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ORIGINAL

Meedace: A 5E modified model to improve students' critical thinking skills

Meedace: Un modelo modificado de 5E para mejorar las habilidades de pensamiento crítico de los estudiantes

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ABSTRACT

Introduction: critical thinking skills are important competencies in the 21st century and support Indonesia's SDGs 2030, which emphasizes the importance of these skills to achieve sustainable development goals. The 5E instructional model, although widely applied, presents challenges for teachers with limited innovation capacity. To address this, the 5E model was modified into the MEEDACE model, which combines mind mapping strategies, inquiry-based approaches, real-life contextual problems, and project-based problem-solving.
Method: this study utilizes the ADDIE development model to design and evaluate the effectiveness of the MEEDA learning model. The resulting MEEDACE instructional syntax consists of seven stages: (1) Mind Mapping, (2) Exploration, (3) Explanation, (4) Discovery, (5) Application, (6) Communication, and (7) Evaluation.
Results: ANCOVA test results showed a significance value of 0,000 (< 0,05), indicating a significant difference in students' critical thinking skills between classes using the MEEDACE model and those using the control model. The corrected average score was 79,926 for MEEDACE, 72,284 for the 5E model, and 68,140 for the conventional model.
Discussion: these findings show that the MEEDACE model effectively improves students' critical thinking skills by integrating innovative and contextual learning strategies that fit the demands of modern education.
Conclusions: the MEEDACE learning model significantly improved critical thinking skills compared to the 5E and conventional models. The integration of mind mapping, exploration, and real-world problem-solving fosters deeper understanding and student engagement.

Keywords: Meedace Model; 5e Learning Model; Critical Thinking Skills; Inquiry-Based Learning.

RESUMEN

Introducción: las habilidades de pensamiento crítico son competencias importantes en el siglo XXI y apoyan los ODS 2030 de Indonesia, que enfatizan la importancia de estas habilidades para lograr los objetivos de desarrollo sostenible. El modelo de instrucción 5E, aunque se aplica ampliamente, presenta desafíos para los maestros con capacidad de innovación limitada. Para abordar esto, el modelo 5E se modificó en el modelo MEEDACE, que combina estrategias de mapas mentales, enfoques basados en la investigación, problemas contextuales de la vida real y resolución de problemas basada en proyectos.
Método: este estudio utiliza el modelo de desarrollo ADDIE para diseñar y evaluar la efectividad del modelo de aprendizaje MEEDA. La sintaxis instruccional MEEDACE resultante consta de siete etapas: (1) Mapas mentales, (2) Exploración, (3) Explicación, (4) Descubrimiento, (5) Aplicación, (6) Comunicación y (7) Evaluación.
Resultados: los resultados de la prueba ANCOVA mostraron un valor de significancia de 0,000 (< 0,05), lo que indica una diferencia significativa en las habilidades de pensamiento crítico de los estudiantes entre las clases que utilizan el modelo MEEDACE y las que utilizan el modelo de control. La puntuación media

corregida fue de 79,926 para MEEDACE, 72,284 para el modelo 5E y 68,140 para el modelo convencional.
Discusión: estos hallazgos muestran que el modelo MEEDACE mejora efectivamente las habilidades de pensamiento crítico de los estudiantes al integrar estrategias de aprendizaje innovadoras y contextuales que se ajustan a las demandas de la educación moderna.
Conclusiones: el modelo de aprendizaje MEEDACE mejoró significativamente las habilidades de pensamiento crítico en comparación con los modelos 5E y convencionales. La integración de mapas mentales, exploración y resolución de problemas del mundo real fomenta una comprensión más profunda y la participación de los estudiantes.

Palabras clave: Modelo Meedace; Modelo de Aprendizaje 5e; Habilidades de Pensamiento Crítico; Aprendizaje Basado en la Indagación.

INTRODUCTION

21st century competencies urgently need to innovate thinking skills, including critical thinking and problem-solving (*critical thinking and problem solving*), communication (*communication*), collaboration (*collaboration*), as well as creative thinking innovations (*creativity and innovation*).[1,2,3,4] Students' understanding of the skills needed in the 21st century needs to be fully empowered.[5] Critical thinking skills are one of the skills needed in the 21st century.[6] Critical thinking skills are skills to perform various analyses, evaluations [8] and reconstruction of decision-making that leads to rational and logical action.[8] Rational and logical actions formed from critical thinking need to be provided to students.[9] Critical thinking skills can facilitate students to find diverse ways to overcome difficulties and access information.[10] Students who have strong critical thinking can make accurate and credible decisions,[11] so that it can be useful in real life and have opportunities to achieve educational goals.[12] Therefore, it is necessary to empower critical thinking skills.[13,14,15]

Facts in the field are found that critical thinking skills have not been optimally empowered. Based on the results of the needs analysis that has been carried out in January-February 2023 to 325 students at Pidie Regency High School, Aceh Province using test instruments in the form of description questions (*Essay*) critical thinking skills, showing the results that the level of achievement of critical thinking skills gets an average score of 38,91 with non-critical criteria. Several other relevant research results found that the level of achievement of critical thinking skills in high school is still relatively low or not optimal. The critical thinking skills found at the Southwest Regency High School, Aceh Province carried out on 143 students are still relatively low, especially Biology learning with an average of 30,2.[16] The critical thinking skills found at SMA Negeri Padang Panjang, West Sumatra, which were carried out on 33 students, received an average of 55,73 with a low category[5] and the level of achievement of critical thinking skills for 195 students at Semarang Regency High School received an average of 56,6 % and was categorized as quite critical.[17] In general, the level of achievement of critical thinking skills in Indonesia is still relatively low.[18] Based on several findings that have been presented regarding the level of achievement of critical thinking skills, critical thinking skills still need to be empowered optimally.[19,20,21]

Student-centered learning provides an active learning space, one of which is the 5E model, has the advantage of being able to help students practice critical thinking skills.[22,23,24,25] However, the 5E model still found some shortcomings, at the *Engage* still lacks to provide students with active involvement in the learning activities that the teacher has planned,[26] implementing active learning in the classroom is not a simple task, especially if the teacher is not experienced with previous approaches,[27] it will be felt to be cognitively burdensome for beginner students. The learning activities of the 5E model are difficult for teachers who do not want to innovate, and must be adjusted to the cognitive load of beginner learners, so the model is innovated into the MEEDACE model, the learning activities contain strategies *A Mind Map,* inquiry approach, problems that are close to students are found in daily life and seek *solution* problem solving is supported by project activities.

The alternative model designed is expected to help students provide an active learning space supported by providing problems that are often found in daily life in learning materials and engaging in project learning activities by producing products as alternative solutions in the problem-solving process as an effort to solve problems found in daily life. The purpose of the research is to modify the 5E model so that learning facilitates learning activities by considering the needs of students and curriculum demands.

METHOD

This study uses a quasi-experimental design with a quantitative approach. The sample selection was carried out intentionally (purposive sampling) based on the characteristics of students who have a homogeneous level of ability and come from high schools (SMA) in Aceh Province. The total number of study participants was 180 students, consisting of 62 students in the experimental group (using the MEEDACE model), 64 students in the

positive control group (using the 5E model), and 54 students in the negative control group (using conventional learning).

This research was conducted in the period from January to April 2023, including the planning, implementation, data collection, and analysis stages.

The development model used in this study is ADDIE (Analysis, Design, Development, Implementation, Evaluation) to design the MEEDA learning model. The operational definition of the MEEDACE model refers to a combination of mind mapping, exploration, concept discovery, and project-based problem solving, which aims to develop critical thinking skills.

The data collection instrument is a critical thinking skills test developed based on the Facione framework, including six indicators: interpretation, analysis, inference, evaluation, explanation, and self-regulation. The test consists of description questions and is equipped with a valid and reliable assessment rubric. The instrument has been tested before and is declared suitable for use.

The procedure for conducting the research began with a pretest to measure students' initial critical thinking ability, followed by the provision of learning treatment according to the model in each group, and ended with a posttest. All learning activities are facilitated through student worksheets (LKPD) and project guides.

The collected data is systematically stored and managed using anonymous encryption to maintain the confidentiality of participants. All digital data is secured in encrypted storage and can only be accessed by the principal investigator. The analysis process was carried out with SPSS software version 24.0, using the Kolmogorov–Smirnov normality test, the Levene's Test homogeneity test, and the ANCOVA test to determine the difference in scores between groups. Hypothetical decisions were determined based on significance values ($p < 0,05$).

RESULTS

The results of the Ancova test showed a significant difference in critical thinking skills between students who studied using the MEEDACE learning model, the 5E model, and conventional learning. This finding was strengthened by the acquisition of the corrected average score of the MEEDACE model, which was 79,92 – higher than the 5E model (72,28) and conventional learning (68,14). MEEDACE's learning model supports the improvement of critical thinking skills.

Table 1. Normality Test Results

Group	Pretest		Postest	
	Nilai Sig.	Information	Nilai Sig.	Information
Eksperimen (MEEDACE)	0,200	Usual	0,062	Usual
Positive Control (5E)	0,189	Usual	0,089	Usual
Negative Control (Conventional)	0,200	Usual	0,200	Usual

Source: Personal data processing

Table 2. Homogeneity results

	Nilai Sig.	Information
Pretest	0,274	Homogeneous
Postest	0,443	Homogeneous

Source: Personal data processing

Table 3. Corrected Average Results

Variable	Group	Mean
Skills	Eksperimen (MEEDACE)	79,926
Think	Positive control (5E)	72,284
Critical	Negative control (Conventional)	68,140

Source: Personal data processing

The initial stage of students is assigned to make *mind map* related to the material to be studied. Teacher assigns assignments *mind map* in the previous meeting. Students work on the assignment at home before the

learning process takes place regarding the material to be studied, by reading various relevant sources,[28] so that students actively dig into initial knowledge information to prepare for learning. Low initial knowledge affects biology learning.[29] Preparation of early knowledge in learning is very important,[30] and has a good influence on learning, so initial knowledge needs to be activated [31] to empower critical thinking skills.[32] Strategy *mind map* Help encourage students to have initial knowledge that can connect relevant information to understand a material, so that students can easily remember information from the learning process. In addition, through *mind map* Help students visualize material by connecting various information in a structured way, by summarizing and organizing information, connecting relevant concepts, and presenting a comprehensive picture of a topic being studied.[33] *Mind map* is an innovative strategy that impacts learning and empowers students' thinking skills.[34] Habituation of thinking skills needs to be empowered so that it makes it easier for students to learn.[35]

Through tasks *mind map* Opportunity to be an interesting resource to help students learn and organize information.[36] Based on previous research, the strategy *mind map* has been shown to be effective in supporting empowering critical thinking skills,[36,37,38] and support Creative thinking skills.[39,40,41,42] *Mind map* is an effective tool that provides opportunities for students to share information with each other during discussion activities. [43] Strategy *mind map* visually plays an important role in helping students explore, analyze, synthesize, share ideas, organize and organize information and connect relevant information.[44] Stategi *mind map* It also helps visualize and construct knowledge so that it acquires complete knowledge [45] such as by improving long-term memory, focusing on learning, facilitating the learning process, increasing motivation, creativity, time efficiency and creating fun learning.[46] Through *Mind Map* makes an important contribution to motivating student learning in the early stages so as to create active learning in the classroom. Learning motivation has a very close relationship to create active learning.[47,48] This learning leads students to do activities that require them to think about what they are doing. Where students build their own learning experience by making a mind map at home.

Stages *exploration*, Students have the opportunity to gain hands-on experience before a formal explanation of the terms, definitions or concepts explained or discussed by the teacher.[49] Students can find information from various relevant sources in solving problems that have been presented in the LKPD. The problems provided are very in accordance with the latest developments and close to students so that it is expected to attract interest in learning to solve them, namely contains problems that occur in Aceh Province such as the damage that occurred in the Gunung Lauser National Park (TNGL) caused by forest conversion, the problem of conflict between Sumatran elephants and humans, the problem of river pollution in the city of Banda Aceh and the problem of fruit skin pollution.

Problems that are close to students encourage meaningful learning. Meaningful learning builds on students' previous knowledge and experience and actively engages them in engaging and challenging tasks, which supports the attainment of conceptual understanding and workable skills,[50] because in the biology learning space itself is faced with complex problems.[51] Furthermore, in solving the problem, students sit in small groups that have been determined, and work on the LKPD in groups. Learning done in groups can help students complete the assigned tasks better.

Phase *explanation*, Students can explain new concepts or ideas that are relevant to the material being studied based on the findings in the exploration results.[27] Students explain the results of the exploration based on the LKPD that has been given, by involving students in groups to Present the results of thinking about alternative problem-solving solutions and the alternative choice of solution and the reason. Giving reasons in choosing alternative solutions is very important, so finding a solution is considered the most appropriate. This stage can provide opportunities for students to give each other responses and input to other group explanations. Provide feedback from fellow peers, provide critical thinking in the learning process. If something is considered inappropriate, students can critically give arguments/opinions for improvement. Giving opinions from other friends' explanations provides opportunities for critical thinking in the form of explanations or providing explanations. Student opportunities can encourage students to explain the big ideas learned at the exploration stage.[52] Furthermore, the results of the activities found at the explanation stage are directed to develop a conceptual understanding that is relevant to real problem-solving activities in the form of project products.

Phase *discovery,* Students put forward ideas/ideas to design the project products to be developed. Result discovery Providing solutions to problems can be developed in the preparation of project products. Students can put forward ideas/plans from each group member who appears. Students discuss in groups to compile or design a project to be done. The ideas they developed. Furthermore, students prepare the tools and materials needed to carry out the project such as designing educational video products related to the preservation of the Gunung Lauser National Park (TNGL) ecosystem, designing Sumatran Elephant conservation education poster products, environmental conservation video products to overcome environmental pollution and making products *Eco-enzymes* to overcome the problem of fruit skin pollution in the surrounding environment. *Eco-enzyme*. *Eco-enzyme* is one of the sources and learning media in the surrounding environment that can be raised in the learning process[53] and Another activity is in the form of making videos. Students are very enthusiastic

about preparing the material that will be presented in the video creation in detail, preparing the images that are loaded in the video. camera *smartphone*, using software in the form of *Capcut* for the editing phase.

Activities *discovery* It looks very enthusiastic so that it makes it active in the process of learning activities. This stage supports the theory developed by Jerome Bruner, where learning emphasizes the importance of students understanding the structure and key ideas of a discipline, the need for students' active involvement in learning, and true learning comes through *discovery* (discovery). Through *discovery* encourages students to empower critical skills to solve problems that occur in life. The curriculum is very suggests that life-based learning can be an effective alternative to embedding subject matter in a meaningful real-world context, where students are encouraged to learn authentic issues, solve real problems, or work on projects with a clear practical goal.[54] Next Students adhere to the schedule of project completion activities. Students ask the teacher for help if they find difficulties. Teachers can play the role of *scaffolding*, that is, providing assistance to students during the early stages of learning then reducing it and giving students the opportunity to take on greater responsibilities after the student is able to do so.

Phase *application*, students carry out project products according to a predetermined schedule, students complete projects Students get guidance if they encounter difficulties. Students test products as problem-solving solutions based on predetermined conditions.[55] Students together with their groups carry out video making activities education related to the preservation of the ecosystem of Gunung Lauser National Park (TNGL), the preservation of Sumatran Elephants, and environmental conservation to overcome environmental pollution that has been designed in *discovery*. The purpose of making videos is to provide education to both their friends and the community.

Video uploads on YouTube provide extensive educational information, with the hope that they can contribute to providing education that it is important to protect the environment so that the balance of the ecosystem remains protected as a future asset. This stage encourages students to think critically in providing information that is considered important to be educated, encourages creativity in designing videos and creates fun learning. Video assignment creates effective and enjoyable learning by providing a meaningful learning experience for students.[56,57] Project activities contain innovative learning elements that are widely effectively applied in the learning process and students must be exposed to the practice of real-life problems, in addition to encouraging linking theory with real practice, students are trained to provide a variety of possible solutions as well as encourage critical thinking and problem-solving skills. Students are actively encouraged and challenged to apply knowledge from various disciplines in formulating ideas that are able to solve complex problems.[58]

Phase *communication*, after students have completed the product or solution and are then communicated or presented to their peers in front of the class, presentations are an important step in the learning process to develop communication and collaboration skills as well as the ability to receive and apply constructive feedback. In addition, project learning stimulates confidence, independence and communication.[58] Students received feedback from teachers regarding the project project presented, as an effort to help students also find difficulties. In addition, the teacher appreciated the presentation that had been made. Giving appreciation for project assignments helps students. The last stage is in the form of *evaluation* to the learning experience. Each group that has presented the project has received an assessment from the teacher. Students in groups and individuals can express their experiences in a discussion. Input from teachers and other students becomes a record for performance improvement as feedback from learning. Students also fill in the reflection column on the learning process and outcomes that have been experienced.[59,60] This series of processes involves students in inquiry activities because they encourage being able to answer the problems that have been given. Overall, the stages of the MEEDACE model have been proven to be effective in improving students' critical thinking skills.

DISCUSSION

The development of the MEEDACE learning model as a modification of the 5E model shows a pedagogical response to the challenges in developing students' critical thinking skills in the 21st century. This model combines *mind mapping* strategies, inquiry-based learning, contextual problem-solving, and real-world product-oriented project activities. The advantage of this model lies in its ability to simultaneously activate various cognitive domains of students, from the activation of initial knowledge to the evaluation of learning outcomes.

Empirically, the results of the ANCOVA test show that the MEEDACE model has a significant influence on improving critical thinking skills compared to the 5E model and conventional learning. This increase was statistically reinforced by a significance value of $p < 0,05$ and a higher mean score in the experimental group. These findings are in line with the research of Mutakinati et al.[21] and Zubaidah et al.[42] which emphasized the importance of project-based strategies and information visualization in stimulating higher-level thinking skills.

Further analysis of MEEDACE's learning stages shows that there is continuity between each phase in encouraging active student engagement. In the *Mind Mapping stage*, students build an initial representation of the concepts to be learned, which theoretically supports schematic activation and strengthens the process of

elaborating new information.[32] This stage shows the importance of student involvement before the learning process begins, as a form of *flipped classroom* that develops learning autonomy.

The *Exploration* and *Explanation* stages in this model present real-world contexts, such as local environmental issues (TNGL forest conversion, animal conflicts, and pollution), which stimulate meaningful *learning*. This strategy affirms the opinion of Ausubel that learning will be more effective when new information can be substantively related to the cognitive structure that students already have. The model also accommodates cross-disciplinary learning and encourages knowledge transfer to authentic situations.

The *Discovery* and *Application* stage reinforces the principle of social constructivism (Vygotsky), in which students collaboratively develop products as solutions to the problems they face. Project activities such as educational video creation and *eco-enzyme* not only encourage creativity, but also integrate concept understanding with communication skills and digital literacy. This process places students as *agents of change* in the context of their environment.

Furthermore, the *Communication* and *Evaluation phase* functions as a reflective space to construct the meaning of the learning experience. The presentation of project results encourages metacognitive skills and opens up space for *peer feedback* and authentic assessment. The evaluation phase, which is formative and summative, ensures continuity between the learning process and assessment, in accordance with the *assessment for learning* approach.

Overall, the MEEDACE model shows that contextual and well-structured learning has great potential in improving critical thinking skills. The integration of *mind mapping* strategies and *project-based learning* provides a great opportunity to support transformative learning, especially in the context of science education at the secondary level. These findings reinforce the importance of learning design innovations that are in favor of students' learning needs and relevant to real-world complexities.

CONCLUSION

The MEEDACE model in biology learning has been shown to be effective in improving critical thinking skills. As an alternative solution, the MEEDACE model has the potential to support the optimal development of critical thinking skills. The MEEDACE learning model makes a great contribution in helping students understand the material in depth according to the learning objectives that have been set.

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CONFLICT OF INTEREST

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