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Enhancing the Collegian of Early Childhood Critical Thinking Skills Through Development of Textbook Integrated STEM Learning Model

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ABSTRACT

The research aims to develop textbooks that are integrated with Science, Technology, Engineering, Mathematic (STEM) in training collegian critical thinking skills as a basic skill to be able to express ideas that have originality. The research carried out is classified as research and development using the ADDIE model which consists of analysis, design, development, implementation and evaluation. The population is early childhood education collegian consisting of two different classes with a total population of 118 collegian. The results shown that in two different classes regarding the urgency of statistics textbooks using the STEM approach and refers to the STEM Critical Thinking rubric and is able to fulfill the achievement of critical thinking skills indicators. Based on the research conducted it was concluded that the critical thinking indicators that integrates the STEM approach model which is supported by interesting features provided in textbooks which make it easy for students to access any information independently and able to make students think critically in learning activities. The implication to the study show that STEM-based statistics textbooks help students to understand educational statistics material thoroughly with the help of various innovative features used in the textbooks.

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1. INTRODUCTION

The educational paradigm is to facilitate students in every activity or learning activity. The learning process will involve the role of educators in helping students to elaborate on each material presented dynamically. It is hoped that the coverage of diverse material will be able to increase the abstraction ability of each subject derivation.

Innovation in the world of education through the implementation of the independent learning curriculum is a form of accommodation to train students' high-level skills, one of which is critical thinking skills as one of the basic skills elements of the 21st century (Trowsdale et al., 2019). Critical thinking skills are basic skills that students must have in formulating ideas, perspectives, as innovative solutions in solving the main problems faced and getting used to thinking metaphorically (Anderson & Davidson, 2019; Irawan et al., 2022). This is based on previous research conducted by Cheng which explained that students must be trained in higher level thinking skills (critical thinking) (Fachri, 2018; Southworth et al., 2023). So that they are able to abstract every idea as the result of original thinking (Sbhatu, 2021).

Research from OCED states that students' critical thinking skills are at a medium level, therefore innovation is needed that is able to facilitate students, especially in the learning process to empower critical thinking skills maximally (Bierman et al., 2021; Matsumoto-Royo & Ramírez-Montoya, 2021). Students who are accustomed to assimilating and mapping material constructively are able to integrate each material concept through an integrated approach to basic science concepts, mastering the use of technology, engineering skills, and skills in mastering mathematical concepts, better known as STEM (Gao et al., 2021; Parameswari et al., 2023). The development of STEM (Science, Technology, Engineering, Mathematics) is a form of integrated integration to accommodate students who not only master the concepts but are able to construct each basic concept they learn in a coherent manner (Rahimi & Shute, 2021).

This is supported by research that has been conducted that STEM does not only develop students' basic skills in certain aspects but is able to empower students to master each basic concept learned. Previous research revealed that using the STEM approach will lead students to be more interested and more sensitive in understanding the coherence of each concept they learn with their learning experience (Thahery, 2023; Wulandari & Supriyanto, 2018). Through attitudes, being proactive in arranging each idea or concept in an integrated manner and systematic way that significantly improves students' critical thinking skills (Zou'bi, 2021).

Similar research conducted in 2021 explained that the STEM approach is very integrative in training students' critical thinking skills because it links each basic concept with the students' ability to interpret each basic concept as something that must be understood thorough and able to train students' metaphorical thinking skills which are the main indicator of achieving critical thinking skills (Lei et al., 2021; Mahanal & Zubaidah, 2017; Syaripudin et al., 2023). Structured interviews conducted by students revealed the fact that innovative approaches and teaching materials are needed that are able to direct and facilitate students to understand the integration of each concept as a whole which correlates in improving students' critical thinking skills. Similar research has been carried out in integrating STEM in training students' skills but is only limited to aspects and indicators of critical thinking skills, so that the research that will be carried out is not limited to just fulfilling the indicators of critical thinking skills but is adjusted to the STEM Critical Component indicators which are interconnected so as to provide implications.

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Based on the problems raised from the results of interviews and initial needs analysis, the obstacles faced by students should not be allowed to occur continuously because it will make students less enthusiastic in every learning process so that they are unable to study every learning material. Thus, the innovation carried out is conducting research by integrating STEM in developing textbooks that are able to facilitate students in abstracting each learning material in a structured manner that is able to train critical thinking skills.

2. METHODS

The research carried out is classified as research and development (R and D). The development model used is the ADDIE model which consists of 5 main stages, namely: 1) Analysis; 2) Design; 3) Development; 4) Implementation; and 5) Development. The choice of model is tailored to the needs for developing teaching materials in educational statistics material which is developed by developing innovative content, constructs and designs and evaluating them in stages in each process/development cycle in a dynamic and continuous manner. The evaluation process carried out aims to improve each content and feature fiber design used in making teaching materials as a form of reflection on the preparation of each component to student needs regarding the statistics teaching materials being developed. The operational design for developing teaching materials can be seen in the **Table 1** below.

Table 1. Operational design and theoretical framework.

Operational Design	**Research design**		**Research Effectiveness**
	Theoretical study	**Development Studies**	
Design Goals	Elaboration on the use of innovative features in teaching materials	Innovative solutions according to collage needs	Initial framework/prototype
Focus on Design Quality	Increase collage learning motivation	Training collage critical thinking skills	Supports the MBKM program
Knowledge Claims/Scientific Output	Integration with STEM	Factual concepts for the material students study	Cooperative learning activities
Practical Contributions	21st Century skills enhancement	implementation Independent Learning Curriculum	Become a prototype for a unique development design

Research procedure for this study can be seen in the **Figure 1**.

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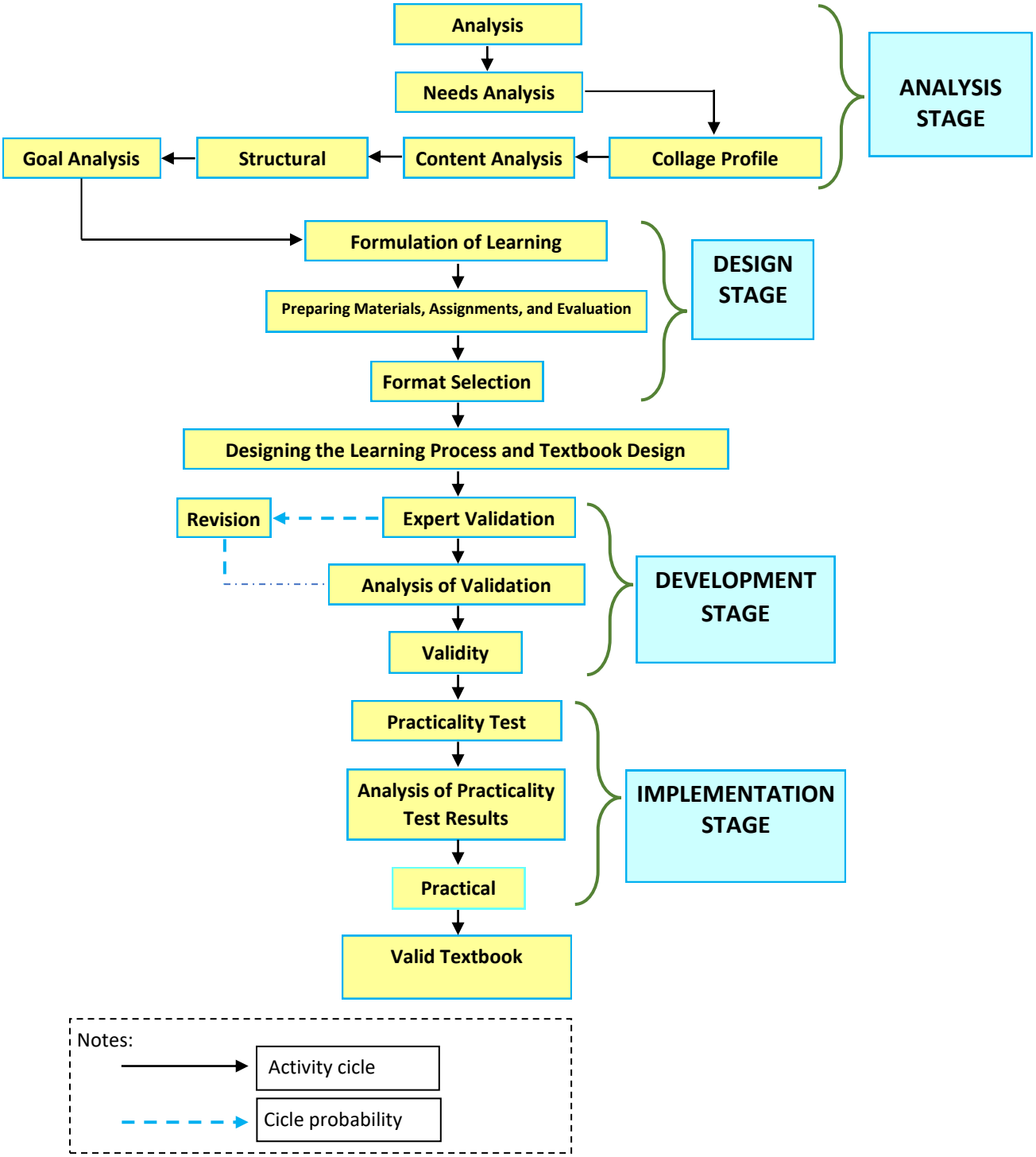

Figure 1. Research procedure.

3. RESULTS AND DISCUSSION

3.1. Analysis stage

Researchers collect primary data as the main data in carrying out the research process in identifying each problem for which a solution will be provided in accordance with the teaching material development process that will be implemented by, (1) conducting initial primary analysis; (2) analyzing student problems; (3) analyzing content; (4) analysis of the structural framework; and (5) determining the main development objectives in accordance with the hierarchy of making teaching materials which is carried out dynamically and carried

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out a simultaneous evaluation process. The needs analysis aims to summarize all factual information which is used as a guide for researchers in bringing together all information from various credible, up-to-date data sources which will be combined into all coherent information about the initial stages of learning material and distribution of questionnaires to students. So, that information is obtained that currently there is a problem.

The urgency faced is the problem of media and learning resources that are less innovative as a result of which students do not understand the material in educational statistics lessons. Based on observations made by researchers, the problem of limited time allocation to understand each derivation of material or basic concepts from the education statistics course with various sub-themes which are reduced to small sub-units in the context of learning material so that the material must be thoroughly understood by every student. Each educational statistics learning sub-material has a different conceptual depth, so students need critical thinking skills to integrate each topic (sub-theme) of the learning material and it is structured comprehensively. Summary of critical thinking sub skills can be seen in the **Table 2**.

Table 2. Summary of critical thinking sub skills.

No	Critical Thinking Skills Indicator	Sub Skills	Description
1	*Interpretation*	Categorization and abstraction of material	Understand and describe in general the integration of each material/general study of the topic or sub-chapter of the learning material
2	A*nalysis*	Review arguments, ideas, and confirm their suitability based on facts	identify/retrace inferential relationships between descriptions, statements, arguments systematically and coherently
3	*Evaluation*	Assess the suitability of the argument with the overall concept	Assessing the credibility of every idea, notion, point of view, perception that is related to each other and must be specifically addressed so as to produce meanings that do not overlaping
4	*Inference*	Develop alternative hypotheses that can be raised as alternative solutions to problems	Identify, formulate and conclude every important information from every idea or initial idea that comes from valid data so that its validity can be accounted for, so that the hypothesis prepared has validity
5	*Explanation*	State the results comprehensively	Provide specific reasoning based on the data that has been obtained so that the ideas presented are the result of students' critical thinking
6	*Self-regulation*	Reflection on yourself	A form of reflection on the cognitive results and changes in attitudes obtained by students in each learning process which is carried out dynamically and effectively

Needs analysis can be seen in the **Table 3**.

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Table 3. Needs analysis.

No	Indicator for assessment	Class A		Class B	
		Totally	Percentage (%)	Totally	Percentage (%)
1	Variations in teaching materials used in the learning process	10	28.5	11	31
2	Collage ability to abstract material concretely through teaching materials	12	34	14	40
3	Students need innovative learning resources	13	37	11	31
4	Students want teaching materials that are representative in understanding statistical material which has very extensive derivations	30	88	32	91
5.	Students need statistics teaching materials that are able to facilitate students in studying and understanding the sequence of materials and statistical application techniques in the field of education	33	91	32	91

Based on the results of the table analysis summarized in **Table 3**, the average percentage shows that of the five aspects used as a basis for assessment. It shows that 56.8 percent of students want a representative statistics textbook that can help them in abstracting each learning material.

3.2. Content analysis

Content analysis is very important to determine the suitability of each content or material that will be presented through teaching materials. Each learning material must have an appropriate hierarchy and the basic concepts do not overlap which can give rise to misconceptions for students when learning using teaching materials that have been designed with appropriate features and materials. Dimension of "STEM Critical Component can be seen in the **Table 4**.

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Table 4. Dimension of "STEM Critical Component".

STEM Aspects	Integration with textbooks	Dimensions	Taxonomy of STEM Achievement	STEM integration	
				Study Activity	Form of evaluation in textbooks
Understand basic concepts in an integrated manner	Textbooks contain material in a coherent manner accompanied by important information in the summary section or video links for more specific elaboration of the material	Able to understand and determine basic concepts hierarchically	Collaborative	Discussion	important terms, quiz
Integration with mathematics/basic science concepts	The sequence of materials is coherent with the novelty of mathematics and the basic concepts of science that apply in general	integration of math/science and engineering science approaches	Receptive	Discussion	Glossary, quizzes, important terms
	The study topic focuses on discussing problems in the field of education which are based on appropriate data	Examining scientific phenomena based on basic concepts of educational science	Collaborativ	Simulation (Practicum)	Forums, assignments
Orientation to the latest technological developments	The material is equipped with a procedural approach regarding how to use SPSS in analyzing related research data	Use of technology in the field of education (Using SPSS in analyzing research data	Collaborativ	Observation	Practice using SPSS software
Collaboration/ cooperation	Interaction of each student in studying, examining problems by using various features that have been provided in the teaching materials that have been prepared	Proactive attitude in using a procedural approach in solving problems in the field of education	Collaborativ	Practicum	Project Tasks

3.3. Design stage

Based on the design of features that can be integrated with indicators of critical thinking skills and STEM Critical Component components. The derivation and coverage of educational statistics material is diverse and consists of sub-chapters which require a certain approach in the process of disseminating the material as a whole and comprehensively so that students are directed in mapping each basic concept of the material being studied. The following innovative features have been developed can be seen in the **Figure 2**, **Figure 3**, and **Figure 4**.

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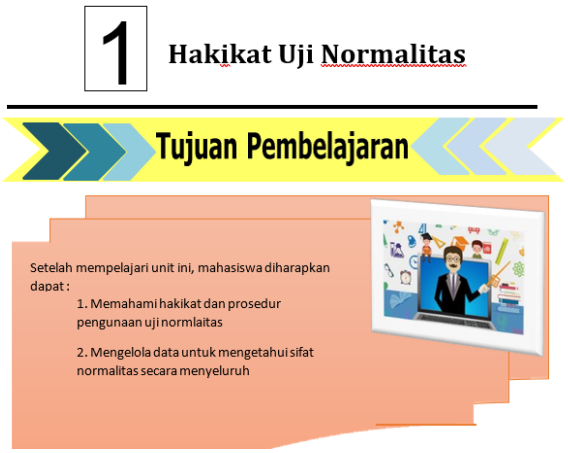

Figure 2. Material design.

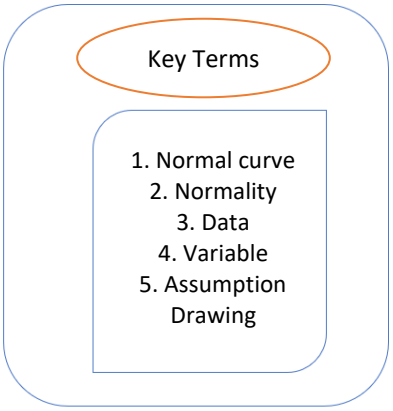

Figure 3. Glossary.

Figure 4. Barcode to access video.

3.4. Development stage

The design of various features and aspects are developed in detail and become a single unit that cannot be separated because they are integrated between each component developed. To determine the suitability of each aspect and component, a validity and reliability test was carried out. The results of which can be seen in the following **Table 5**.

Table 5. Validity and reliability results.

No	Aspects	Reliability	Validity		Decision
			r value	r table	
1	Feasibility and scope of material/content	0,85	0,672	0,189	valid
2	Presentation procedures	0,87	0,598	0,201	valid
3	Language Use Techniques	0,80	0,612	0,184	valid
4	Complete range of innovative features	0,88	0,534	0,210	valid
5	Ease of use of features in textbooks	0,81	0,521	0,183	valid
6	The teaching material features are adaptive, innovative and in accordance with student needs	0,82	0,611	0,161	valid

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3.5. Development of STEM-based teaching materials

The development of teaching materials is adapted to the basic elements of STEM which includes several main components based on the "STEM Critical Component". Dimensions consist of the ability to abstract basic concepts in a hierarchical manner. This is based on the first component of STEM, namely the ability to reason with scientific concepts in training students' critical thinking skills.

Students are expected to have high retention skills in detailing each topic of learning material as one of the characteristics of critical thinking skills by using the learning resources used (Trowsdale et al., 2019). Previous research explains that student retention can be increased by using innovative media or learning resources that do not cause boredom for students. So that motivation to understand each learning material increases continuously and this becomes a factual basis for students to take part in learning (Binali et al., 2021).

The textbook materials prepared are oriented towards the basic principles of science that recognize basic concepts in basic statistics courses. The teaching materials developed are equipped with a contextual study of the material (Lobczowski et al., 2020; Sharif, 2019). This is supported by previous research which shows the results that the main basic concepts of STEM are based on the ability to master scientific concepts by students in a coherent manner, and this is actually proven by the ability to abstract the concepts/facts learned by students (Irawan et al., 2022; Zhou, 2021).

The textbook materials developed are equipped with applicable techniques in using the SPSS application which are integrated with the ability to master technology which is a basic element in understanding STEM principles (Utami et al., 2021). This is based on the results of previous research, the results of which show that technology is an integrative basic aspect in training and empowering the STEM approach in training students' critical thinking skills through assimilation of managing inferential data in a sustainable manner (Lei et al., 2021; Zhang & Chen, 2021). The concept of mastering technology is very appropriate to the statistics textbook because it directly trains students' interpersonal skills in using the latest technology (*cutting-edge* technology) which is used in the field of education as study material in analyzing and mapping data to be managed into complete and unique information. As a form of integration in the STEM approach (Kaczkó & Ostendorf, 2023; Yildiz & Yildiz, 2021).

3.6. Development of teaching materials to train critical thinking skills

Fulfillment of indicators of critical thinking skills in the process of developing teaching materials is based on the initial ability to abstract the material. Through the teaching materials developed, students will review each material which is the main content for students to provide a real picture of the depth of each learning material in each sub-chapter. The development of educational video features in teaching materials becomes a reference for students to be able to directly apply the SPSS application, so that students are able to abstract any data provided according to the orientation of the data that will be processed by students (Bilik et al., 2020; Németh & Palmer, 2019).

This trains students to analyze each data comprehensively using technology. This is the integration of the STEM approach in empowering students' critical thinking skills through the process of interpretation and analysis of each data component. Research which examined the development of textbooks in training students' critical thinking skills, revealed the results of their research that initial interpretation and analysis skills in mapping each source of information/data sources became a basic framework (Li et al., 2021; Tikva & Tambouris, 2021; Fricticarani et al., 2023; Zulkarnain et al., 2021). Substantive elements that

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became the foundation students must be trained to be able to think critically and comprehensively about each problem given in relation to the main content of the learning material (Alsaleh, 2020; Zhou, 2021).

The important terms feature will enable students to understand each term of the interrelated concepts and be able to summarize these important terms through further literature review which is part of fulfilling indicators of interpretive skills in categorizing and creating concept maps by combining and aligning each term. important. This is supported by research conducted by Zubaidah (2022) that students need to summarize every important term that can be categorized and arranged in a unified concept map so that the relationship between each important term can be explained flexibly as a student's critical thinking ability.

Further feature development based on analysis and evaluation indicators is equipped with a video about analysis techniques using SPSS which are adapted to the test techniques in each sub-chapter (Dolničar et al., 2020; Pujiati & Yulianto, 2021). Students can watch the videos provided by scanning the barcode which has been equipped with appropriate analysis instructions. In this way, it is hoped that students will be able to evaluate any data provided in training students' critical thinking skills in understanding each data correlation inferentially which is able to empower students' critical thinking skills because students are accustomed to managing each data and its derivations through appropriate analysis techniques (Facer & Sriprakash, 2021). Furthermore, discussion space is provided for students by providing study topics that are appropriate to practical educational problems that require a statistical approach in solving or providing solutions to the problems being studied (Kaffah, 2020; Matsumoto-Royo & Ramírez-Montoya, 2021).

Similar research reveals that in training students' critical thinking skills, they must be accustomed to solving factual problems related to educational studies obtained in the classroom and in the community environment (Sennen et al., 2020; Kokshagina et al., 2021). The task or assignment forum feature outlined in the textbook aims to train students' inference and explanation abilities in completing the tasks given which relate to students' reasoning abilities in exploring various ideas, concentrating ideas in tracing each information from the data obtained (Anshori, 2018; Zhou, 2021). So that they are able to create causality of ideas from the results of reasoning power so that they are able to provide informative ideas and suggestions as a product of critical thinking (Santos, 2017).

4. CONCLUSION

Based on the results of the research that has been carried out, it can be concluded that the development of textbooks using the STEM approach is able to train students' critical thinking skills through various innovative features that suit the needs of students in training and improving each skill they want to train in a dynamic and structured manner. The limitations of the research conducted are that the variables measured are still limited to students' critical thinking skills, so it is hoped that in subsequent research the variables measured can be developed more broadly so that they have broad implications in the world of education.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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