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DEVELOPMENT OF E-MODULE OF ABSTRACT CONCEPTS OF MATERIAL CHANGES IN THE FORM OF OBJECTS TO IMPROVE THE CRITICAL THINKING SKILLS OF AUTISTIC CHILDREN

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ABSTRACT

The research aims to: (1) produce e-modules of abstract concepts of material changes in the form of objects that are appropriate to improve the critical thinking of autistic children, (2) produce e-modules of abstract concepts of material changes in the form of objects to improve the critical thinking of autistic children that are practically used by teachers and students, and (3) produce e-modules of abstract concepts of material changes in the form of objects that are effective in improving the critical thinking of autistic children. This research was development research or research and development (R&D), using the ADDIE model (analysis, design, development, implementation, and evaluation). The subjects in this study were seven autistic students, with two students as test subjects and five students as effective test subjects. Data collection techniques used were interviews, expert questionnaires, educator response questionnaires, and tests to understand abstract concepts of material changes in the form of objects. The data analysis used was qualitative and descriptive, presented in the form of graphs. The effectiveness test was carried out by comparing the scores of the pretest and posttest before and after using the e-module of abstract concepts of material changes in the form of objects. The results of research and development include: (1) the e-module of abstract concepts of material changes in the form of objects is declared to be very feasible in supporting the learning of autistic children with an average score of 48.5 from 47 material experts and 50 media experts, (2) the results of the practicality of the e-module abstract concepts of material changes in the form of objects from the questionnaire of educators responses with an average score of 4.85 in the very practical category, and (3) the e-module of abstract concepts of material changes in the form of objects can improve the ability of critical thinking of autistic children, as indicated by the average score of the Normalized Gain Test of 0.66 (moderate).

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1. INTRODUCTION

Education plays a crucial role in an individual's life. In Indonesia, progress in education continues with an emphasis on innovative and creative learning. The main objective of education is to shape character and develop

the potential of students, including their thinking skills, morals, insight, creativity, independence, personality, and religious spirituality.

Science education requires a fundamental understanding of concepts. This aligns with the report by the American Association for the Advancement of Science (AAAS) titled "Science for All Americans," which emphasizes that students must understand both foundational concepts and advanced material, including science and knowledge (Wisudawati & Sulistyowati, 2014). In special education, science learning is not only about understanding theories but also focuses on mastering knowledge concepts, skills, and practical functional abilities to support daily activities in a contextual and factual manner.

Every student's thinking ability is different, including autistic children. Autism is a complex developmental disorder that encompasses aspects of communication, social interaction, and imaginative activities that occur from birth or during early childhood (Suaidah, 2017: Atmajaya, 2018). Children with autism interact and communicate differently from other students. The difficulties experienced by children with autism are caused by their difficulty in connecting and applying experiences they have previously obtained or experienced.

Children with autism are visual learners who tend to understand and remember information more easily through sight, so they have difficulty understanding abstract concepts because these concepts cannot be measured or seen directly. A preliminary study at a special school in phase D on the subject of science, specifically the material on changes in the form of objects, found that the achievement of autistic children was below average. The science learning process has not yet enabled students to develop independently through exploration and critical thinking because it is still dominated by the teacher. The existing teaching materials do not directly involve students, and there is no innovation in the learning process using current technology. Teachers still rely on textbooks that are not tailored to the needs of autistic children when teaching, assigning tasks, and conducting practical activities. Abstract concepts are concretized by teachers by showing pictures and/or videos only. Students do not gain meaning from learning these abstract concepts to apply them in solving everyday problems because they only memorize rather than understand.

The thinking ability of autistic children in the subject of changes in the form of objects is still considered low. Autistic children tend to be passive, waiting for instructions from teachers, and they often do not remember concepts that were previously taught. Autistic children also have difficulty answering teachers' questions because they do not understand what is being asked or they do not know the answers. This condition reflects that autistic children lack critical thinking skills.

Children with autism cannot think critically because they have difficulty understanding abstract concepts, making it hard for them to find solutions to problems they face in daily life. Williams, et al. (2018: 1-25) state that autistic individuals with normal to high IQs are capable of understanding abstract concepts, especially if they are provided with appropriate support and learning strategies such as visual methods, concrete examples, and repetition. They can also be taught critical thinking skills, which involve the ability to analyze information, make decisions, and solve problems through structured practice and guidance.

To understand the subject matter, a logical mindset is essential for children with autism. The concept of the transformation of objects is abstract and therefore illogical for children with autism. Teachers, as facilitators, are required to make science lessons on the transformation of objects logical and acceptable to children with autism. One of the efforts teachers can make is to create teaching materials that are tailored to the needs of children with autism using technology. This situation can be addressed by developing teaching materials as a medium for instilling abstract concepts in students, namely e-modules tailored to the needs of children with autism, featuring structured organization, clear visualizations with contrasting colors to enhance visual appeal, and the use of simple, communicative, and practical language. These e-modules can be repeated anywhere with guidance from a caregiver or even independently. The use of e-modules can provide many practical applications, enabling students to think critically and helping them build conceptual knowledge to achieve learning objectives. Thus, the use of e-modules is an appropriate choice to support the delivery of learning materials on the transformation of objects to help children with autism master abstract concepts, so that by mastering abstract concepts, students can think critically. Science encourages students to develop logical and critical thinking skills and the ability to explain practical events or phenomena (Hanafi, 2023:3). Teaching and learning activities are linked to everyday phenomena around students. Learning activities that are close to children's daily lives are easier to learn. The learning process can develop students' activities and critical thinking through various interactions and experiences in the learning process. Students who are accustomed to being trained to think critically through simple experiences will be able to solve problems related to everyday life much more easily.

This study aims to develop an e-module on abstract concepts related to the transformation of objects to enhance the critical thinking skills of children with autism. The e-module is designed using a multisensory approach because its components combine various media such as text, graphics, audio, images, and videos, as well as activities and evaluations to prevent students from feeling bored with text-only presentations. After learning science, students are expected to be able to apply their knowledge in daily activities in a functional and meaningful way.

2. RESEARCH METHODS

Type of Research

This research applies a research and development method using the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) as a development framework to ensure that each stage of development is structured and systematic.

Trial Design

The product trial design was conducted in two main stages: a limited trial and a large-scale (field) trial. The limited trial aimed to evaluate the practicality and readability of the e-module on abstract concepts of changes in the form of objects developed by students. This limited trial was conducted on two autistic students at SLB Citra Mulia Mandiri. The trial results were used as input for product revisions. Following the limited trial, the e-module was tested in a field trial that involved implementing the developed e-module in a broader learning process to measure its impact on the critical thinking abilities of autistic children. The e-module was tested in an effectiveness trial to assess its impact on improving children's critical thinking abilities. Five autistic children at SLA Fredofios were selected for the effectiveness test, and their critical thinking abilities were compared before and after using the e-module on abstract concepts related to the transformation of objects.

Test Subjects

The test subjects in this study consisted of seven autistic children at SLB Citra Mulia Mandiri and SLA Fredofios. Subject selection was based on children with autism in phase D who had normal to high IQs, with initial abilities including the ability to read, basic device operation skills (turning on, touching, or clicking the screen according to instructions), understanding simple instructions, focusing on the screen and material for a certain period of time, even briefly, understanding icons, colors, or images as cues in the e-module, and responding interactively.

Data Collection Techniques

The data collection techniques used in this study included questionnaires, interviews, and tests. Questionnaires were used to collect data on the suitability of the e-module from subject matter experts, media experts, and the practicality of the e-module from teacher responses. Interviews were conducted with teachers to analyze needs and identify challenges in implementing the learning process. Tests were conducted to assess improvements in children's critical thinking skills in understanding abstract concepts of changes in the form of objects before and after using the e-module.

Data Analysis Techniques

Data obtained from questionnaires, interviews, and tests were analyzed using a quantitative descriptive approach visualized in graphs. Quantitative descriptive analysis was used to explain and provide an overview of the collected data without aiming to generalize or draw broad conclusions (Sugiyono, 2015, pp. 256–272). Product feasibility analysis was conducted by calculating the average score from questionnaires filled out by subject matter experts and media experts. These average scores were then converted into qualitative categories to assess product feasibility based on guidelines from Widoyoko (2017: 238). Analysis of the practicality of the e-module was obtained through educator responses by calculating the average scores from questionnaires filled out by teachers, which were then converted into qualitative categories to assess product practicality and presented in graphical and narrative form. Pretests and posttests were conducted to assess the effectiveness of the product by calculating the percentage of science scores on the topic of changes in the state of matter based on the formula from Ridwan (2004: 71-95) and analyzing differences in critical thinking abilities among autistic children using the Normalized Gain test with the formula and categories developed by Hake (1999, in Nani & Kusumah 2015, pp. 190-191). Test results are presented in graphs and narratives to provide a comprehensive overview of the effectiveness of the e-module

3. RESULT AND ANALYSIS

Results

This study aims to develop and evaluate an e-module on abstract concepts of changes in the form of objects as teaching material to improve critical thinking in autistic children. This study was conducted using the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation. The following are the results of each stage.

a. Analysis Stage

In the analysis stage, this research began with a needs analysis to analyze the needs and identify obstacles in the implementation of science education for autistic children in phase D. The researchers used various methods, including interviews with teachers and direct observation in the field to gather information related to the difficulties children face in learning science. Additionally, the researcher conducted a literature review to explore theories related to effective teaching strategies for science education on the topic of the states of matter and the design of e-modules tailored to the needs of children with autism.

The analysis revealed that children with autism struggle with problem-solving related to everyday life, particularly in understanding abstract concepts of changes in the states of matter. Problem-solving ability is one of the indicators of critical thinking. This e-module is designed to support learning in understanding abstract concepts of matter change in order to improve the critical thinking skills of children with autism.

b. Design Stage

The e-module design was carried out by considering the results of the needs analysis, which included several important aspects, namely material that is in line with the curriculum, the characteristics of children with autism, and an attractive e-module display design. Based on the analysis results, this e-module is structured according to critical thinking indicators, including interpreting (categorizing and classifying), analyzing (testing and identifying), problem-solving, explaining (writing results and presenting arguments), and drawing conclusions (observing data and explaining conclusions).

c. Development Stage

The e-module development process was carried out using the Canva and Heyzine Flipbook applications. Canva was used to design the module, while Heyzine Flipbook was used to convert the learning module from PDF format into

a digital book that allows each page to be opened and accessed interactively. The e-module design was developed with an emphasis on visually appealing and easy-to-understand aspects, using contrasting colors and graphic elements appropriate for the characteristics of children with autism.

The learning process within the e-module is complemented by various activities that support children's understanding of abstract concepts related to the physical properties of objects and connect them to everyday phenomena in the students' surroundings. The e-module is easy to learn and can develop students' activities and critical thinking skills because it includes diverse interactions and experiences in the learning process, such as material presentation, hands-on activities, observation tables, drawing conclusions, and evaluation. The developed e-module will then be validated by subject matter experts and media experts. The results from the subject matter experts received a score of 47, categorized as "very good," and the media experts' validation results received a score of 50, also categorized as "very good," making this e-module suitable for use in science education.

Cover Page Learning Activity

Figure 1. E-module Interface

d. Implementation Phase

An implementation test was conducted to measure the feasibility of the e-module after it was developed. The field trial was conducted from November 4 to 14, 2025, at SLA Fredofios Yogyakarta. In this field trial, critical thinking data was obtained from two tests, namely a pretest and a posttest. The assessment was based on critical thinking indicators presented in the e-module. The results of the implementation test showed that the average score in the pretest was 41, while in the posttest it increased to 80. The increase in the critical thinking skills of autistic children was recorded at 39%, which is classified as "good." This increase was due to the material on the changes in the form of objects in the e-module attracting the children's interest and attention and being related to their daily activities, making it easy to understand.

e. Evaluatio

An evaluation was conducted to assess the feasibility, practicality, and effectiveness of the e-module in improving the critical thinking skills of autistic children regarding the material on changes in the form of objects. This evaluation involved validation from subject matter experts, media experts, educator responses, and pre- and post-tests conducted on the research subjects.

The results of the expert validation evaluation: subject matter expert validation was carried out by Dr. Sukinah, S.Pd., M.Pd., with aspects of assessment of content feasibility, presentation, language, and graphics resulting in a score of 35 in stage 1 and a score of 50 for stage 2 assessment, which was categorized as "Very Good".

The results of the media expert validation evaluation were conducted by Oki Pambudi, M.Pd. as the First Expert PTP at the Education Communication Technology Center of the Yogyakarta Provincial Education, Youth, and Sports Agency. The media expert's assessment of the aspects of content feasibility, presentation, language, and graphics resulted in a score of 38 in stage 1 and a score of 47 in stage 2, which was categorized as "Very Good".

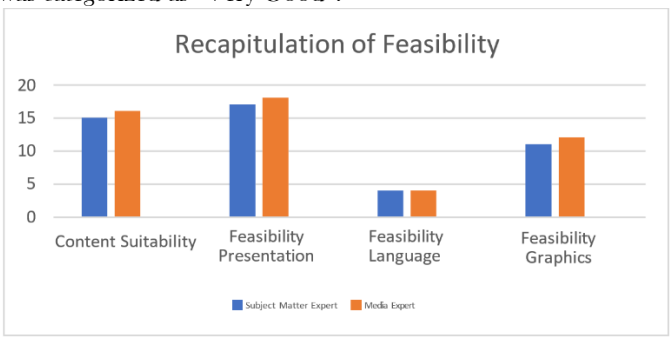

Figure 2. Graph of Expert Material and Media Validation Results

The results of the practicality test of the educator response questionnaire showed an average score of 4.85, which falls into the very practical category. In addition to the score, the questionnaire also produced qualitative data in the form of general input and suggestions from educators. One of the inputs and suggestions submitted was that with the e-module, students were very interested in paying attention to each material provided because it was created based on everyday experiences. Another comment stated that the e-module was easy for students to understand because it was accompanied by more specific and detailed experiments.

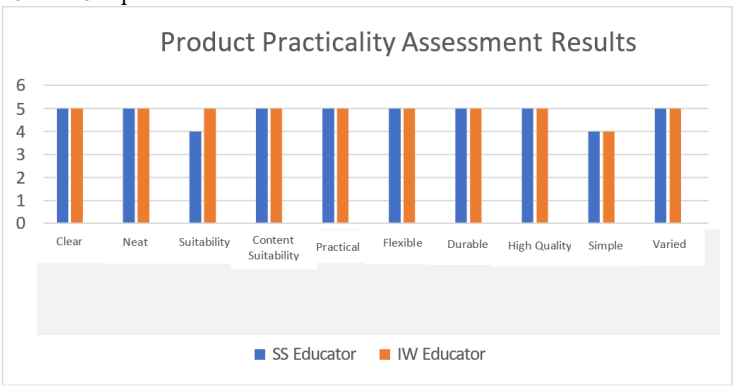

Figure 3. Graph of Educator Response Results

Product Trial Results: the average score on the pretest was 41, while on the posttest it increased to 80. The score range on the pretest was between 35 and 50, while on the posttest it was between 70 and 85.

The increase in the thinking skills of children with autism was recorded at 39% with an increase range of between 30% and 45%.

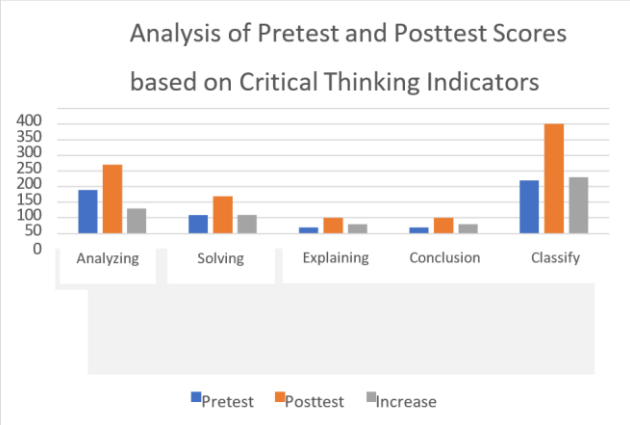

Figure 4. Graph of Analysis Results on Pretest and Posttest Based on Critical Thinking Indicators

Evaluation Results from Effectiveness Testing: Effectiveness testing was conducted to measure the improvement in children's critical thinking skills after using the e-module. Based on the Normalized Gain test, the improvement in critical thinking skills was in the moderate category with an average score of 0.66. The improvement in critical thinking skills for the five subjects was in the low to high category.

Table 1. Results of the Normalized Gain Test on the Critical Thinking Skills of Children with Autism

Subject	Normalized Gain Score	Interpretation
Ki	0,60	Medium
Vr	0,75	High
Gf	0,75	High
Rw	0,54	Medium
Ag	0,67	Medium
Average	0,66	Medium

These results indicate that the e-module is considered effective and suitable for use as teaching material on changes in the form of objects to help understand abstract concepts and improve the critical thinking skills of children with autism.

Disussion

The final product developed is an e-module on abstract concepts of matter transformation to enhance critical thinking skills in children with autism. The e-module was developed using the Canva and HeyZine Flipbook applications. Canva was used to design the module layout, while HeyZine Flipbook was used to convert the PDF-format learning module into a digital book that can be opened on each page. The e-module on abstract concepts of changes in the form of objects can be accessed via the link https://s.id/mmGyf.

The content of the e-module consists of three main sections: introduction to the form of objects, changes in the form of objects, and evaluation. The development of this e-module was designed using a structured, simple, and visual approach featuring images and videos, with a focus on supporting the learning style of children with autism and fostering their critical thinking skills through relevant concepts. Additionally,

there are hands-on activities designed to help children with autism understand abstract concepts directly through real-world experiences.

The development process of this e-module was carried out using the ADDIE development model, which includes five main stages: analysis, design, development, implementation, and evaluation. Every educational module developed must meet evaluation criteria covering aspects of content suitability, presentation, language, and graphics (Muslich, 2010, pp. 291–231). Based on the feasibility assessment conducted by experts, it was concluded that the e-module product on abstract concepts to enhance critical thinking skills is suitable for use with autistic children on the topic of changes in the form of objects.

The research produced an e-module on abstract concepts related to the transformation of objects to enhance critical thinking skills in autistic children that is appropriate, practical, and effective. The feasibility of the e-module on the subject matter was determined through expert assessment of both the content and the medium. The qualitative assessment of the e-module product by experts yielded an excellent score of 48.5, thereby deeming the e-module suitable for application with autistic children.

One of the expert recommendations regarding the e-module is that the concepts used should be arranged in a stepwise manner, starting from simpler levels and progressing to more complex ones. This aligns with the opinion of Manzil et al. (2022:122), who state that the presentation of material in e-modules should begin with

simple concepts and progress to more complex ones, while also including experimental activities that can enhance student engagement and enthusiasm during learning.

The e-module on abstract concepts of material changes is designed in accordance with critical thinking indicators, namely: 1) interpreting, which involves categorizing and classifying; 2) analyzing, which involves testing and identifying; 3) problem solving; 4) explaining, which involves writing down results and presenting arguments; 5) drawing conclusions, which involves observing data and explaining conclusions. The final outcome of the e-module on abstract concepts of matter transformation to improve the thinking skills of children with autism is as follows:

a. In the introduction, there is information about the e-module description, instructions for teachers, and instructions for students. The instructions for teachers contain information about the children's goals, educational achievements, learning objectives, competency achievement indicators, and concept maps.
b. The content section presents material on the introduction to the forms of objects, changes in the forms of objects, and evaluations designed to help autistic children understand abstract concepts directly through real experiences with hands-on activities. Children's learning activities also vary; they are not limited to reading alone. In the e-module, children are encouraged to sing, look at pictures, and watch videos of changes in the forms of objects. The process of building abstract concepts of changes in the form of objects involves very complex thinking, beginning with categorizing and classifying, analyzing, problem solving, explaining simply, and drawing conclusions based on facts or problems in their daily lives. The revision of the e-module by subject matter experts in the content section is in the image of an adult blowing up a balloon. The image is used to provide readers with a concrete illustration of the process taking place, so the image can be replaced to help children internalize the concept of gaseous objects. This aligns with the opinion of Putikadyanto and Purnomo (2019:18) that the use of images must consider their relevance to the research topic being studied, particularly by presenting concepts that are difficult to explain with words alone. The subject matter expert also provided revisions to the experiment and evaluation activities. The experiment activities were simplified with observation tables and conclusions. According to Putikadyanto and Purnomo (2019:17), the use of tables facilitates readers in understanding and interpreting data quickly and easily in identifying relationships. The evaluation is not in the form of an essay because such a test requires abstract processing, and composing answers independently is often challenging for children with autism. A test format suitable for measuring a child's ability to identify information based on simple relationships and connect two things is matching. This aligns with Arifin's (2012) view that the more connections between premises and responses are created, the better the questions are designed.
c. The closing section contains follow-up and expectations after students have studied this e-module.

Additional components play a role in presenting elements to support the e-module on abstract concepts of material changes, including the title page, foreword, table of contents, bibliography, answer key, and author biography. In the additional components section, there are revisions from subject matter experts to add pages to the table of contents, making it easier for readers to find the information they are looking for without having to search through all the pages, and to provide an overview of the e-module's structure. This aligns with Ana Rosmiati's (2017: 100) view that the table of contents serves as a guide for readers to know the page numbers and topics discussed in a scientific paper. The subject matter expert also suggested adding the author's biography so that readers can get to know the author of the e-module better, as a biography is data containing a description of the author based on factual information to convince readers, as stated by Indriyana and Handayaningsih (2015).

The e-module has also been revised according to the advice of media experts, particularly regarding the selection of colors in the e-module background, which was distracting to the eyes, and has been changed to a single color to make the text more legible, namely white. Color is important for children with autism because it stimulates their perceptual abilities and enhances their attention. This aligns with Astuti's (2018: 37) view that color influences the behavior of children with autism and helps determine their ability to perform tasks. The font size has also been standardized to the same size, following media experts' recommendations. The selection and use of fonts, including their size, shape, and color, are an important aspect of e-module design because not all available font sizes, types, and shapes are suitable for e-module development. Readability and clarity are the primary factors in selecting and using the appropriate font. This aligns with Kusrianto's (2004) view that a typeface is considered legible or clear if it can be read clearly at any size. The shape and size of fonts significantly influence the reading speed of children with autism, as Kusrianto (2004) noted that students' reading speed can increase or decrease, influenced by various factors, one of which is the font—its shape, color, and size. The final e-module design features video sizes adjusted to avoid being too small and placed in symmetrical positions to ensure the readability of the e-module.

In this study, the practicality of e-modules on abstract concepts of changes in the form of objects was tested to improve the critical thinking skills of autistic children through educator responses. The results obtained were

that the use of e-modules on abstract concepts of changes in the form of objects was practical for autistic children to use in improving their critical thinking skills, with a score of 4.85 (very good). The results of this study align with research conducted by Utami (2023: 108), which found that teaching materials such as electronic modules based on flipbooks developed using Heyzine Flipbooks in the subject of energy transformation are practical tools for supporting the implementation of science education.

The effectiveness was tested through pretest and posttest. The improvement in critical thinking skills of children with autism can be analyzed through the average score on the pretest, which was 41, and the posttest, which was 80. The critical thinking skills of children improved by an average of 39%. All research subjects' posttest scores were higher than their pretest scores. The increase in critical thinking skills among children with autism can be observed based on the results of the Normalized Gain Test, which revealed an increase in critical thinking skills among children in the low to high categories. The highest increase in critical thinking skills was found in subjects Vr and Gf with a score of 0.75.

The findings of the study indicate that the e-module on abstract concepts of material changes in the form of objects can improve the critical thinking skills of children with autism. All research subjects experienced improvements in every critical thinking indicator, namely: 1) interpretation, which involves categorizing and classifying, increased from 170 to 350; 2) analysis, which involves testing and identifying increased from 140 to 220; 3) problem-solving increased from 60 to 120; 4) explanation, which involves writing results and presenting arguments, increased from 20 to 50; 5) drawing conclusions is looking at data and explaining conclusions increased by 30 from 20 to 50. These results are very important because learning material about changes in the form of objects with e-modules has a positive influence on the quality and quantity of children's thinking skills in understanding abstract concepts in everyday life.

These research results align with those of Nurohman (2021: 148), who found that the use of e-modules can effectively enhance children's critical thinking skills because the e-module design is engaging and easily accessible to students, the content is easy to understand and explores students' thinking processes, and the learning objectives align with assessment elements.

An interesting finding in this study is that after learning with e-modules, children can apply what they have learned in their daily lives and increase their independence and reduce their dependence on others, such as being able to prepare tea for themselves or others because usually children make tea but do not stir the sugar even though they have been reminded every time they make and serve tea to their teacher. Additionally, children can also hang clothes and towels to dry after bathing on their own, and they know that room fresheners will smell better if placed near a fan.

The primary focus of this study is the development of e-modules specifically designed for children with autism. Therefore, a teacher's guidebook has not yet been developed at this stage. The development of the e-module is prioritized so that the material can be accessed by children with autism according to their needs and characteristics and can enhance their critical thinking skills. However, in its implementation, the teacher's guidebook is still necessary as a guide in accompanying children with autism when using the e-module. The guidebook will later include learning strategies and technical instructions for using the e-module.

4. CONCLUSION

Conclusions about the Product

Based on the results of research and development of e-modules on abstract concepts of material changes in objects to improve the critical thinking skills of autistic children, it can be concluded that:

a. The e-module product on abstract concepts related to the transformation of physical objects, designed to enhance critical thinking skills in children with autism, can be used by children with autism based on expert evaluations of the content and media, which were rated as very good with a score of 48.5.
b. The product obtained from this research and development is an e-module on abstract concepts related to the transformation of objects, designed in accordance with critical thinking indicators, namely: Interpreting, which involves categorizing and classifying; 2) analyzing, which involves testing and identifying; 3) problem-solving; 4) explaining, which involves writing down results and presenting arguments; 5) drawing conclusions, which involves observing data and explaining conclusions. The product developed, according to the educators' response assessment, is practically very good qualitatively with a score of 4.85. The product developed is effective in improving the critical thinking skills of autistic children, as assessed from the overall aspects of critical thinking indicators, which are: 1) interpreting, which involves categorization and classification; 2) analyzing, which involves testing and identification; 3) problem-solving; 4) explanation, which involves writing down results and presenting arguments; 5) drawing conclusions, which involves observing data and explaining conclusions. The improvement in critical thinking in children with autism was reflected in an average total increase of 39%. The results of the Normalized Gain Test showed that the highest improvement in critical thinking skills was observed in subjects Vr and Gf, with a score of 0.75.

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