Development of E-Module Assisted with Augmented Reality Integrated STEAM to Improve Students' Creative and Critical Thinking Abilities

Susilawati
Sekolah Tinggi Agama Islam Al-Bahjah
susilawati@staialbahjah.ac.id

Abstract
21st-century learning emphasizes the use of technology in the teaching and learning process. One way that educators can optimize technology-based learning is by developing interesting teaching materials in the form of e-modules. This research aims to develop an e-module assisted by Augmented Reality (AR) integrated with Science, Technology, Engineering, Art, and Mathematics (STEAM) to improve middle school students' creative and critical thinking abilities. The research method used is Research and Development (R&D) with the ADDIE model. The subjects of this research were class XII IIK students at a school in Cirebon City. The instruments used include validation, practicality, student responses, and tests. The research results showed that the e-module developed was in the very valid, very practical category and received a very positive response from students. The N-Gain test score obtained was 0.7240, which is included in the high category. This proves that the STEAM-integrated AR-assisted e-module is effective in improving students' creative and critical thinking abilities. This e-module innovation introduces AR technology as the newest approach in STEAM learning, so it is hoped that it can become a reference for the development of teaching materials in the future.
Keywords: ADDIE, Augmented Reality, E-Module, STEAM.

Introduction

The learning process in the 21st century requires students to have the ability to survive and compete globally. The abilities that students must have are the 4C abilities (Critical, Creative, Collaborative, Communicative). This is in line with (Rohmatulloh et al., 2023) which states that 21st century learning in educational units requires students to have 4C abilities, which include the ability to think critically. 4C abilities are basic abilities in the 21st century that are needed to cultivate talent and social development in the future (Ye & Xu, 2023). (Zhao et al., 2023) stated that 4C capabilities are also very important to apply in various situations. This shows that the 4C abilities not only help students learn but are also able to adapt to various situations in everyday life.

The ability to think creatively and critically is part of the 4C abilities which are very important in learning mathematics. The ability to think creatively is one of the key factors in 21st century life (Ayyildiz & Yilmaz, 2021) (Aisyah et al., 2024). According to (Hidajat, 2022), creative thinking is characterized by the ability to solve problems in an unusual,

unique, different, new and original way. The ability to think creatively is a mental process that is very useful and needs to be possessed by everyone to achieve success in every problem solving (Rahayuningsih et al., 2021). The ability to think creatively can train students to develop their knowledge through active and creative learning so that students can gain new experiences (Marliani, 2015); (Azzahra et al., 2023)

Critical thinking skills can help students process information logically and practice independent learning (Fatmiyati & Juandi, 2023). Through critical thinking, the ability to reason and face problems will increase, one of which is in the learning process (Ardiansyah et al., 2022); (Evendi et al., 2022). Students who have a strong capacity for critical mathematical thinking enable them to act logically and choose the best options for themselves (Al-Fanny & Roesdiana, 2019; (Firdaus et al., 2019). (Rachmantika & Wardono, 2019) stated that with the ability to think critically and mathematically, students can analyze, evaluate, reason, and interpret information. Based on this, creative and critical thinking skills are very important for students to have.

However, even though creative and critical thinking skills are very important, the reality on the ground is that these two abilities are still relatively low. According to (Siswanto & Ratiningsih, 2020), students' thinking abilities are still low, which results in students having difficulty solving mathematics problems. (Hastawan et al., 2023) also stated that students' abilities in critical and creative thinking are still relatively low. Based on observations made at one of the schools in Cirebon City, the results showed that students' creative and critical thinking abilities were still low, as seen from their answers which were still wrong in solving mathematical problems.

The above is because the learning provided does not produce problem-solving which results in a low ability to think critically mathematically (Benyamin et al., 2021), the learning process is still teacher-centered (Nurfitriyani et al., 2022); (Ratnawati et al., 2020); (Rismayanti et al., 2022), teaching materials that are not in line with advances in technology and science and do not support students in improving their ability to think critically (Dwijayanti et al., 2020). Students only focus on textbooks so that learning becomes monotonous (Liando et al., 2022). (Wannapiroon & Pimdee, 2022) stated that students' creative mathematical thinking abilities must be further improved by using a learning model that is supported by teaching materials that adapt to technological advances. So based on these conditions, efforts are needed to improve students' creative and critical thinking abilities in mathematics learning. Mathematics learning must be designed so that students

can develop creative thinking and critical thinking skills (Nugraha & Suparman, 2021); (Yuliani et al., 2021).

One effort to improve students' creative and critical thinking skills is by using electronic modules (e-modules) in the learning process (Suherman et al., 2021); (Nurlaili et al., 2021). E-module is a type of teaching material that contains material presentation that is arranged systematically and can display audio-visuals, animated videos, and interesting illustrations to attract students' interest in learning (Hardeli et al., 2023). Learning using e-modules is one way to make learning interesting (Lah et al., 2024). The use of e-learning modules is very relevant to technological developments (Padwa & Erdi, 2021). One of the newest technologies that can be integrated into e-modules is Augmented Reality (AR).

E-module assisted by Augmented Reality (AR) is a form of e-module that can develop students' creative and critical thinking abilities (Dewi & Kuswanto, 2023); (Noverianto & Munahefi, 2023). (Arena et al., 2022) stated that AR is a technology that allows users to see virtual objects in the real world which was developed from virtual reality technology. AR can display virtual objects in various forms, such as 3D models, animations, videos, or text (Ramadhan & Waluyo, 2023). (Rachmawati et al., 2020) stated that the use of AR is a model manipulation in a form that corresponds to reality so that it can be well received by students. In line with this, Arifin & Efriani (2024) stated that the use of AR in mathematics learning does not only make abstract concepts more concrete and easier to understand. Thus, AR is a technology that can improve and support the development of high-level thinking skills (Dewi & Kuswanto, 2023)

To maximize the use of AR-assisted e-modules, they are integrated with learning approaches. One of the learning approaches that has been in the spotlight in education in recent years is STEAM (Science, Technology, Engineering, Art, and Mathematics) (Kartikawati, 2023). The STEAM approach is becoming increasingly important because the world needs more STEM professionals who have broad skills and can adapt to change (Alfayez, 2024). In line with this, (Guimeráns-Sánchez et al., 2023) stated that STEAM prioritizes openness and equality in learning, and prepares students to face the challenges of the 21st century. STEAM also encourages students to observe, investigate, and ask questions to understand more deeply about the world around them (Rusni et al., 2023). Therefore, developing an AR-assisted mathematics e-module that integrates STEAM can be an alternative for improving students' creative and critical thinking skills in mathematics learning.

Method

The research method used in this research is the R&D research method. Research and development are research techniques used to create and test products that will be used in the educational sector (Rusni et al., 2023). The development model used is the ADDIE model. According to (Widyastuti & Susiana, 2019), the ADDIE model is a model for developing teaching materials that consist of a systematic sequence of steps to solve learning problems that focus on learning resources according to student needs and characteristics. The ADDIE research model consists of five stages, namely: Analysis, Design, Development, Implementation, and Evaluation (Kawete et al., 2022); (Tu et al., 2021). These five phases are interrelated and interact with each other (Zhang, 2020).

The proposed stages in product development and research have a more systematic and comprehensive approach compared to the other model, with more detailed and structured framework (Irviana, 2020; Iftitah, 2023). This is in line with Adeoye et al. (2024) which states that the ADDIE model provides systematic guidance for educators in designing and building quality learning. According to Luo et al. (2024) this model is designed with a systematic approach that fully takes into account the needs of students, so as to minimize the potential for bias.

One of the main advantages of the ADDIE model is the flexibility of the revision stages that can be carried out at each stage of development, allowing for continuous improvement and adaptation that is responsive to learning needs (Martatiyana et al., 2023). Thus, the ADDIE model allows developers to continuously improve the quality of products or learning materials based on the feedback and evaluations obtained. This ability to make revisions at each stage makes the ADDIE model a dynamic and effective approach in learning development.

The ADDIE model is currently widely applied technologically in various countries and has become the subject of extensive research in the Western region (Spatioti et al., 2022). Some researchers believe that the ADDIE model is flexible enough to be applied in a variety of learning environments and is suitable for integrating technology into teaching (Maddison & Kumaran, 2016); (Almelhi, 2021). In line with this, (Kurnia et al., 2019) also stated that the ADDIE model is still very relevant to use because it is flexible in various situations and

allows for revision and evaluation at each stage. The five steps for developing ADDIE in this research are explained in the following figure.

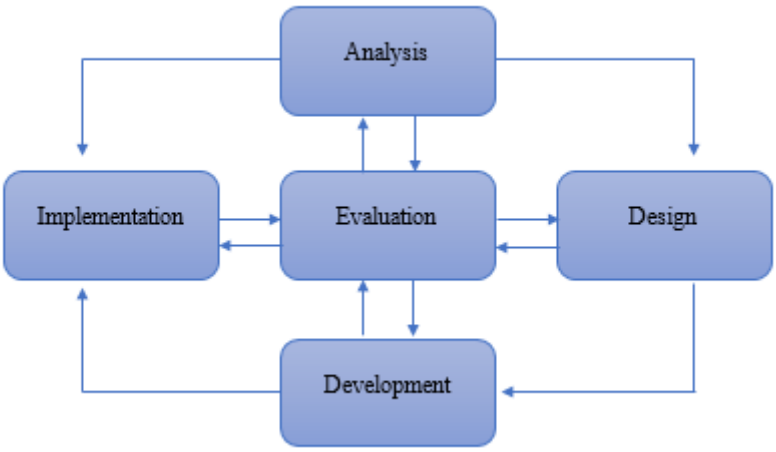

Figure 1. ADDIE Model

The subjects of this research were class XII IIK students at a school in the city of Cirebon. Subject selection is based on the student's condition by research needs. This research is also supported by the school environment, both from external and internal aspects and supported by the availability of adequate facilities and infrastructure. This research was also carried out by the learning plan that had been designed by the teacher.

The instruments used in this research are validation instruments, practicality, student responses, and tests. The validation instrument is a material expert and media expert validation sheet. This validation instrument is used to test the validity or validity of the development of a mathematics e-module assisted by STEAM-integrated Augmented Reality to improve students' creative and critical thinking abilities. The practicality instrument is used to test the practicality of the e-module being developed. Next, a student response questionnaire is used to determine student responses after using the developed e-module. These three instruments use a Likert scale with five alternative answers.

The test instrument used questions on critical and creative thinking skills on the subject of enumeration rules. The test instrument consists of class XII material questions in the form of descriptions that refer to indicators of creative and creative thinking abilities. Indicators of creative thinking abilities are fluency, flexibility, originality, and elaboration (Toheri et al., 2020); (Yaniawati et al., 2020); (ramirobass, 2023). Meanwhile, indicators of

critical thinking skills were adopted from (Facione, 2023), namely interpretation, analysis, evaluation, and inference.

The results of this test will be analyzed using N-Gain to measure the effectiveness of the STEAM integrated Augmented Reality assisted mathematics e-module developed to improve students' creative and critical thinking abilities. The N-Gain value will show an increase in student learning outcomes on the subject of enumeration rules before and after using the e-module. Next, the N-Gain value will be classified to determine the extent of the module's effectiveness in improving students' creative and critical thinking abilities. The following is a table of N-Gain level criteria (Komalasari et al., 2024).

Table 1. N-Gain level criteria

Average	Criteria
$g > 0,7$	High
$0,3 \leq g \leq 0,7$	Moderate
$0 < g < 0,3$	Low
$g \leq 0$	Fail

Results and Discussion

At this stage, an analysis of the curriculum, materials, student characteristics, and problems in learning is carried out. Based on the results of observations and interviews, several important things were found that became the basis for developing this e-module. First, the curriculum used is still based on the 2013 Curriculum, where the main learning source is textbooks borrowed from the library. The use of technology in teaching mathematics in class is still limited, even though all students have smartphones. Therefore, opportunities to integrate technology into learning become very relevant to help improve the quality of learning. In this case, Augmented Reality (AR) technology was chosen as the main component in the e-module because of its interactive nature and the ability to provide a more interesting and in-depth learning experience. Research by (Zulyati et al., 2022) shows that the use of technology in learning can improve student learning outcomes. This finding is in line with the opinion of (Adri & Suwarjono, 2023) which states that learning will be easier and more practical if you use technology-based teaching materials. For qualitative research, the results section contains detailed sections in the form of sub-topics that are directly related to the research focus and categories.

The results of the analysis also reveal that students' creative and critical thinking abilities still need to be improved. Considering that the material to be studied is Enumeration Rules, it is important to introduce a STEAM-based approach as an effort to improve students'

creative and critical thinking abilities. Based on these findings, the e-module design is designed not only as teaching material but also as a medium that encourages the development of high-level thinking skills through the use of technology.

The second stage in the ADDIE model is design. At this stage, an e-module was developed on the topic of Enumeration Rules, designed with the help of STEAM-integrated Augmented Reality. The design of this e-module involves determining an attractive and interactive visual display, systematic logical presentation of material, as well as interactive elements that support the mathematics learning process. So that the e-module developed can be easily accessed by students anytime and anywhere (Hamidi et al., 2024). In the development process, this e-module was created using various applications, namely Microsoft Word, Unity, and Canva. Microsoft Word was used to create the main content of the e-module. Unity is used to integrate Augmented Reality. Where unity is a game engine with the ability to distribute to various platforms (Sarosa et al., 2019). Apart from that, Canva is also used to strengthen the visual aspects of the module. Canva is a computer-based visual application designed to help beginners create, design, or edit various projects via a web platform (Saputra et al., 2022).

After the design stage is complete, it continues to the development stage. At this stage, the product to be developed is created. What is done is creating an e-module, creating image objects that will be used in the Augmented Reality application, and preparing learning videos. The learning material chosen is the Enumeration Rules material which is contained in the STEAM integrated AR-assisted e-module. This e-module will be validated by experts including material experts and media experts. According to (Rohmawati et al., 2019), material experts assess aspects of content and linguistic suitability. According to Hutabri (2022), media experts carry out validation to assess the design quality and effectiveness of multimedia learning media. This is in line with (Hapsari & Zulherman, 2021) who state that media validation is a process of assessing product design by experienced experts. Below are presented the results of material and media validation from the validator.

Table 2. Material expert validation results

No	Aspect	Average (%)	Category
1.	Suitability of material to the curriculum	100	Very Valid
2.	Clarity of concept delivery	94	Very Valid
3.	Conceptual accuracy	94	Very Valid
4.	STEAM integration	90	Very Valid
5.	Development of thinking skills	94	Very Valid
6.	Application in the real world	94	Very Valid
Average of All Aspects (%)		**94**	
Category		**Very Valid**	

Based on Table 2, it can be seen that the overall average validation of material experts is 94% which is included in the very valid category. E-modules that are proven to be valid can be considered a very feasible and effective learning media (Subarkah et al., 2021). The material experts consist of 2 mathematics teachers and 1 mathematics lecturer. When carrying out validation, the validator provides criticism and suggestions which are used to improve and perfect the e-module before it is tested on students. Criticism and suggestions from material expert validators include: (1) one of the material points needs to be clarified more, (2) practice questions need to be integrated with a more interactive platform, and (3) the type of font used in the e-module needs to be changed. The researcher then revised the e-module according to the criticism and suggestions provided by the material expert validator.

Next, media expert validation was carried out by 2 people, namely 1 IT teacher and 1 IT staff. The following are the results of media expert validation.

Table 3. Media expert validation results

No	Aspect	Average (%)	Category
1	Visual design	100	Very Valid
2	Navigation	100	Very Valid
3	Quality of Augmented Reality (AR)	100	Very Valid
4	Compatibility	96	Very Valid
5	Application stability	90	Very Valid
6	Effectiveness of using AR	96	Very Valid
Average of All Aspects (%)		**96**	
Category		**Very Valid**	

Based on Table 3, the overall average validation of media experts is 96%, which is included in the very valid category. This shows that the media used in the e-module is included in the very valid category, meaning that the media is suitable for use. According to Izzah et al. (2023), the suitability of a product can be determined through a validation

assessment process by several experts. This is in line with Purwoko et al. (2023) who stated that a product that is declared valid means that the product being developed is suitable for use in the field.

Apart from the validation test, a practicality test was also carried out to determine the practicality of the STEAM-integrated AR-assisted e-module. The practicality tests carried out are individual trials and limited trials or small group trials. Individual trials were carried out on 3 mathematics teachers at different schools. The following are the results of individual practicality tests.

Table 4. Results of teacher practicality test and limited test

No	Aspct	Individual Trials	Limited Trials
1	Ease of Use	4,7	4,6
2	Effectiveness in Learning	4,6	4,7
3	Display Quality	4,8	4,4
4	Student Engagement and Interactivity	4,8	4,5
5	Conformity to Curriculum and Goals	4,7	4,7
Total Score		**23,6**	**22,9**
Total Maximum Score		**25**	**25**
Percentage		**94,4%**	**91,6%**

Based on Table 4, the average calculation result at the individual trial stage is 94.4%. This shows that the e-module developed is included in the very practical category. This result is in line with research by (Putri & Junaedi, 2022)which found that the e-module developed was in the very practical category with a percentage of 87.33%. Therefore, e-modules are stated to be very practical for use in mathematics learning (Aprilia et al., 2024). However, there are several revisions related to errors in writing. After that, the e-module was revised again before being tested on students.

The revised e-module was tested in a small group. Limited trials were carried out on 11 students selected based on various levels of knowledge using a questionnaire. The limited trial results shown in the table above show a percentage of 91.6%. This proves that the development of AR-assisted mathematics e-modules integrated with STEAM is included in the very practical category. Thus, this e-module can be accepted and used well by users in the learning process (Rani & Maarif, 2021). This shows that the characteristics and content of the e-module have met learning needs and made it easier for users to understand the material presented. The following displays the e-module which has been revised based on input and suggestions from validators.

Figure 2. Augmented reality application display

Figure 3. Initial e-module view

Figure 4. Learning materials

Figure 5. Learning Tasks

The next stage is the implementation of the e-module which has been revised based on criticism and suggestions. This mathematics e-module was applied to class XII IIK students at MAN 2 Cirebon City with a total of 32 students. At this implementation stage, learning was carried out in 8 meetings or the equivalent of 16 hours of lessons. The average student score in carrying out the assignments given during the learning process is 87.89. This shows that students have been able to exceed the KKM score, which is 70.

At the implementation stage, an evaluation stage is also carried out which is intended so that students can immediately provide an assessment of the e-module. At this stage, students are given tests in the form of a pretest and posttest. The pretest is carried out before implementing the e-module, consisting of 4 essay questions. After the pretest is completed, learning using mathematics e-modules assisted by Augmented Reality which is integrated with STEAM is carried out. After the pretest is carried out, learning begins using AR-assisted mathematics e-modules integrated with STEAM. Then, at the end of the lesson, a posttest is carried out using questions that have been validated.

After students have finished working on the post-test questions, the pretest and post-test results are compared to see the increase in students' creative and critical thinking abilities

after using the STEAM integrated Augmented Reality-assisted mathematics e-module. The average pretest result of students before carrying out learning with the STEAM integrated AR-assisted mathematics e-module was 21.97 with the minimum score obtained being 9 and the maximum score being 40. Meanwhile, the average obtained after carrying out learning with the mathematics e-module assisted by STEAM integrated Augmented Reality, namely 78.15, with a minimum score of 27 and a maximum score of 100. According to (Nuryana & Wintarti, 2022) the average posttest score is higher than the pretest showing the effectiveness of the media used in improving student learning outcomes. Based on the pretest and post-test scores, the N-Gain Test can be used to determine the effectiveness in improving the creative and critical thinking abilities of students whose learning uses the following STEAM integrated Augmented Reality assisted mathematics e-module calculation results using N-Gain.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
NGain	32	.18	1.00	.7240	.23407
Valid N (listwise)	32				

Figure 6. N-Gain test results

Based on the table above, it can be seen that the N-Gain test of student learning outcomes obtained an average of 0.7240 which is included in the high criteria. This shows that the use of mathematics e-modules assisted by Augmented Reality integrated with STEAM is effective in improving students' creative and critical thinking abilities. Apart from the pretest and posttest, students were also given a questionnaire regarding student responses to the use of e-modules. The results of student responses were obtained as follows.

Table 5. Results of student response questionnaire

No	Aspect	Total Score	Percentage (%)
1	Understanding the Material	282	88,13
2	Ease of Use	291	90,94
3	Interest and Motivation to Learn	272	85
4	Critical and Creative Thinking Ability	280	87,5
5	Understanding of STEAM	274	85,63
6	Motivation to learn	283	88,44
7	Active Student Participation	267	83,44
8	Clarity of Material	284	88,75
Total Score		**2.233**	
Maximum Score		**2.560**	
Percentage		**87,23 %**	

Based on the table above, it shows that the average percentage of student responses is 87.23%. This means that students gave a very positive response to the e-module used. This average shows a high level of student acceptance of the characteristics and content presented in the e-module. So, this e-module can be used as teaching material in learning mathematics.

Based on the stages above, it shows that the e-module developed is included in the very valid and very practical category. Apart from that, the e-module developed is effective in improving students' creative and critical thinking abilities. This is in line with the research results of Adha et al. (2023) who found that e-modules integrated with the STEAM approach can improve critical and creative thinking skills, thereby creating meaningful learning. This is in line with Alif et al. (2020) who stated that learning that uses augmented reality in STEM learning can improve high-level thinking abilities (A. M. Arifin et al., 2020; Jesionkowska et al., 2020).

The advantage of this electronic module lies in the use of new technology, namely augmented reality. Augmented reality can attract students' interest in learning mathematics. Apart from that, this e-module integrates the STEAM (Science, Technology, Engineering, Art, and Mathematics) approach, so that the material presented is more contextual and in-depth. The e-module design is also made very attractive so that students do not get bored easily while studying the material. This module is written in language that is easy to understand and is compatible with almost all Android smartphones, making it easy for users to access. However, the weakness of this module is its limitations in device compatibility, because it cannot yet be used on iOS devices.

Conclusion and Suggestion

Based on the research results, it can be concluded that the development of a mathematics e-module assisted by Augmented Reality (AR) which is integrated with STEAM can improve the creative and critical thinking abilities of class XII students at MAN 2 Cirebon City. By using the Research and Development (R&D) method with the ADDIE model, this e-module has proven to be very valid and practical and has received positive responses from students. The high N-Gain value of 0.7240 indicates its effectiveness in achieving learning objectives.

As a suggestion, it is hoped that the development of this AR-assisted e-module can be applied in other schools to test its effectiveness in a wider context. Apart from that, further development needs to be carried out regarding increasing interactive features in e-modules

to enrich students' learning experiences. Educators are also advised to carry out training related to the use of AR technology in order to optimize the use of e-modules in the learning process.

References

Adeoye, M. A., Wirawan, K. A. S. I., Pradnyani, M. S. S., & Septiarini, N. I. (2024). Revolutionizing Education: Unleashing the Power of the ADDIE Model for Effective Teaching and Learning. *JPI (Jurnal Pendidikan Indonesia)*, *13*(1), Article 1. https://doi.org/10.23887/jpiundiksha.v13i1.68624

Adha, T. Z., Asrizal, A., & Rahim, F. R. (2023). Development of E-Module Integrated STEM Approach to Improve Students' Critical and Creative Thinking Skills. *Physics Learning and Education*, *1*(2), Article 2. https://doi.org/10.24036/ple.v1i2.27

Adri, H. T., & Suwarjono. (2023). Developing Science E-Modules based on Scientific reasoning Skills for Primary Education Course. *Jurnal Penelitian Pendidikan IPA*, *9*(8), Article 8. https://doi.org/10.29303/jppipa.v9i8.4727

Aisyah, N. A., Abdullah, A. A., Mubarrok, M. N., Adawiya, R., & Sholihah, D. A. (2024). Penerapan Model Discovery Learning Berbasis Etnomatematika Berbantuan Geogebra terhadap Kemampuan Berpikir Kreatif Matematis. *MATHEMA: JURNAL PENDIDIKAN MATEMATIKA*, *6*(1), Article 1. https://doi.org/10.33365/jm.v6i1.2431

Alfayez, M. Q. E. (2024). Availability of STEAM Approach Requirements among IntermediateStage Mathematics Teachers and Their Attitudes towards It. *International Journal of Instruction*, *17*(1), Article 1. https://e-iji.net/ats/index.php/pub/article/view/503

Almelhi, A. M. (2021). Effectiveness of the ADDIE Model within an E-Learning Environment in Developing Creative Writing in EFL Students. *English Language Teaching*, *14*(2), 20–36. https://eric.ed.gov/?id=EJ1284437

Aprilia, V. A., Effendi, M. M., & Rosyadi, A. A. P. (2024). Development of Project-Based E-Module to Facilitate Student's Mathematics Collaboration and Communication in Boarding School. *Kreano, Jurnal Matematika Kreatif-Inovatif*, *15*(1), Article 1. https://doi.org/10.15294/517pn340

Ardiansyah, K., Kurniati, D., Trapsilasiwi, D., & Osman, S. (2022). Truth-Seekers Students' Critical Thinking Process in Solving Mathematics Problems with Contradiction Information. *Kreano, Jurnal Matematika Kreatif-Inovatif*, *13*(1), Article 1. https://doi.org/10.15294/kreano.v13i1.33286

Arena, F., Collotta, M., Pau, G., & Termine, F. (2022). An Overview of Augmented Reality. *Computers*, *11*(2), Article 2. https://doi.org/10.3390/computers11020028

Arifin, A. M., Pujiastuti, H., & Sudiana, R. (2020). Pengembangan media pembelajaran STEM dengan augmented reality untuk meningkatkan kemampuan spasial matematis siswa. *Jurnal Riset Pendidikan Matematika*, *7*(1), Article 1. https://doi.org/10.21831/jrpm.v7i1.32135

Arifin, S., & Efriani, A. (2024). ACTIVITIES FOR USING THE PMRI E-MODULE ASSISTED BY AUGMENTED REALITY. *Lentera Sriwijaya : Jurnal Ilmiah Pendidikan Matematika*, *6*(1), Article 1. https://doi.org/10.36706/jls.v6i1.10

Ayyildiz, P., & Yilmaz, A. (2021). 'Moving the Kaleidoscope' to see the effect of creative personality traits on creative thinking dispositions of preservice teachers: The mediating effect of creative learning environments and teachers' creativity fostering

behavior. *Thinking Skills and Creativity*, *41*, 100879. https://doi.org/10.1016/j.tsc.2021.100879

Azzahra, U., Arsih, F., & Alberida, H. (2023). PENGARUH MODEL PEMBELAJARAN PROJECT-BASED LEARNING (PjBL) TERHADAP KETERAMPILAN BERPIKIR KREATIF PESERTA DIDIK PADA PEMBELAJARAN BIOLOGI: LITERATURE REVIEW. *BIOCHEPHY: Journal of Science Education*, *3*(1), Article 1. https://doi.org/10.52562/biochephy.v3i1.550

Benyamin, B., Qohar, A., & Sulandra, I. M. (2021). Analisis Kemampuan Berpikir Kritis Siswa SMA Kelas X Dalam Memecahkan Masalah SPLTV. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *5*(2), Article 2. https://doi.org/10.31004/cendekia.v5i2.574

Dewi, P. S., & Kuswanto, H. (2023). Developing an Augmented Reality-Assisted E-Module Based on Local Wisdom of Pedicabs for Physics Teaching. *Jurnal Penelitian Pendidikan IPA*, *9*(4), Article 4. https://doi.org/10.29303/jppipa.v9i4.1933

Dwijayanti, I., Nugroho, A. A., & Pratiwi, Y. I. (2020). Meta-analysis: Effect of problem approach and inquiry approach toward students' cathematical critical thinking skill over the past 4 years. *Al-Jabar : Jurnal Pendidikan Matematika*, *11*(1), 1–10. https://doi.org/10.24042/ajpm.v11i1.4944

Evendi, E., Al Kusaeri, A. K., Pardi, M. H. H., Sucipto, L., Bayani, F., & Prayogi, S. (2022). Assessing Students' Critical Thinking Skills Viewed from Cognitive Style: Study on Implementation of Problem-Based e-Learning Model in Mathematics Courses. *EURASIA Journal of Mathematics, Science and Technology Education*, *18*(7). https://eric.ed.gov/?id=EJ1353307

Facione, P. A. (2023). Critical Thinking: What It Is and Why It Counts 2023 Update. *Insight Assessment, ISBN 13: 978-1-891557-07-1.*, Article ISBN 13: 978-1-891557-07-1. https://www.mendeley.com/catalogue/3d3b36b4-fa44-3c08-a8a4-2b74359d298d/

Fatmiyati, N., & Juandi, D. (2023). EFEKTIVITAS FLIPPED CLASSROOM TERHADAP KEMAMPUAN PEMAHAMAN KONSEP DAN BERPIKIR KRITIS MATEMATIS: SYSTEMTIC LITERATURE REVIEW. *JPMI (Jurnal Pembelajaran Matematika Inovatif)*, *6*(3), 1161–1176. https://doi.org/10.22460/jpmi.v6i3.17405

Firdaus, A., Nisa, L. C., & Nadhifah, N. (2019). Kemampuan Berpikir Kritis Siswa pada Materi Barisan dan Deret Berdasarkan Gaya Berpikir. *Kreano, Jurnal Matematika Kreatif-Inovatif*, *10*(1), Article 1. https://doi.org/10.15294/kreano.v10i1.17822

Guimeráns-Sánchez, P., Alonso-Ferreiro, A., Zabalza-Cerdeiriña, M.-A., & Monreal-Guerrero, I. M. (2023). E-textiles para la educación STEAM en educación primaria: Una revisión sistemática. *RIED-Revista Iberoamericana de Educación a Distancia*, *27*(1), 417–448. https://doi.org/10.5944/ried.27.1.37645

Hamidi, A., Akmala, R., Suyanta, & Wilujeng, I. (2024). Development of PBL Based E-Modules to Boost Students' Science Process Skills. *Jurnal Penelitian Pendidikan IPA*, *10*(2), Article 2. https://doi.org/10.29303/jppipa.v10i2.5939

Hapsari, G. P. P., & Zulherman, Z. (2021). Pengembangan Media Video Animasi Berbasis Aplikasi Canva untuk Meningkatkan Motivasi dan Prestasi Belajar Siswa. *Jurnal Basicedu*, *5*(4), Article 4. https://doi.org/10.31004/basicedu.v5i4.1237

Hardeli, Yenti, M. L., Yusmaita, E., & Yerimadesi. (2023). The effectiveness of e-modules based on discovery learning model integrated by probing-prompting questions in high school chemistry learning. *Kasetsart Journal of Social Sciences*, *44*(4), Article 4. https://so04.tci-thaijo.org/index.php/kjss/article/view/268985

Hastawan, I., Suryandari, K. C., & Ngatman, N. (2023). Penerapan Model Problem Based Learning (PBL) untuk Meningkatkan Kemampuan Berpikir Kritis dan Kreatif. *Kalam Cendekia: Jurnal Ilmiah Kependidikan*, *11*(3), Article 3. https://doi.org/10.20961/jkc.v11i3.73498

Hidajat, F. A. (2022). *Buku Ajar Pengembangan Berpikir Tingkat Tinggi dan Berpikir Kreatif Matematis*. Penerbit NEM.

Iftitah, S. L. (2023). Designing Effective Instructional Media in Early Childhood Education: A Comparative Review of the ADDIE and Dick and Carey Instructional Design Models. *Advances in Educational Technology*, *2*(1), Article 1. https://www.euclid.id/journal/index.php/advancesineducationaltechnology/article/view/19

Irviana, I. (2020). Understanding the Learning Models Design for Indonesian Teacher. In *Online Submission* (Vol. 1, Issue 2, pp. 95–106). https://eric.ed.gov/?id=ED608335

Izzah, A., Kusmaharti, D., & Yustitia, V. (2023). PENGEMBANGAN E-MODUL MATEMATIKA BERBASIS PROBLEM BASED LEARNING UNTUK MEMECAHKAN MASALAH MATEMATIKA MATERI KECEPATAN DAN DEBIT DI SEKOLAH DASAR. *Jurnal Lebesgue : Jurnal Ilmiah Pendidikan Matematika, Matematika Dan Statistika*, *4*(2), Article 2. https://doi.org/10.46306/lb.v4i2.382

Jesionkowska, J., Wild, F., & Deval, Y. (2020). Active Learning Augmented Reality for STEAM Education—A Case Study. *Education Sciences*, *10*(8), Article 8. https://doi.org/10.3390/educsci10080198

Kartikawati, A. (2023). PENGARUH IMPLEMENTASI SMART FARMING TERINTEGRASI STEAM TERHADAP HASIL BELAJAR IPA KELAS 4 SEKOLAH DASAR. *Jurnal Penelitian Pendidikan Guru Sekolah Dasar*, *11*(11). https://ejournal.unesa.ac.id/index.php/jurnal-penelitian-pgsd/article/view/58034

Kawete, M., Gumolung, D., & Aloanis, A. (2022). Pengembangan Video Pembelajaran Materi Ikatan Kimia Dengan Model ADDIE Sebagai Penunjang Pembelajaran Di Masa Pandemi COVID-19. *Oxygenius: Journal Of Chemistry Education*, *4*(1), Article 1. https://doi.org/10.37033/ojce.v4i1.374

Komalasari, Y., Nugraha, M. E., Danim, S., & Razak, A. Z. A. (2024). Implementation of STEM Learning with a Scientific Approach to Improving Critical, Creative Thinking, and Learning Outcomes. *Jurnal Pendidikan IPA Indonesia*, *13*(2), Article 2. https://doi.org/10.15294/nkwfa914

Kurnia, T. D., Lati, C., Fauziah, H., & Trihanton, A. (2019). *MODEL ADDIE UNTUK PENGEMBANGAN BAHAN AJAR BERBASIS KEMAMPUAN PEMECAHAN MASALAH BERBANTUAN 3D PAGEFLIP*.

Lah, N. H. C., Hashim, M., Harun, J., & Abdullah, Y. (2024). The evaluation of problem-solving oriented e-module in learning computer-based subject. *International Journal of Evaluation and Research in Education (IJERE)*, *13*(1), Article 1. https://doi.org/10.11591/ijere.v13i1.25486

Liando, N. V. F., Tatipang, D. P., Tamboto, G., Poluan, M., & Manuas, M. (2022). Pictures as a Learning Media in Teaching Vocabulary. *Jurnal Ilmiah Universitas Batanghari Jambi*, *22*(3), Article 3. https://doi.org/10.33087/jiubj.v22i3.2832

Luo, R., Li, J., Zhang, X., Tian, D., & Zhang, Y. (2024). Effects of applying blended learning based on the ADDIE model in nursing staff training on improving theoretical and practical operational aspects. *Frontiers in Medicine*, *11*. https://doi.org/10.3389/fmed.2024.1413032

Maddison, T., & Kumaran, M. (2016). *Distributed Learning: Pedagogy and Technology in Online Information Literacy Instruction*. Chandos Publishing.

Marliani, N. (2015). Peningkatan Kemampuan Berpikir Kreatif Matematis Siswa melalui Model Pembelajaran Missouri Mathematics Project (MMP). *Formatif: Jurnal Ilmiah Pendidikan MIPA*, *5*(1), Article 1. https://doi.org/10.30998/formatif.v5i1.166

Martatiyana, D. R., Usman, H., & Lestari, H. D. (2023). APPLICATION OF THE ADDIE MODEL IN DESIGNING DIGITAL TEACHING MATERIALS. *Jurnal Pendidikan Dan Pengajaran Guru Sekolah Dasar (JPPGuseda)*, *6*(1), Article 1. https://journal.unpak.ac.id/index.php/JPPGuseda/article/view/7525

Noverianto, B., & Munahefi, D. N. (2023). Analisis Kemampuan Berpikir Kreatif Matematis Ditinjau dari Motivasi Belajar Siswa pada Scientific Problem Based Learning Berbantuan Javanese Culture Augmented Reality. *JNPM (Jurnal Nasional Pendidikan Matematika)*, *7*(1), 106. https://doi.org/10.33603/jnpm.v7i1.7706

Nugraha, T., & Suparman, S. (2021). Heterogeneity of Indonesian primary school students' mathematical critical thinking skills through problem-based learning: A meta-analysis. *Al-Jabar : Jurnal Pendidikan Matematika*, *12*(2), 315–328. https://doi.org/10.24042/ajpm.v12i2.9645

Nurfitriyani, Makki, M., & Husniati. (2022). Analisis Kemampuan Berpikir Kritis Pada Mata Pelajaran Matematika: Studi Pembelajaran Menggunakan Model Problem Based Learning (PBL). *Journal of Classroom Action Research*, *4*(3), Article 3. https://doi.org/10.29303/jcar.v4i3.1884

Nurlaili, R., Zubaidah, S., & Kuswantoro, H. (2021). Pengembangan E-module Berbasis Discovery Learning untuk Meningkatkan Kemampuan Berpikir Kritis Siswa Kelas XII Berdasarkan Penelitian Analisis Korelasi Kanonik dari Persilangan Tanaman Kedelai. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, *6*(2), 213. https://doi.org/10.17977/jptpp.v6i2.14451

Nuryana, E., & Wintarti, A. (2022). Development of Electronic Module with Augmented Reality on Pyramid for VIII Grade. *MATHEdunesa*, *11*(3), 894–903. https://doi.org/10.26740/matheduneSa.v11n3.p894-903

Padwa, T. R., & Erdi, P. N. (2021). Penggunaan E-Modul Dengan Sistem Project Based Learning. *Jurnal Vokasi Informatika*, 21–25. https://doi.org/10.24036/javit.v1i1.13

Purwoko, R. Y., Kusumaningrum, B., Laila, A. N., & Astuti, E. P. (2023). Development of Open Ended Based Mathematics E-Modules to Enhance Students' Critical Thinking Ability. *Mathline : Jurnal Matematika Dan Pendidikan Matematika*, *8*(1), Article 1. https://doi.org/10.31943/mathline.v8i1.337

Putri, M., & Junaedi, I. (2022). Development of Ethnomathematics-Based E-Module Using the Inquiry Learning Model to Improve Mathematical Problem Solving Ability. *Unnes Journal of Mathematics Education*, *11*(2), Article 2. https://doi.org/10.15294/ujme.v11i2.59938

Rachmantika, A. R., & Wardono, W. (2019). Peran kemampuan berpikir kritis siswa pada pembelajaran matematika dengan pemecahan masalah. *PRISMA, Prosiding Seminar Nasional Matematika*, *2*, 439–443. https://journal.unnes.ac.id/sju/prisma/article/download/29029/12759

Rachmawati, R., Wijayanti, R., & Anugraini, A. P. (2020). Pengembangan eksplorasi MAR (Matematika Augmented Reality) dengan penguatan karakter pada materi bangun ruang sekolah dasar. *Delta-Pi: Jurnal Matematika dan Pendidikan Matematika*, *9*(2), Article 2. https://doi.org/10.33387/dpi.v9i2.2315

Rahayuningsih, S., Sirajuddin, S., & Ikram, M. (2021). Using Open-ended Problem-solving Tests to Identify Students' Mathematical Creative Thinking Ability. *Participatory Educational Research*, *8*(3), Article 3. https://doi.org/10.17275/per.21.66.8.3

Ramadhan, M. A. N., & Waluyo, A. F. (2023). Development of Android-Based 3D Building Augmented Reality Application at Jogja Student Islamic Boarding School 2. *International Journal Software Engineering and Computer Science (IJSECS)*, *3*(3), Article 3. https://doi.org/10.35870/ijsecs.v3i3.1674

ramirobass. (2023, August 27). Creative thinking in students of mathematics in universities and its relationship with some variables. *Перспективы науки и образования*. https://pnojournal.wordpress.com/2023/08/27/sbaih/

Rani, L., & Maarif, S. (2021). Development E-Module Three Variables Linear Equations System Based On Mathematic Communication. *Journal of Medives : Journal of Mathematics Education IKIP Veteran Semarang*, *5*(2), Article 2. https://doi.org/10.31331/medivesveteran.v5i2.1707

Ratnawati, D., Handayani, I., & Hadi, W. (2020). Pengaruh Model Pembelajaran Pbl Berbantu Question Card Terhadap Kemampuan Berpikir Kritis Matematis Siswa Smp. *Edumatica : Jurnal Pendidikan Matematika*, *10*(1), Article 1. https://doi.org/10.22437/edumatica.v10i01.7683

Rismayanti, T. A., Anriani, N., & Sukirwan Sukirwan. (2022). Deskripsi Kebutuhan E-Modul Berbantuan Smartphone untuk Meningkatkan Kemampuan Berpikir Kritis Matematis Siswa SMP. *Wilangan: Jurnal Inovasi dan Riset Pendidikan Matematika*, *3*(3), 203–211. https://doi.org/10.56704/jirpm.v3i3.13292

Rohmatulloh, R., Nindiasari, H., & Fatah, A. (2023). PENGEMBANGAN E-MODUL INTERAKTIF BERBASIS PROBLEM BASED LEARNING (PBL) UNTUK MENINGKATKAN KEMAMPUAN BERPIKIR KRITIS MATEMATIS. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *12*(4), Article 4. https://doi.org/10.24127/ajpm.v12i4.8172

Rohmawati, I., Sudargo, S., & Menarianti, I. (2019). Pengembangan Game Edukasi Tentang Budaya Nusantara "Tanara" Menggunakan Unity 3D Berbasis Android. *Jurnal SITECH : Sistem Informasi dan Teknologi*, *2*(2), Article 2. https://doi.org/10.24176/sitech.v2i2.3907

Rusni, I., Fitria, Y., Ahmad, S., & Zen, Z. (2023). Development of E-Modules Oriented by A Science, Technology, Engineering, Art, and Mathematics (STEAM) Approach to Improve High Level Thinking Ability. *Jurnal Penelitian Pendidikan IPA*, *9*(9), Article 9. https://doi.org/10.29303/jppipa.v9i9.5345

Saputra, A. G., Rahmawati, T., Andrew, B., & Amri, Y. (2022). Using Canva Application for Elementary School Learning Media. *Scientechno: Journal of Science and Technology*, *1*(1), Article 1. https://doi.org/10.55849/scientechno.v1i1.4

Sarosa, M., Chalim, A., Suhari, S., Sari, Z., & Hakim, H. B. (2019). Developing augmented reality based application for character education using unity with Vuforia SDK. *Journal of Physics: Conference Series*, *1375*(1), 012035. https://doi.org/10.1088/1742-6596/1375/1/012035

Siswanto, R. D., & Ratiningsih, R. P. (2020). Korelasi Kemampuan Berpikir Kritis dan Kreatif Matematis dengan Kemampuan Pemecahan Masalah Matematis Materi Bangun Ruang. *ANARGYA: Jurnal Ilmiah Pendidikan Matematika*, *3*(2), Article 2. https://doi.org/10.24176/anargya.v3i2.5197

Spatioti, A. G., Kazanidis, I., & Pange, J. (2022). A Comparative Study of the ADDIE Instructional Design Model in Distance Education. *Information*, *13*(9), Article 9. https://doi.org/10.3390/info13090402

Subarkah, C. Z., Alhak, A. A., Sari, S., Ruswandi, U., & Rochman, C. (2021). Developing E-module on the Topic of Integrated Addictive Substances with Islamic Values. *JTK (Jurnal Tadris Kimiya)*, *6*(1), Article 1. https://doi.org/10.15575/jtk.v6i1.9802

Suherman, Vidákovich, T., & Komarudin. (2021). STEM-E: Fostering mathematical creative thinking ability in the 21st Century. *Journal of Physics: Conference Series*, *1882*(1), 012164. https://doi.org/10.1088/1742-6596/1882/1/012164

Toheri, Winarso, W., & Haqq, A. A. (2020). Where Exactly for Enhance Critical and Creative Thinking: The Use of Problem Posing or Contextual Learning. *European Journal of Educational Research*, *9*(2), 877–887. https://eric.ed.gov/?id=EJ1250377

Tu, J.-C., Zhang, X., & Zhang, X.-Y. (2021). Basic Courses of Design Major Based on the ADDIE Model: Shed Light on Response to Social Trends and Needs. *Sustainability*, *13*(8), Article 8. https://doi.org/10.3390/su13084414

Wannapiroon, N., & Pimdee, P. (2022). Thai undergraduate science, technology, engineering, arts, and math (STEAM) creative thinking and innovation skill development: A conceptual model using a digital virtual classroom learning environment. *Education and Information Technologies*, *27*(4), 5689–5716. https://doi.org/10.1007/s10639-021-10849-w

Widyastuti, E. & Susiana. (2019). Using the ADDIE model to develop learning material for actuarial mathematics. *Journal of Physics: Conference Series*, *1188*(1), 012052. https://doi.org/10.1088/1742-6596/1188/1/012052

Yaniawati, P., Kariadinata, R., Sari, N., Pramiarsih, E., & Mariani, M. (2020). Integration of e-Learning for Mathematics on Resource- Based Learning: Increasing Mathematical Creative Thinking and Self-Confidence. *International Journal of Emerging Technologies in Learning (iJET)*, *15*(6), 60–78. https://www.learntechlib.org/p/217189/

Ye, P., & Xu, X. (2023). A case study of interdisciplinary thematic learning curriculum to cultivate "4C skills." *Frontiers in Psychology*, *14*, 1080811. https://doi.org/10.3389/fpsyg.2023.1080811

Yuliani, A., Kusumah, Y. S., & Dahlan, J. A. (2021). Critical Thinking: How is it Developed with the Experiential Learning Model in Junior High School Students? *Al-Jabar : Jurnal Pendidikan Matematika*, *12*(1), 175–184. https://doi.org/10.24042/ajpm.v12i1.8857

Zhang, J. (2020). The Construction of College English Online Learning Community under ADDIE Model. *English Language Teaching*, *13*(7), 46–51. https://eric.ed.gov/?id=EJ1259586

Zhao, Z., Zainuddin, N. A., Singh, C. K. S., Rahmat, A. N., Risfendra, & Juhari, M. I. (2023). Development of 21st Century 4C Skills E-Module for Zhumadian Vocational and Technical College Students. *Journal of Technology and Humanities*, *4*(1), Article 1. https://doi.org/10.53797/jthkkss.v4i1.2.2023

Zulyati, Z., Sulastri, S., Nurmalia, C., Yusrizal, Y., & Hasan, H. (2022). Application of Problem-Based Worksheet on Hydrocarbon Combustion Materials through E-Learning to Enhance Studentâ€™s Learning Outcomes and Enviromental Care Attitude. *Jurnal Penelitian Pendidikan IPA*, *8*(6), Article 6. https://doi.org/10.29303/jppipa.v8i6.2055