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META-ANALYSIS OF THE RELATIONSHIP BETWEEN LEARNING MEDIA IN HYBRID LEARNING AND CRITICAL THINKING AND CREATIVITY IN SCIENCE

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ABSTRACT

The 21st-century learning paradigm is characterized by integrating technology into learning facilitating flexible and accessible learning experiences. One such model is hybrid learning, enabling education to transcend time and place with technological aid. Amidst this backdrop, it is crucial that hybrid learning provides education and fosters essential skills of the 21st century, including critical thinking and creativity. This research endeavors to establish a connection between the learning media employed in hybrid learning and the enhancement of critical thinking and creativity skills within the Science and STEM education context. The study also investigates the utilization of laboratory-based applications in chemistry instruction. Employing a meta-analysis approach with descriptive analysis methods, the researchers scrutinized 50 articles cataloged in Scopus, focusing on publications from the past decade. The meta-analysis findings unveil a significant effect size of 0.87, indicating a substantial correlation between the use of learning media and the cultivation of critical thinking skills. Moreover, the association between hybrid learning's learning media and creativity skills is evidenced by an effect size of 0.94. Consequently, it can be inferred that a substantial correlation exists between learning media in hybrid learning and the development of creativity and critical thinking abilities. The impact of laboratory-based applications and software in science education, particularly chemistry, is greatly influenced by pedagogical aspects and instructional strategies.

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INTRODUCTION

The emergence of the COVID-19 pandemic has brought about a transformative disruption in education. This global crisis has prompted the educational sphere to recognize the significance of online and hybrid learning approaches. In response to the pandemic, governmental authorities have mandated the transition to online learning, leading numerous educational institutions to adopt hybrid learning methods. As a result of the pandemic, hybrid learning and online education have swiftly shifted from optional strategies to imperative modes of instruction. Consequently, comprehending the influence of learning media on students' critical thinking and creativity has become paramount in this rapidly evolving educational landscape.

Teachers are required to understand and be experts in using various technology-based learning media [1]. This learning media is used to support online and hybrid learning. The problem is whether it is true that the use of online-based learning media can have an impact on students' critical thinking and creativity [2]. Critical thinking and creativity are essential for students to master to survive in the industrial era 4.0 and be ready to face the global megatrend [3]. STEM integrates science, technology, engineering, and mathematics [4]. Applying STEM has optimized critical thinking skills, creativity, and problem-solving [5]. STEM has been easy to apply by applying learning in everyday life and experimental-based learning [4,6]. STEM has been very possible to be applied in chemistry [7,8].

The learning process can significantly affect the achievement of students' creativity and critical thinking abilities [9,10]. Technology in the context of learning media significantly impacts student achievement [11]. Many researchers are trying to develop various learning media to improve students' abilities [12], especially critical thinking and creativity in STEM. Research has used various research media to improve students' abilities [13]. In their various articles, researchers focus not only on the empirical part of the project but also on developing the idea of developing instructional media in online environments and hybrid learning [14]. This concept has attracted interest for decades [15]. Chemistry lessons have required discussion, inquiry, and laboratory activities to understand concepts and phenomena [7,16]. However, how laboratory-based applications and media have significantly impacted chemistry students has received little attention from researchers.

Diverse interpretations of critical and creative thinking have led to varying assessment approaches among researchers [17,18]. Similarly, discrepancies arise in strategies to nurture students' critical thinking and creativity [19]. This discourse gains further momentum within the context of hybrid learning. Nonetheless, a degree of skepticism exists among many researchers. The question is whether suitable educational tools can effectively enhance students' critical thinking and creative skills within the STEM domain. To address this, our meta-analysis aims to elucidate the intricate interplay between learning media in the hybrid learning framework, critical thinking competencies, and creativity within STEM education.

Examination of the impact of diverse pedagogical tools in science education on the comprehension of fundamental principles is pursued in this study. Specifically, the focus is directed towards Lab-based applications within the spectrum of hybrid learning instruments. The insights derived from this research will provide upcoming scholars with a clear and compelling frame of reference, confirming the effectiveness of hybrid learning media in nurturing critical thinking skills and cultivating creativity. Additionally, they will possess the ability to discern the learning media that yields the most significant effect size. These findings have the potential to guide researchers in making well-informed choices concerning the technology-driven educational resources utilized in STEM-focused hybrid classrooms.

METHOD

1. Study Design

This study employed a survey research design encompassing three stages: preparation, implementation, and data analysis. The independent variable encompasses a hybrid learning-based learning media, while critical thinking and creativity are the dependent variables.

2. Sample Selection

The analysis was conducted on 50 selected articles, which were internationally recognized journal articles indexed in Scopus (Q1, Q2) and were published by reputable sources like Taylor & Francis and Science Direct. The analysis included journals published within the timeframe of 2010-2021. The selection criteria for articles encompassed keywords related to critical thinking, creativity, and the correlation between these concepts. The article review process utilized the PRISMA diagram (Figure 1) for search and selection.

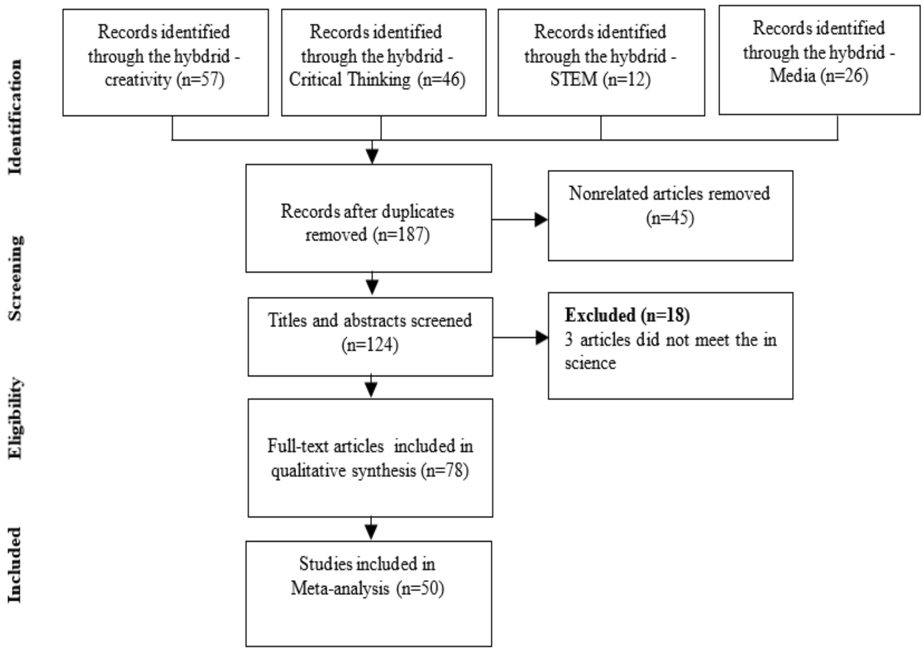

Figure 1. PRISMA Flow Diagram of The Articles Search and Selection

Table 1. Formula to Calculate The Effect Size [20]

Statistical Data Provided	Equation
Mean and standard deviation in one group	$ES = \frac{\bar{x}_{post} - \bar{x}_{pre}}{SD_{pre}}$
Average and standart deviation in one group	$ES = \frac{\bar{x}_{experiment} - \bar{x}_{control}}{SD_{control}}$
Average and standart deviation in each group (two groups pre-post test)	$ES = \frac{(\bar{x}_{post} - \bar{x}_{pre})_{experiment} - (\bar{x}_{post} - \bar{x}_{pre})_{control}}{\left(\frac{SD_{pre\ control} + SD_{pre\ experiment} + SD_{post\ control}}{3}\right)}$
Chi-square	$ES = \frac{2r}{\sqrt{1-r^2}};\ r = \sqrt{\frac{\chi^2}{n}}$
t table	$ES = t\sqrt{\frac{1}{n_{eksprimen}} + \frac{1}{n_{kontrol}}}$
p	CMA (Comprehensive Meta Analisis Software)

3. Data Collection

Research data collection was carried out starting July 2020. The effect size in this study was calculated using Table 1, with criteria according to Cohen's formula [20]. Table 2 provides a classification of effect sizes based on Cohen's criteria.

4. Data Analysis

The effect size analysis focused on two key variables: creativity and critical thinking. For each type of learning media employed in 2020, researchers computed the extent of its impact—the scope of this study's target variables extended from junior high school to university students. The effect size computation followed the methodology outlined in Table 1, adhering to Cohen's formula [20] for the criteria. This process is detailed in Table 2.

The final stage encompassed data analysis, wherein effect size analysis was carried out based on the target variables, i.e., creativity and critical thinking. Additionally, the researcher calculated the effect size associated with each learning media employed.

Table 2. Classification of Effect Size [17]

Effect Size (ES)	Cohen's standard categories
0< ES ≤ 0.2	Small effect
0.2 < ES ≤ 0.5	Medium effect
0.5 < ES ≤ 0.8	Big effect
ES > 0.8	Very large effect

RESULTS AND DISCUSSION

The core focus of this study is centered on a meta-analysis that delves into the intricate relationship between learning media, critical thinking capabilities, and creativity within hybrid learning contexts. The primary objective of this analysis is to uncover the impact of various instructional media on students' capacities for critical and creative thinking, particularly in hybrid learning environments. Initially, an in-depth examination will be conducted on the effect size measures obtained from the meta-analysis. These measures serve as indicators of the strength of the link between learning media and the enhancement of critical thinking and creativity. By closely analyzing these effect size values, a clearer understanding can be gained regarding how different learning media contribute to the enrichment of these essential skills.

The ensuing discussion will shed light on the specific learning media that have demonstrated substantial influence in nurturing critical thinking and creativity. Noteworthy tools such as web-based simulations, e-modules, learning management systems, interactive videos, and others will be highlighted, as these have shown remarkable enhancements in these cognitive faculties. Additionally, the pivotal role of lab-based applications in science education, a domain that has gained prominence within hybrid learning contexts, will be emphasized. This will encompass an exploration of how these applications contribute to the comprehension of fundamental scientific concepts and their correlation with the augmentation of critical thinking and creativity among students.

To provide a comprehensive perspective, it is imperative to consider the implications of these findings for educators. A critical evaluation of the methodological intricacies underpinning the robustness of the outcomes will be undertaken, acknowledging the potential biases and limitations intrinsic to such analyses. This acknowledgment of constraints will ensure a well-rounded interpretation of the results. In conclusion, this extensive inquiry aims to illuminate the crucial role played by learning media in shaping students' critical thinking and creativity in hybrid learning environments. By understanding the intricate interplay between media, cognitive skills, and education, educators can access invaluable insights that contribute to the cultivation of essential competencies necessary for the modern educational landscape.

1. Impact of Learning Media on Critical Thinking and Creativity

Upon analyzing the data, the derived effect sizes of 0.78 (indicating a significant effect according to Cohen's standard classification) signify the connection between employing online-based learning media and critical thinking. Similarly, effect sizes of 0.91 denote a pronounced correlation with creativity, aligned with Cohen's standard classification of a large effect. Figure 2 provides a comparative illustration of the calculated effect size values across diverse hybrid learning-based learning media about critical thinking.

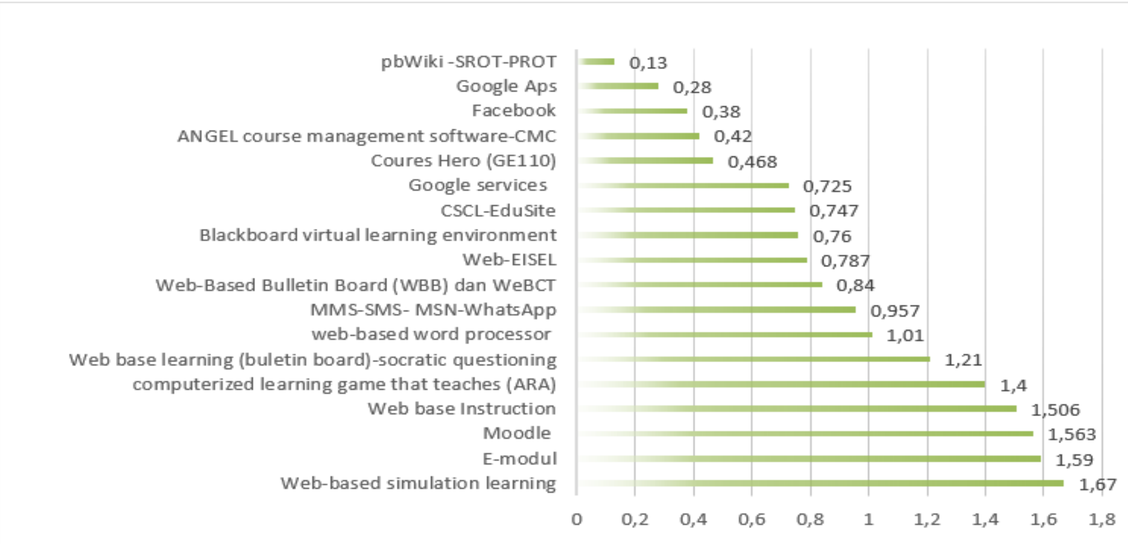

Figure 2. Effect Size of Media Learning-Critical Thinking

Figure 2 illustrates that certain learning media have exhibited a substantial effect size on critical thinking. This interpretation suggests a noteworthy enhancement in critical thinking when employing specific learning media, such as web-based simulation/instruction [21-23], e-modul [24-27], moodle (LMS) [17,28,29], game [30-33] and social media [34-37]. Technology has continued to develop following the development of the world of education [38-40]. Technology-based learning media can encompass a range of technological and social elements [41,42], blending to facilitate the desired creativity indicators. Critical thinking is a mode of thinking that consistently seeks to explore existing phenomena to attain a profound comprehension [43].

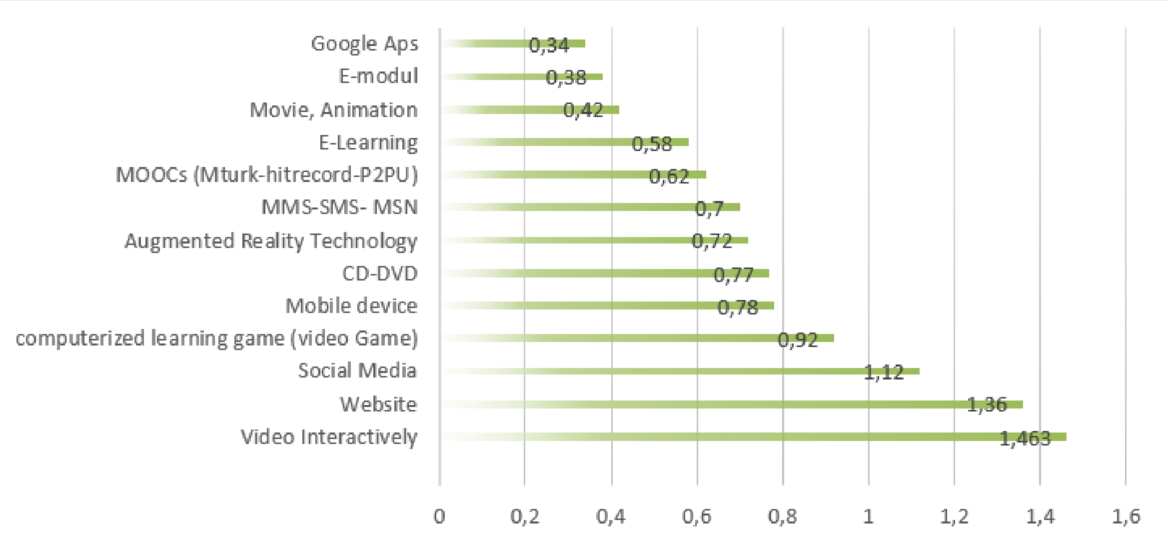

Figure 3. Effect Size of Media Learning-Creativity

Creativity is a cognitive process characterized by the generation and organization of innovative ideas [44,45]. It encompasses various dimensions, including fluency, flexibility, originality, and elaboration, which collectively contribute to the depth and novelty of generated concepts. Additionally, creativity is linked to certain personality traits such as curiosity, which drives the exploration of novel ideas; independence, fostering autonomous thinking; risk-taking, encouraging venturing into uncharted territories; and task commitment, instilling dedication to pursuing creative endeavors [46,47]. This intricate interplay between cognitive processes and personality attributes underscores the multifaceted nature of creativity, making it a multidimensional construct that transcends mere idea generation.

The manifestation of creativity within the context of learning media and its impact is encapsulated in the effect size value, as represented in Figure 3. The effect size value serves as a quantified measure of the relationship between the utilization of learning media and the enhancement of creativity. This visual representation provides a comprehensive overview of the extent to which different learning media mediums contribute to fostering creativity. Notably, several learning media emerge as prominent contributors to bolstering creative thinking, as evidenced by their substantial effect size values. Among these contributors are interactive videos [48,49], platforms such as websites, and website media [11,19,50]. These findings underline the substantial positive influence that certain learning media have on nurturing creativity among learners.

Creativity embodies a complex mental process encompassing idea generation and organization. It encompasses dimensions such as fluency, flexibility, originality, and elaboration, complemented by personality traits like curiosity, independence, risk-taking, and task commitment. The effect size value depicted in Figure 3 captures the essence of creativity's relationship with learning media, highlighting the significant role that specific mediums, including interactive videos and websites, play in cultivating creativity. This nuanced understanding sheds light on the multifaceted nature of creativity and its dynamic interaction with diverse learning media.

2. Lab-Based Applications and Enriching Science Learning

Figure 4 illustrates the Effect Size of Lab-Based Media Learning in Science. Integrating chemistry lectures with various laboratory-based applications and software has significantly enhanced the educational landscape. This study reveals that the subjects extensively covered in hybrid learning are biochemistry, biotechnology, chemistry (including organic, analytical, and physical chemistry), energy, environment, biophysics, and engineering mechanics. This focus aligns with the STEM approach, benefitting from the abundant technological tools available for learning. Several subjects necessitate direct environmental observations and experimentation, facilitating the measurement of their correlation with critical thinking and creativity. [43,51–53]. The effect size value of lab-based applications (Figure 4) has greatly helped the science learning process, especially in chemistry. Science is learning that has been heavily influenced by inquiry activities to understand concepts and natural phenomena [7,54].

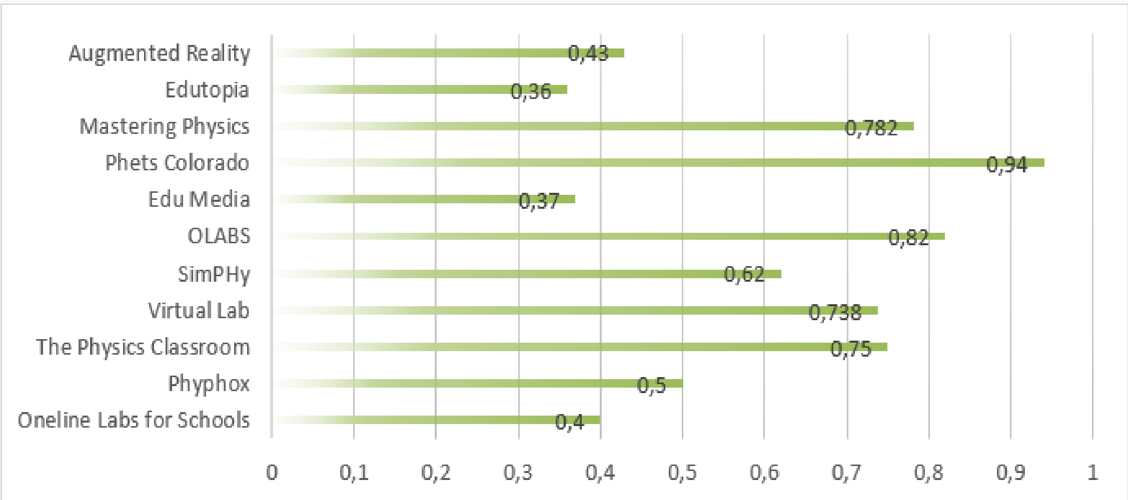

Figure 4. Effect Size of Media Learning based Lab in Science

The integration of the Internet to curate diverse educational resources within hybrid learning hinges on educators' expertise and learning outcomes. Utilizing digital tools like learning websites, management systems, and online communities, teachers can align with learning goals, enhance students' skills, and promote knowledge construction, critical thinking, and creativity. Incorporating creative and critical thinking into learning media empowers students as active learners, fostering higher-order thinking skills [28]. The Technological Pedagogical Content Knowledge (TPACK) framework underscores the significance of educators possessing technological competence to effectively curate and integrate online resources.

Research emphasizes the positive impact of infusing creative and critical thinking into learning settings. Integrating technology into education, as demonstrated by [57], enhances problem-solving skills and nurtures critical and creative thinking. Through leveraging the Internet for hybrid learning, educators create authentic learning experiences that foster students' creativity and critical thinking [28]. Harnessing the Internet's potential within hybrid learning relies on educators' proficiency. By integrating creative and critical thinking aspects into learning media, educators can enrich students' skills and promote active learning. The TPACK framework highlights the role of technological competence in successful Internet integration for hybrid learning.

Creativity and critical thinking are pivotal skills underpinning problem-solving and innovation, surpassing traditional assessment methods, as emphasized by [55]. Nurturing these competencies among students is essential to bolster their problem-solving abilities and real-world application of these skills. Hybrid learning, which melds in-person instruction with online experiences, has gained prominence, offering flexibility and accessibility for students to learn at their convenience and location [28]. The fusion of online resources and digital tools within hybrid learning environments provides a platform for nurturing creativity and critical thinking [56]. This approach allows students to engage in collaborative projects using platforms such as Learning App, Miro, and Quizlet [2].

3. Harnessing Hybrid Learning and Implications for Educators

Evidence underscores the effectiveness of hybrid learning across diverse educational contexts. Research by [28] highlights the positive reception of the hybrid approach among language learners, suggesting it could be a solution for distance education [56]. Moreover, hybrid learning is an efficient strategy, especially given evolving socio-economic dynamics [50]. In conclusion, harnessing the Internet to curate learning resources for hybrid education relies heavily on educators' expertise. By incorporating creativity and critical thinking into learning media, instructors can amplify students' learning experiences. Hybrid learning, a blend of in-person and online learning, empowers students with flexibility, enriched by digital resources that promote creativity and critical thinking.'

Research emphasizes the potential of suitable media selection in hybrid learning to enhance vital 21st-century competencies, particularly critical thinking and creativity. E-learning media's effectiveness in fostering critical thinking skills has been demonstrated through improvements in pre-test and post-test assessments and its integration within blended learning models [10].

However, it's important to acknowledge that the robustness of findings in meta-analyses is contingent upon the quality of empirical studies and the rigor of analytical approaches. The effectiveness of e-learning media in promoting critical thinking skills may vary across diverse contexts, underscoring the need for a thorough evaluation of methodological soundness when interpreting results [12]. In a relevant study, the feasibility of e-learning media was validated by experts, achieving a commendable feasibility rating. The practicality of e-learning media, endorsed by educators and students, further solidifies its role in nurturing critical thinking skills [58].

The thoughtful selection of media in hybrid learning holds promise for enriching pivotal 21st-century proficiencies, particularly critical thinking and creativity. E-learning media's capacity to augment critical thinking skills is supported by tangible assessment improvements and its integration within blended learning paradigms. However, the credibility of meta-analytical findings rests upon the methodological integrity of empirical studies and analytical processes, which must be critically assessed for trustworthy interpretations. The feasibility and practicability of e-learning media, substantiated through research, further underscore its potential in cultivating critical thinking abilities [60].

4. Limitations and Future Directions

This study has certain limitations that should be acknowledged. Firstly, it must delve into the theoretical underpinnings that shape critical thinking and creativity constructs. A deeper exploration of the theoretical foundations could have provided a more comprehensive understanding of these aspects within the research context. Additionally, the meta-analysis needs to differentiate findings based on the specific instruments employed to measure critical thinking and creativity. It's essential to recognize that the choice of assessment tools can significantly influence the researcher's perspective on the attainment of these variables within STEM education. Different assessment instruments might capture varying critical thinking and creativity facets, leading to nuanced interpretations. In summary, this research possesses limitations related to the need for an in-depth theoretical examination of critical thinking and creativity's conceptual frameworks.

The meta-analysis needs a more nuanced analysis of how different assessment instruments may shape the researcher's insights into the complexities of critical thinking and creativity within the STEM field. Addressing these limitations could offer a more nuanced and comprehensive understanding of the research outcomes [39,61–64]. So that furth er research can develop this meta-analysis research by considering the aspects of construction and assessment of critical thinking and creativity in STEM

CONCLUSION

Based on the results and data analysis, it was found that the average percentage of student activity implementation was 95%, with a very good interpretation. These results indicate that students can take part in learning with the problem-based flipped classroom model very well. The environmental literacy of students after being given learning using the problem-based flipped classroom model has increased significantly. Overall, environmental literacy increases with a medium interpretation with an N-gain value of 0.64. The environmental literacy attitude aspect gets an average score of 80 with a very good interpretation, and the percentage of students' attitudes that agree is 79%. Internalized attitudes and actions towards the environment are suggested through programs or projects to overcome the problem of plastic waste by using other learning models and need to be carried out by students continuously so that they become part of good character for students. For further research, it is hoped that we can apply the problem-based flipped classroom model to other chemical concepts and develop this model into higher-order thinking skills.

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