



Transforming Science Learning with Augmented Reality: The Impact of Assemblr Edu on Cognitive Dissonance and Thinking Skills

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ABSTRAK

Siswa kelas III SD sering mengalami kesulitan dalam memahami konsep metamorfosis sempurna, yang dapat memicu disonansi kognitif dan menghambat perkembangan kemampuan berpikir kompleks. Penelitian ini bertujuan untuk mengembangkan media pembelajaran Assemblr Edu berbasis augmented reality dalam pembelajaran metakognitif guna mengurangi disonansi kognitif dan meningkatkan kemampuan berpikir kompleks siswa. Pengembangan dilakukan menggunakan model ADDIE (Analyze, Design, Development, Implementation, and Evaluation). Strategi metakognitif yang diterapkan mencakup aspek planning, monitoring, dan evaluating. Pengumpulan data dilakukan melalui kuesioner, tes uraian, serta wawancara dengan wali kelas. Validitas media dinilai oleh empat ahli media dan empat ahli materi, sedangkan kepraktisan diuji melalui respons 24 siswa kelas III. Efektivitas media dianalisis menggunakan desain one-group pretest-posttest dengan sampel 24 siswa. Data dianalisis secara kualitatif dan kuantitatif. Hasil penelitian menunjukkan bahwa media Assemblr Edu memiliki validitas tinggi dengan skor 0,94 dari ahli media dan 0,93 dari ahli materi. Kepraktisan media memperoleh persentase 92,88% dalam kategori sangat baik dan praktis. Uji efektivitas menunjukkan bahwa media ini berpengaruh signifikan dalam mengurangi disonansi kognitif dan meningkatkan kemampuan berpikir kompleks siswa. Dengan demikian, media ini efektif sebagai alat bantu dalam pembelajaran metakognitif di sekolah dasar.

ABSTRAK

Third-grade elementary school students often struggle to comprehend the concept of complete metamorphosis, which can trigger cognitive dissonance and hinder the development of complex thinking skills. This study aims to develop an Assemblr Edu-based augmented reality learning media within a metacognitive learning framework to reduce cognitive dissonance and enhance students' complex thinking abilities. The development process follows the ADDIE model (Analyze, Design, Development, Implementation, and Evaluation). The applied metacognitive strategies encompass planning, monitoring, and evaluating. Data collection methods include questionnaires, essay tests, and interviews with homeroom teachers. Media validity was assessed by four media experts and four subject matter experts, while practicality was evaluated based on responses from 24 third-grade students. The effectiveness of the media was examined using a one-group pretest-posttest design with a sample of 24 students. The data were analyzed using both qualitative and quantitative approaches. The results indicate that Assemblr Edu demonstrates high validity, with scores of 0.94 from media experts and 0.93 from subject matter experts. The practicality assessment yielded a score of 92.88%, categorizing the media as highly effective and practical. Effectiveness testing revealed a significant impact in reducing cognitive dissonance and improving students' complex thinking skills. Thus, this media is effective as a learning aid in metacognitive instruction at the elementary school level.

1. INTRODUCTION

Science education is the process of understanding natural phenomena through scientific methods

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(Mariana, 2009; Salsabil et al., 2024). Science can be defined as a systematically structured body of knowledge formulated through general principles, characterized by the use of scientific methods and the emergence of a scientific attitude. Broadly, science studies natural phenomena through a series of processes known as the scientific process (Winangsih & Harahap, 2023). Science is divided into several fields, including biology, physics, and chemistry, based on the nature and perspectives of natural phenomena. Given its close relationship with the environment, science education plays a crucial role in fostering students' interactions with their surroundings (Hariri & Yayuk, 2018). Consequently, science education is a fundamental subject in primary schools, requiring complex thinking skills. These high-order thinking skills are essential in addressing the dynamic global demands of the 21st century, necessitating a pedagogical shift toward learners capable of advanced reasoning. This shift requires a more comprehensive approach than conventional learning, as high-order thinking skills are at the core of the learning process (Afrita & Darussyamsu, 2020; Nasution & Harahap, 2024).

The implementation of the Merdeka Curriculum has significantly influenced science education by emphasizing a student-centered approach. This paradigm shift aligns with the principles of 21st-century education, which prioritizes student-centered learning (Afrita & Darussyamsu, 2020; Munawaroh & Budijastuti, 2024). This approach enables students to monitor, regulate, and control their cognitive processes, known as metacognition. Metacognitive learning involves conscious reflection on one's cognitive processes, aligning with 21st-century learning skills that emphasize the 6Cs: character, citizenship, critical thinking, creativity, collaboration, and communication (Pangesti et al., 2023; Sari, 2024). Science education provides students with opportunities to explore concepts, develop practical skills, and minimize cognitive dissonance, which arises when students experience conflicts between their beliefs, values, and actions (Minquan, 2024). Cognitive dissonance can hinder learning outcomes, making it essential to implement strategies such as metacognitive learning, which fosters self-awareness and higher-order thinking (Harahap & Wandini, 2023; Susiani, 2021). By addressing cognitive dissonance and promoting complex thinking, metacognitive strategies enhance students' ability to navigate the demands of modern education.

Based on interviews and direct observations conducted in third-grade classrooms at SD Negeri 1 Pacung, SD Negeri 1 Baktiseraga, SD Negeri Banyuning, and SD Mutiara regarding cognitive dissonance and students' complex thinking abilities in the science topic of complete metamorphosis, it was found that many students experience cognitive dissonance, which impacts their high-order or complex thinking skills. This is indicated by students' difficulty in analyzing problems, expressing their opinions, and participating actively in class, leading to low 21st-century skills. Initial test data from 79 students across these four schools revealed that 67% of students face cognitive dissonance, with 16.5% in the moderate category and 16.5% in the safe category. Additionally, data on students' complex thinking skills indicated that 66% of students require guidance, 20% are in the moderate category, and 14% exhibit strong complex thinking abilities. These results suggest that many students still face cognitive dissonance and have underdeveloped complex thinking skills, indicating a need for intervention to address cognitive dissonance and enhance students' complex thinking. Interviews with third-grade teachers revealed that the teaching method predominantly used is lecture-based, making the learning process less engaging for students. The learning is also often monotonous, and concrete, engaging teaching media is rarely used. Piaget's cognitive development theory suggests that students in elementary school are still in a stage of more concrete thinking and may struggle with abstract or complex thought processes, leading to increased cognitive dissonance when faced with tasks requiring abstract thinking or complex problem-solving.

The issues identified suggest the need for solutions to address cognitive dissonance and enhance students' complex thinking skills in elementary schools. Individual skill development must be planned, with the majority of the plans executed in a well-functioning school (Magdalena et al., 2023; Suchyadi et al., 2022). Teachers play a crucial role in the learning process, and the achievement of learning outcomes is highly dependent on the teaching methods employed. Previous research indicates that "Teachers, as one of the key components in schools, occupy an important role in the teaching and learning process" (Hazmi, 2019). Therefore, teachers must innovate to make learning enjoyable, including through the use of learning media. Educators can innovate not only in teaching methods but also in creating engaging and varied learning media (Rahma & Wijaya, 2023). Learning media is one way for teachers to make lessons more enjoyable. One way to address the above issue is through the creation of learning media that can alleviate cognitive dissonance and enhance students' complex thinking skills. Among the various types of learning media, virtual learning media stands out. Virtual learning media refers to media that uses digital technology, which has become pervasive in the 4.0 industrial era, known as the digital revolution, due to the rapid spread of computers and technological advancements. The sophistication of this era has transformed information and convenience into a modern lifestyle (Nurjani, 2018; Sugiono & Waruwu, 2021). Hence, the use of technology in education is crucial. Conventional learning media are being replaced by digital learning media. Educational materials delivered through technology-based media are vital for students, fostering

quality learning (Trinaldi et al., 2022; Utami & Atmojo, 2021).

Research on cognitive dissonance and complex thinking skills in elementary school students has evolved significantly, particularly in the context of science education. Previous studies have explored the effects of cognitive dissonance on students' conceptual understanding and problem-solving abilities, emphasizing the need for instructional strategies that minimize dissonance and promote higher-order thinking (Adikaram & Higgs, 2024; Ho et al., 2022). Recent research has also highlighted the importance of engaging and interactive learning environments in overcoming cognitive conflicts and fostering critical thinking (Iskandar & Mayarni, 2022). Additionally, studies have shown that digital learning media, particularly virtual and augmented reality-based platforms, can enhance students' cognitive engagement and comprehension of abstract concepts (Kaur & Mantri, 2024). However, while previous research has focused on the role of technology in education, limited studies have specifically investigated the integration of virtual learning media to address cognitive dissonance and improve complex thinking skills in elementary school students.

The novelty of this study lies in the development and implementation of Assemblr Edu-based virtual learning media as a targeted intervention to reduce cognitive dissonance and enhance students' complex thinking skills in science education. This study aims to design, develop, and evaluate the effectiveness of Assemblr Edu-based virtual learning media in addressing cognitive dissonance and improving students' complex thinking skills, particularly in understanding scientific concepts. Unlike conventional learning methods, which often rely on direct instruction and lack interactive engagement, this research introduces an innovative approach that combines digital interactivity with pedagogical strategies to support students' cognitive development. By leveraging the capabilities of Assemblr Edu, this study not only contributes to the growing body of research on digital learning media but also offers a practical and scalable solution for elementary education. Furthermore, this study provides empirical evidence on the effectiveness of virtual learning media in mitigating cognitive dissonance, a relatively underexplored area in existing literature, thereby advancing both theoretical and practical understandings of student cognitive development in the digital learning era.

2. METHOD

This study employs a development research approach utilizing the ADDIE development model. The ADDIE model, which stands for Analysis, Design, Development, Implementation, and Evaluation (Wijayanti & Isnawati, 2023), provides a structured and systematic framework for addressing learning challenges related to students' critical thinking skills, learning needs, and instructional characteristics. The research follows five sequential stages: (1) the analysis phase involves identifying students' characteristics through classroom observation and interviews with the homeroom teacher of Grade III at SD Negeri 1 Pacung, as well as assessing learning and media needs; (2) the design phase includes developing a storyboard and determining the learning material, specifically the concept of complete metamorphosis in frogs, mosquitoes, and butterflies, while integrating metacognitive aspects such as planning, monitoring, and evaluating; (3) the development phase focuses on producing the learning media, including a 14-page learning book, 3D and AR media created using Assemblr Edu, instructional videos, and interactive quizzes; (4) the implementation phase involves testing the media's effectiveness through a one-group pretest-posttest design, in which students complete a pretest, engage with the media, and then take a posttest to measure learning outcomes; and (5) the evaluation phase includes expert reviews from media and content specialists, as well as student response assessments to determine the validity, practicality, and effectiveness of the developed media.

The subject of this research is the Assemblr Edu augmented reality-based learning media designed for metacognitive learning on the topic of complete metamorphosis. The research object focuses on evaluating the validity, practicality, and effectiveness of this learning media in facilitating metacognitive learning processes. Through this investigation, the study aims to determine the extent to which Assemblr Edu AR-based media supports students' cognitive engagement and enhances their conceptual understanding of complete metamorphosis in elementary science education.

The data collection methods in this study include both test and non-test approaches. The non-test data collection consists of interviews and field observations, while the test method is employed to assess the effectiveness of the developed media. The effectiveness test is conducted using a questionnaire containing several statements related to cognitive dissonance and open-ended questions designed to measure students' complex thinking skills. Prior to administering the effectiveness instrument to students, a content validity test is carried out by four expert judges. The content validity analysis of the effectiveness instrument is conducted using the Content Validity Ratio (CVR) formula. Once the instrument is deemed valid, data collection proceeds in the field. The collected data is analyzed quantitatively to evaluate the

impact of the learning media. The instrument grids used in this study are presented in Table 1, Table 2, Table 3, Table 4, and Table 5.

Table 1. Expert Validation Sheet Grid for Content Validity

Indicator	Statement
Relevance (Appropriateness)	The presented material aligns with the Learning Outcomes (CP). The presented material corresponds to the Learning Objectives (TP). The learning material is consistent with the Learning Objectives Flow (ATP). The conceptual accuracy of the learning material aligns with the media used.
Consistency (Coherence)	The content presented in the media is relevant to the scope of complete metamorphosis in frogs, mosquitoes, and butterflies for fourth-grade students. The consistency of the material with the main topics is well maintained. The coherence between the main topics and subtopics is well structured.
Content Sufficiency	The clarity and depth of the presented material are adequate. The clarity of explanations for each topic is appropriate and highly comprehensible. The media provides learning material that contains concepts easily understood by students.

Table 2. Expert Validation Sheet Grid for Media Validity

Indicator	Statement
Media Display	The use of visual elements in this learning media is engaging and supports the learning process. The clarity and completeness of the media content are well-maintained. The graphic elements and layout design in this learning media enhance content comprehension. Animations and visual effects in this learning media clarify complex concepts. The suitability of the media layout design aligns with the content.
Media Feasibility	The arrangement of content and instructional guidelines is appropriate. The media aligns with the Learning Outcomes (CP). This learning media supports varied instructional strategies that enhance material comprehension.
Ease of Use	The accuracy of the material presented in the media is well-ensured. The media is easy to use. Users can quickly find the information they need within this learning media. The use of this media encourages students to engage in complex thinking.

Table 3. Student Response Questionnaire Grid

Aspect	Indicator
Content	The material is comprehensive and easy to understand. The language used is simple and clear. The presentation of the material in the media is appropriate. The material delivery in the media is clear.
Visual Appeal	The media content display is engaging. The text is readable. The use of images is clear and effective.
Usability	The usage instructions are clear and easy to follow. The media is easy to access.
Benefits	The learning media increases students' interest in learning. The media facilitates access to information and knowledge.

Table 4. Essay Test Grid for Complex Thinking Skills

Complex Thinking Skill Indicator	Question Indicator	Question Number	Total Questions
Application	Applying knowledge of metamorphosis to maintain ecosystems	7,10	2
Analysis	Analyzing the differences in metamorphosis experienced by frogs, mosquitoes, and butterflies	1,2	2

Complex Thinking Skill Indicator	Question Indicator	Question Number	Total Questions
Synthesis	Analyzing the major physical changes that occur at each stage of metamorphosis	3,5,6	3
	Analyzing the similarities in the metamorphosis of frogs, mosquitoes, and butterflies	4,8	2
	Designing solutions to problems in animal life cycles	9	1
Total Items			10

Table 5. Questionnaire Grid for Cognitive Dissonance

Dimension	Indicator	Question Number	Total Questions
Psychological Tension	Recognizing the level of anxiety experienced	1,2	4
	Understanding the level of emotional tension experienced	3,4	
Motivation to Reduce Tension	Identifying ways to avoid certain conditions or situations	5,6	4
	Identifying ways to express emotions or feelings	7,8	
Level of Reward	Recognizing rewards gained from learning materials or social environments	9,10	4
	Recognizing emotional rewards obtained from learning or social environments	11,12	
Forced Compliance	Recognizing forms of discomfort experienced from learning or social environments	13,14	4
	Identifying inconsistencies between beliefs and actions based on learning experiences or social environments	15,16	
Total Items			16

3. RESULT AND DISCUSSION

Results

This study was conducted with third-grade students at SD Negeri 1 Pacung during the odd semester of the 2024/2025 academic year. The research aims to develop a product in the form of Assemblr Edu Augmented Reality (AR) learning media for metacognitive learning on the topic of perfect metamorphosis for third-grade students. The subjects of the study included four content experts, four media experts, twenty-four student respondents (for practicality), and twenty-four third-grade students. The development model used in this research is the ADDIE model, which consists of several stages: (1) analysis, (2) design/planning, (3) development, (4) implementation, and (5) evaluation.

In the first stage, analysis, data was collected from four schools to obtain pre-test data on the topic of perfect metamorphosis. The pre-test results involving 79 students across these schools revealed that 67% of the students experienced cognitive dissonance. Among these, 16.5% were in the moderate category, and 16.5% were in the safe category, showing no significant cognitive dissonance. Furthermore, pre-test data on students' complex thinking skills indicated that 66% of the students still needed guidance, 20% were at an adequate level, and 14% demonstrated good complex thinking skills.

In the design stage, the development of the Assemblr Edu Augmented Reality (AR) learning media for metacognitive learning was carried out. This stage began with the creation of a storyboard for the media. The design and development of the Assemblr Edu AR learning media involved using several software tools. Assemblr Edu was used to develop AR components related to the topic of metamorphosis, which included the metamorphosis of frogs, mosquitoes, and butterflies. Canva was utilized for the creation of a digital book for the Assemblr Edu AR learning media. Wordwall was employed to create quizzes embedded within the media book, while Capcut was used to produce the educational videos. The visual design of the product is illustrated in [Figure 1](#), [Figure 2](#), and [Figure 3](#).



Figure 1. The Initial Page



Figure 2. The Core Page

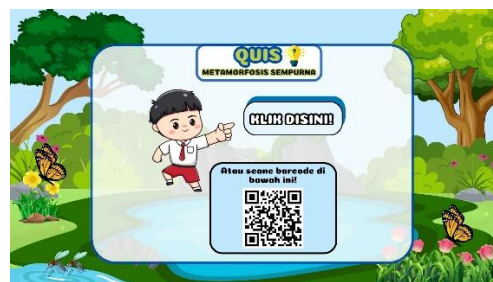


Figure 3. The Final Page

The development stage involves the creation of media in accordance with the design established in the design phase. In the development of the Assemblr Edu Augmented Reality media, it is aligned with metacognitive aspects, including (1) planning activities, (2) monitoring an individual's cognition, and (3) evaluation related to understanding. After the product has been developed, it is followed by product validity testing, which is conducted by subject matter experts, media experts, and the practicality of the media. The validity analysis by subject matter experts, media experts, and the practicality of the media is presented as shown in Table 6.

Table 6. Results of Media and Material Feasibility Calculation

Description	Evaluation				S1	S2	S3	S4	$\sum s$	V	Remarks
	1	2	3	4							
Media 1-12	45	48	45	46	33	36	33	34	136	0.94	Tinggi
Material 1-10	37	40	38	37	27	30	28	27	112	0.93	Tinggi

Based on Table 6, the media expert feasibility analysis obtained a validity score of 0.94, and the material feasibility analysis obtained a validity score of 0.93. According to Aiken's validity criteria, a score greater than 0.8 indicates that the developed product has a high level of validity. Therefore, it can be concluded that both analyses received the "high validity" rating. The practicality test of the Assemblr Edu Augmented Reality (AR) learning media in metacognitive learning was conducted by providing worksheets to 24 third-grade elementary school students. The average validity score from the respondents for the Assemblr Edu Augmented Reality (AR) learning media was 92.88%. According to the practical model guideline for calculating the percentage of practicality (student responses), with a percentage score range

of 90-100, the Assemblr Edu Augmented Reality (AR) learning media can be considered to have the rating of "very good."

The implementation stage involves the application of the Assemblr Edu Augmented Reality learning media in metacognitive learning on the topic of frog metamorphosis at SD Negeri 1 Pacung in third-grade classes. The implementation of the learning media is conducted to determine the effectiveness of the developed media. Effectiveness testing is carried out through a pretest before applying the media and a posttest after applying the learning media. The effectiveness analysis is performed using a t-test, which is preceded by normality and homogeneity tests. The effectiveness calculations are performed using SPSS 30.0 software. Before conducting the t-test analysis, it is essential to first assess the normality and homogeneity of the data to ensure that the conditions for the t-test are met. As shown in Table 7, the normality test was conducted to determine if the data distribution for both the pretest and posttest results met the assumptions of normality, using the Shapiro-Wilk test. A significance value (p-value) greater than 0.05 indicates that the data is normally distributed.

Table 7. Results of the Normality Test Analysis

Variable	Test	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Cognitive	Pre-test	0.122	24	0.200	0.970	24	0.656
Dissonance	Post-test	0.169	24	0.075	0.926	24	0.077
Complex	Pre-test	0.203	24	0.012	0.930	24	0.096
Thinking Ability	Post-test	0.222	24	0.004	0.931	24	0.101

Similarly, as presented in Table 8, the homogeneity test was performed to evaluate whether the variances of the pretest and posttest groups were equal. This step is crucial for validating the assumptions required for the t-test, ensuring that the analysis results are reliable and valid.

Table 8. Results of the Homogeneity Test

Parameters		Levene Statistic	df1	df2	Sig.
Cognitive	Based on Mean	0.203	1	46	0.654
Dissonance	Based on Median	0.178	1	46	0.675
	Based on Median and with adjusted df	0.178	1	43.893	0.675
	Based on trimmed mean	0.237	1	46	0.628
Complex	Based on Mean	0.012	1	46	0.912
Thinking	Based on Median	0.068	1	46	0.796
Ability	Based on Median and with adjusted df	0.068	1	45.841	0.796
	Based on trimmed mean	0.013	1	46	0.911

The paired sample t-test analysis for cognitive dissonance (Y₁) and complex thinking ability (Y₂) was conducted to examine whether there is a significant difference between the pretest and posttest scores for both variables. The paired t-test compares the means of the two related groups to determine if the application of the learning media had an effect on the participants' cognitive dissonance and complex thinking ability. The significance value (p-value) from the t-test determines whether the observed differences between the pretest and posttest are statistically significant. A p-value less than 0.05 indicates a significant difference, suggesting that the media has had an impact on the development of these cognitive aspects. The specific results for both variables are detailed in Table 9.

Table 9. Results of the Paired Sample T-Test Analysis

Paired Group	Paired Differences					Significance			
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	One-Sided p	Two-Sided p
				Lower	Upper				
Pair 1 Y ₁ Pre-test - Y ₁ Post-test	-9.958	5.513	1.125	-12.286	-7.631	-8.850	23	<0.001	<0.001

Paired Group	Paired Differences					t	df	Significance	
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				One-Sided p	Two-Sided p
				Lower	Upper				
Pair 2 Y ₂ Pre-test - Y ₂ Post-test	-23.750	7.109	1.451	-26.752	-20.748	-16.366	23	<0.001	<0.001

Based on the analysis results in [Table 9](#) for the paired sample t-test on both dependent variables, the significance value in the Sig. (2-tailed) column is <0.001. From this result, it can be observed that the p-value is less than 0.05. Therefore, it can be concluded that the null hypothesis (H₀) is rejected and the alternative hypothesis (H₁) is accepted, indicating that there is a significant difference in the cognitive dissonance of students on the topic of metamorphosis in third-grade elementary school before and after learning using the Virtual Assemblr Edu Learning Media in metacognitive learning. Thus, the use of this media is effective in reducing students' cognitive dissonance on the topic of complete metamorphosis. Additionally, there is a significant difference in the improvement of students' complex thinking ability on the topic of complete metamorphosis in third-grade elementary school before and after learning with the use of the Virtual Assemblr Edu Learning Media in Metacognitive Learning.

Discussion

The findings of this study indicate that the use of Assemblr Edu, an Augmented Reality (AR)-based learning media, in science education significantly contributes to reducing cognitive dissonance and enhancing students' complex thinking skills. In terms of content, this media presents the concept of complete metamorphosis through interactive visual representations, allowing students to connect abstract concepts with real-life experiences. This aligns with the cognitive constructivist theory, which emphasizes that conceptual understanding is more effective when students can relate new information to concrete experiences. Furthermore, by integrating metacognitive strategies, this media provides students with opportunities to reflect on their understanding more deeply, helping them overcome cognitive discomfort caused by conceptual conflicts. The effectiveness of this media is demonstrated by its high validity, as assessed by media and subject matter experts, and by students' positive responses, indicating that the media is not only visually engaging but also easy to use and comprehend.

From a media perspective, the integration of AR technology into an interactive e-book introduces a new dimension to elementary science education. Unlike conventional static media, Assemblr Edu enables dynamic three-dimensional visualizations, thereby increasing student engagement in exploring metamorphosis concepts. Previous studies have shown that AR technology enhances conceptual understanding and learning motivation ([Suatan & Irwansyah, 2021](#)). However, this study offers a novel perspective by revealing that AR also plays a role in reducing cognitive dissonance, which frequently arises in science learning. By providing a more concrete learning experience, students can better grasp the relationships between concepts that initially seemed contradictory, thereby improving conceptual accuracy and reducing confusion ([Nurhasanah et al., 2022; Saro'i et al., 2024](#)).

Regarding instructional design, the application of the ADDIE model in developing this media ensures that each phase—from needs analysis to evaluation—is systematically implemented to produce valid, practical, and effective media. In the design phase, the developed storyboard incorporates principles of metacognitive-based instructional design, allowing students not only to receive information but also to regulate and evaluate their own understanding. This finding is consistent with the study which asserts that metacognitive strategies in technology-based learning enhance conceptual comprehension through improved reflection and cognitive control ([Afrita & Darussyamsu, 2020](#)). Thus, this approach not only improves learning quality but also strengthens students' independent thinking skills.

When compared to previous research, most studies on AR in education have primarily focused on improving conceptual understanding and student motivation ([Anggreani & Satrio, 2021; Mustaqim, 2017](#)). However, this study extends these findings by highlighting how AR-based media also help address psychological barriers arising from conceptual inconsistencies in students' minds. By offering a more interactive learning experience, students not only better understand the material but also undergo a more effective cognitive alignment process. This underscores that AR-based learning is not merely a visual aid but also has profound psychological effects in fostering more stable conceptual understanding.

Overall, this study makes a significant contribution to digital learning media innovation, particularly in the context of metacognitive learning in elementary education. The findings suggest that integrating Assemblr Edu into learning not only supports conceptual understanding but also helps students overcome cognitive dissonance, an aspect that has received little attention in prior AR studies. Therefore, the implications of this research can be expanded by exploring how AR-based media can be applied to various other learning topics and how metacognitive strategies can be further optimized to enhance students' complex thinking skills across diverse educational contexts.

4. CONCLUSION

This study successfully developed the Assemblr Edu learning media, resulting in the output of a book on Assemblr Edu augmented reality learning media for metacognitive learning on the topic of complete metamorphosis, aimed at reducing cognitive dissonance and enhancing complex thinking abilities among third-grade elementary students. The learning media received high validation from media and subject matter experts. The practicality of the media was rated as very good, and this Assemblr Edu learning media proved effective in helping students reduce cognitive dissonance and improve their complex thinking skills. This learning media can serve as a solution for enhancing 21st-century skills, particularly the 4Cs (Critical thinking, Communication, Collaboration, and Creativity).

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