; others only wrote the final formula, and some did not attempt the questions. This is due to the limitation of the cooperative learning model in the teaching-learning process, which tends to be dominated by one or two students (Nurdyansyah & Fahyuni, 2016). Difficulties in solving application problems include students struggling to understand the known and unknown variables and difficulty in accurately writing physics symbols (Charli, Amin, & Agustina, 2018). Students also lack practice in answering varied questions and do not pay attention to the problem-solving process (Afriani, Kade, & Supriyatman, 2017). Although teaching materials based on learner autonomy face some difficulties in implementation, this research proves that the materials are effective in training students' science process skills at a moderate level, supported by similar findings in other studies (Salam & Miriam, 2016; Zakiati, Mastuang, & Suyidno, 2019).

Achievement of Students' Science Process Skills (SPS)

The achievement of students' science process skills is measured through the observation of two observers trained in SPS indicators at each meeting. In the first and second meetings, the indicators include formulating hypotheses, identifying variables, collecting data, analyzing data, and drawing conclusions. In the third meeting, the indicator is added with the preparation of experimental procedures. The results of students' achievement in SPS can be seen in Table 7.

Table 7. Results of Students' Achievement in SPS

Aspect	Meeting 1		Meeting 2		Meeting 3	
formulate a hypothesis	Average	C	Average	C	Average	C
identify variables	3.50	VG	4.00	VG	4.00	VG
develop experimental procedures	2.70	G	3.90	VG	3.60	VG
try or collect data				VG	3.60	VG
analyze data	3.20	G	3.90	VG	3.90	VG
draw a conclusion	3.40	G	3.60	VG	2.80	G
Total of Average	3.10	G	4.00	VG	3.20	G
formulate a hypothesis	3.18	G	3.88	VG	3.52	VG

C = Category
G = Good
VG = Very Good

The results of the students' SPS observations have increased at each meeting for each indicator because they have started to be trained in conducting experiments and already know what components they must include when filling out the LKS for each SPS indicator completely and correctly (Karmila, Zainuddin, & An 'nur, 2014). Alhamdhani et al., (2017) stated that the use of direct teaching models has a good influence in training psychomotor skills. The increase in students' science process skills is due to teachers implementing guided inquiry and cooperative investigation group type learning models which emphasize students' science process skills (Zakiati, Mastuang, & Suyidno, 2019). The use of learning materials based on learner autonomy can improve science process skills (Salam & Miriam, 2016).

Conclusion

Based on the development of teaching materials and the trial results, it can be concluded that learner autonomy-oriented physics teaching materials on elasticity and Hooke's law for training science process skills of students at SMA Negeri 6 Banjarmasin are suitable for use in the learning process as they meet the criteria for being valid, practical, and effective. This conclusion is supported by: 1) the validity results of teaching materials being categorized as very valid, 2) the practicality results of teaching materials being categorized as very practical, 3) the effectiveness results of teaching materials

being categorized as moderate, and 4) the achievement of students' science process skills being categorized as good.

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