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Development of Density Meter Learning Media Using Arduino Uno to Improve Critical Thinking Abilities

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Abstract: This research aims to develop an Arduino Uno-based learning media that focuses on measuring the density of substances, with the aim of determining the suitability of the density meter, the accuracy of the density meter and improving students' critical thinking skills. The research method used is Research and Development (R&D) with a Four-D model with the steps Define, Design, Develop and Disseminate. This learning media is designed to provide students with practical experience in understanding the concept of density through direct experiments using a density meter connected to an Arduino Uno. Apart from that, this media is also designed to encourage students to develop critical thinking skills, such as analysis, evaluation and problem solving skills through reflective questions that are integrated into learning. Validation and testing are carried out through certain stages to ensure the quality and effectiveness of this learning media. Assessments are carried out on aspects of clarity of instructions, relevance to lesson material, appropriateness of level of difficulty, and impact on students' critical thinking abilities. The collected data was analyzed quantitatively and qualitatively. The results of the development of the density meter tool show that the assessment of experts is in the very appropriate category with a score of 90.50. The tool's accuracy results are an average of 99.55%. Apart from that, the post-test results revealed that the density meter was proven to be effective in improving students' critical thinking skills with an N-Gain value of 0.80 in the high category. It is hoped that the results of this research can make a positive contribution in the development of learning media that focuses on practical aspects and critical thinking skills. It is hoped that the Density Meter learning media using Arduino Uno can help teachers teach density concepts with a more interesting and effective approach, as well as encourage students to think more critically in understanding and applying science concepts in everyday life.

Keywords: Arduino uno; Critical thinking; Density meter; Development; Learning media

Introduction

Effective education must be able to go beyond understanding basic concepts and develop students' critical thinking skills. The ability to think critically is a mental ability that is important in processing information, analyzing situations, evaluating arguments, and making the right decisions (Ennis, 2018; Naja et al., 2020; Zulhamdi et al., 2022). However, in practice, the development of critical thinking skills is often neglected in learning processes that focus more on passively providing information.

The ability to think critically is an invaluable intellectual competency in dealing with the complex challenges of the modern world (Matsun et al., 2021). Improving critical thinking skills involves the process of analyzing, evaluating, and interpreting information to make the right decisions and creative solutions. Unfortunately, many learning approaches are still limited to the transfer of information, while practical

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application and the development of critical thinking skills are often sidelined.

Technology and innovation in education have great potential to improve students' critical thinking skills. One technology that is attracting attention is the Arduino Uno, an electronics development platform that can be used in a variety of interactive projects. The use of Arduino Uno in developing learning media can stimulate student interest and involvement, as well as provide practical experience in understanding abstract concepts (Matsun et al., 2022). So that it can improve students' critical thinking skills (Wasyilah et al., 2021).

One concept that is often difficult for students to understand is the concept of density (Liana et al., 2020). Density has wide applications in physics and engineering, but to understand it, students need to understand the relationship between mass and volume and be able to apply the concept of density to real-world situations. Developing learning media that utilizes Arduino Uno and focuses on the concept of density has the potential to provide a more interesting and interactive learning approach. In addition, the learning media can also be designed in such a way as to stimulate and train students' critical thinking skills (Wardiyanto & Yundra, 2019).

Combining science concepts with practical experiments and the application of critical thinking skills, it is hoped that students can develop a deeper understanding of the concept of density and at the same time improve critical thinking skills that are useful in various aspects of life. Therefore, this research will examine the development of Arduino Uno-based learning media that integrates the concept of density and the application of critical thinking skills (Sukisna & Suparwoto, 2020). In this way, it is hoped that this innovative learning approach can provide significant benefits in improving the quality of learning and students' critical thinking abilities.

In this context, this research introduces the concept of developing innovative and interactive learning media entitled "Development of Density Meter Learning Media Using Arduino Uno to Improve Critical Thinking Abilities". The novelty of the research "Development of Density Meter Learning Media Using Arduino Uno to Improve Critical Thinking Abilities" lies in the combination of several elements that have not been explored much before, as well as an innovative approach in integrating educational concepts, technology, and the development of critical thinking skills (Sukisna & Suparwoto, 2020). Some novel aspects of this research include: Integration of Density Concepts and Microcontroller Technology. Combining the concept of substance density with Arduino Uno microcontroller technology to develop learning media is an approach that is not yet common. This concept combines aspects of science with the application of technology, providing a holistic learning experience; Practical Application in Learning. The learning media developed does not only focus on transferring theoretical information, but also provides practical experience to students through direct experiments using a density meter. This provides added value in understanding theoretical concepts in a concrete manner; Increased Critical Thinking Ability. This research explores how to integrate reflective questions in learning media to stimulate students' critical thinking abilities. This has not been widely applied in the context of technology learning; Use of Arduino Uno in Education. The application of the Arduino Uno microcontroller in developing learning media is not common. This research explores the potential for applying this technology in an educational context, especially in improving students' conceptual understanding and critical thinking skills.

The other novel aspects of this research include: Relevance to Modern Educational Needs. This research is very relevant to the needs of modern education that integrates technology in learning. By presenting an innovative approach, this research can provide inspiration for educational practitioners to develop more interesting and effective learning methods; Science Learning Context. The development of this learning media can have an impact on a more interactive and practice-based science learning approach, allowing students to understand scientific concepts more deeply and apply them in real-world situations; Development of New Literature. The relationship between the concept of density, microcontroller technology, and the development of critical thinking skills in learning media contributes to the development of new literature in the fields of education, technology, and science. Through an innovative approach and multidisciplinary integration, this research provides new contributions in understanding how technology can help improve students' conceptual understanding and critical thinking skills in educational contexts (Liana et al., 2020).

Method

Students from the IKIP PGRI Pontianak physics education study program involving 50 students as research subjects. The form of research is research and development with the Four-D (R&D) model. The development model is carried out using the Define, Design, Develop and Disseminate steps (Rizki et al., 2021). The steps for developing Density Meter Learning Media Using Arduino Uno to Improve Critical Thinking Skills consist of define loading material analysis, programming language analysis, and sonor analysis.

The design stage includes the activities of making product designs, validating and revising. The development stage includes initial trials, and main trials. Disseminate Step In this step the tools and materials that have been developed will be disseminated to tool users, namely students and students.

The percentage of instrument validity was obtained from the average value of the questionnaire using the Likert scale validation questionnaire. The scale used is in the form of numbers 4, 3, 2, 1. Score 4 If the rating strongly agrees, score 3 if the rating agrees, score 2 if the assessment does not agree, score 1 if the rating strongly disagrees (Umar et al., 2021). For analysis of the results, you can see Equation 1.

$$P = \frac{\sum X}{\sum Xi} \times 100\% \quad (1)$$

Where:
P = Percent valueexpected
$\sum X$ = Total score
$\sum Xi$ = Maximum score

Density meter learning media using Arduino Uno to improve critical thinking skills that are developed are said to be feasible if the interpretation is 61% and above. The criteria for interpreting the eligibility score are 81-100% with Very worthy interpretation, 61-80% with Worthy interpretation, 41-60% with Decent enough interpretation, and 21-40% with Less worthy interpretation, and 0% -20% with Not worthy (Khairati et al., 2021).

Analysis of the accuracy of the density meter tool developed using Arduino Uno to improve critical thinking skills using Equation 2.

$$\text{Accuracy} = \frac{\alpha_i}{\alpha_f} \times 100\% \quad (2)$$

Where α_i is the reading value on the developed density meter tool, and α_f is the result of manual measurements.

Students' critical thinking abilities are analyzed using N-gain with Equation 3 below.

$$N - \text{Gain} = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Ideal score} - \text{Pretest Score}} \quad (3)$$

The results of this calculation are then converted into criteria for increasing critical thinking skills based on the provisions, namely with a value of $g > 0.7$ with a high category, a value of $0.3 \leq g \leq 0.7$ with a medium category, and a value of $g < 0.3$ with a category low.

Result and Discussion

Result

Development of Density Meter Learning Media Using Arduino Uno

The process of developing a density meter tool using the Arduino Unon begins with the defining stages which consist of: Material analysis. The material really needs to be analyzed because it fits the needs of its users, namely students. The material used is density material. Selection of material is very important to support and assist students in the learning process; Programming language analysis. The choice of programming language is very necessary so that the media created can be used. The programming language used is C++; Sensor Analysis. In order for the developed tool to operate and according to the desired material, several sensors are needed that can be used in addition to the Arduino microcontroller, namely load cells and ultrasonic sensors (Matsun et al., 2021).

The design stages are made so that the practicum tools are made according to what is desired. The design of the density meter tool is made based on needs and is easy to use. At this stage, a density meter tool is made in accordance with the content framework of the results of curriculum and material analysis (Rahman et al., 2021). The design for developing a density meter using Arduino Uno can be seen in Figure 1.

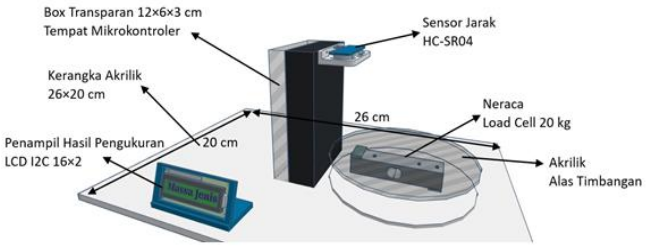

Figure 1. Design of a density meter tool using Arduino Uno

The next stage after the design stage is the development stage. The development stage requires experts to assess the product being developed. Material and media experts are used to assess whether the product being made is feasible or not (Fitriani & Ikhsan, 2018; Ilfiana et al., 2021; Wahyuni et al., 2021; Fitriani et al., 2022). The results of product development can be seen in Figure 2.

The next stage is the dissemination stage carried out by socializing the media created to students and lecturers within the physics education study program. If the user response is good, the density meter tool that has been developed will be developed to manufacture in large quantities and market it so that the density meter

learning media is used by a wider target audience (DeRuisseau, 2016; Dehghanzadeh & Jafaraghaee, 2018; Zulhamdi et al., 2022).

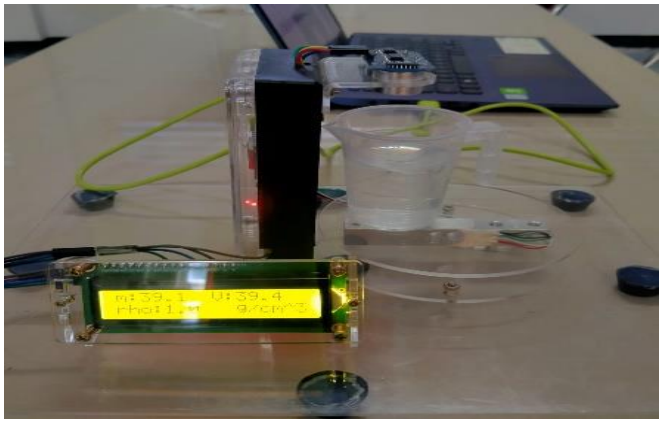

Figure 2. Appearance of the density meter tool after development

Expert Validation

Values obtained from material and media expert validators through questionnaires given to experts (Neswary & Prahani, 2022). Material expert assessment with indicators of relevance to aspects of clarity of instruction, relevance to subject matter, appropriate level of difficulty, and impact on students' critical thinking skills (Karmana & Samsuri, 2018; Rahmadita et al., 2021; Priska et al., 2021; Menap et al., 2021). The assessment of media experts with indicators of tool durability, tool system speed in reading measurement results, tool efficiency, aesthetics, security, and ease of use. The average value of the validation of material and media experts with a score of 90.50% is in a very feasible category. The expert validation range line can be seen in Figure 3 below.

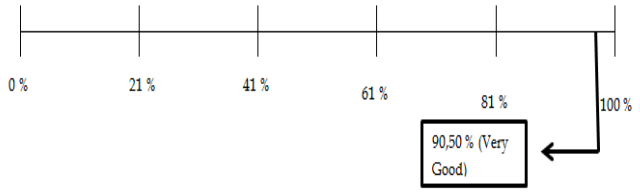

Figure 3. Expert validation range line

Tool Accuracy

Determining the accuracy of the density meter tool is by comparing the density value obtained with the Arduino-based density meter tool which was developed by manually measuring the density of materials. Manual density measurement is done by measuring the volume of each material, measuring the mass of each material, and finally by entering the density equation, namely $\rho = m/V$, the density measured is cuprum, brass, iron, and aluminum. From the results of the accuracy measurement, the density meter based on the Arduino Uno obtained an average accuracy value of 99.55% according to table 1.

Table 1. Accurasy Developed Density Meter Tool

Material Name	Density manually (g/cm^3)	Developed density meter tool (g/cm^3)	Accuracy (%)
Cuprum	8.90	8.81	98.98
Brass	8.50	8.48	99.76
Iron	7.90	7.89	99.87
Aluminum	2.60	2.59	99.61
Average			99.55

Use of Density Meters to Improve Students' Critical Thinking Abilities

The next stage after the density meter tool is declared feasible to use, the tool developed is used in the classroom to improve students' critical thinking skills. The indicators of students' critical thinking abilities are focus, reason, inference, situation, clarity, and overview (Rahman et al., 2021). The results of this test are presented in Table 2. Based on the table of statistical test results, students' critical thinking abilities were obtained, namely an average pretest score of 64, an average posttest score of 80, and an N-gain value of 0.80 in the high category.

Table 2. Statistical Results of Critical Thinking Ability

Pretest Score	Posttest Score	N-gain
64	80	0.80

Discussion

The development of the density meter tool has gone through the development stages and has been validated with the criteria that it is very suitable for application in learning. The density meter tool that has been developed can improve students' critical thinking skills. This reason is in accordance with research conducted by (Liana et al., 2020). Density meter tools using ardouno uno can improve students' ability to conclude and draw conclusions, examine reasons to strengthen opinions, clarify how far the range of reasons is, be able to compare between two situations, be able to explain logically, and be able to provide explanations so that they are not ambiguous. Research conducted by Purnamawati et al. (2021), Density meter equipment using Ardouno Uno can improve students' critical thinking skills in designing and conducting experiments. Students are asked to reassemble the tools and materials used in the experiment. With this activity, students' critical attitudes can increase.

The density meter tool using the Arduino Uno microcontroller is very relevant in improving students'

critical thinking skills. The following are several aspects that can be concluded so that they can describe this relationship: Problem Solving. Using the Arduino Uno microcontroller in learning media can involve students in solving real problems. Students must design, code, and connect components to create a functioning device or system. This triggers analytical thinking in overcoming technical and logical obstacles in development (Sukisna & Suparwoto, 2020); Analysis and Evaluation. In developing projects with Arduino Uno, students need to analyze various components, the relationship between input and output, and the efficiency of the solution that students design. students must also identify and address potential problems that may arise during the process. This encourages critical thinking skills in evaluating alternative solutions and optimizing device performance (Triatmaja & Khairudin, 2018); Creativity. The Arduino Uno microcontroller gives students the freedom to design a wide variety of projects, from simple to complex. This design process encourages creative thinking skills in creating innovative solutions to given problems or tasks (González et al., 2019); Decision Making. In developing a project with the Arduino Uno, students need to make various decisions, such as component choices, design approaches, and programming strategies. These decisions must be based on in-depth analysis and evaluation of potential impacts, encouraging critical thinking skills in making sound decisions (Stahre Wästberg et al., 2019); Logical Thinking Skills. Development with microcontrollers involves programming, which requires logical thinking to organize the flow of program execution. Students must understand control structures, conditionals, and loops to achieve desired results, strengthening their logical thinking skills (Shuaibu, 2014); and Troubleshooting. In the development process, technical problems or errors in programming may arise. Students need to analyze the problem, identify its causes, and find effective solutions. It trains critical thinking skills in overcoming challenges. By integrating the Arduino Uno microcontroller in learning media, students are involved in practical experiences that combine elements of technology, design, and science concepts (Lin et al., 2020). This process inherently encourages critical thinking skills because students are faced with tasks that require in-depth analysis, rational evaluation, and planned problem solving.

Conclusion

The development of a density meter tool can be used because it has a feasibility value from material and media experts with an average score of 90.50% with the Very Good criteria. The results of the accuracy of the tool with an average of 99.55%, and the N-gain value of 0.80 are in the high category so that it can be concluded that the density meter tool can improve students' critical thinking skills in the high category.

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Conflicts of Interest

The authors declare no conflict of interest.

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