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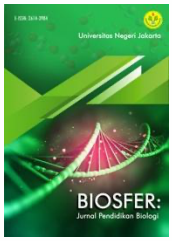

AI-Based socioscientific learning media for collaborative skills in biology education

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ABSTRACT

Limited availability of engaging and contextual learning media often limits students' active participation and the development of collaborative skills in biology learning, particularly in environmental topics. This study aims to determine the validity, practicality, and effectiveness of developing Kling-AI application-based learning media through the Socioscientific Issue (SSI) approach in supporting students' collaborative skills. This study employed a Research and Development (R&D) method using the ADDIE development model, which consists of analysis, design, development, implementation, and evaluation stages. The research subjects included media experts, subject matter experts, teachers, and students. Data were collected through expert validation, practicality questionnaires, and pre-test and post-test assessments. Data analysis was conducted using descriptive quantitative analysis. The results showed that the developed learning media achieved a high level of validity, with media expert validation reaching 86.50% and subject matter expert validation reaching 97.72%. The practicality of the media was categorized as very practical based on student responses (92.00%) and practical based on teacher responses (80.00%). The effectiveness of the media was indicated by an N-gain value of 0.33 in the moderate category and a collaborative skills mastery percentage of 86.36%, classified as highly effective. These findings indicate that the Kling-AI application-based learning media integrated with the SSI approach is valid, practical, and effective in supporting students' collaborative skills.

INTRODUCTION

Collaboration is a core competency in 21st-century biology education, particularly in learning contexts that require students to engage with complex environmental and societal problems (Yokhebed, 2019). Collaborative learning enables students to exchange ideas, negotiate meaning, and construct scientific understanding through social interaction (Zeidler, 2025; Zeidler et al., 2005). However, biology learning in coastal and under-resourced contexts often lacks instructional media that meaningfully integrate real-world environmental issues with collaborative learning activities. Students in coastal areas frequently experience limited learning facilities, uneven access to technology, and learning experiences that are disconnected from their socio-ecological realities (Semken & Freeman, 2008; van Deursen & van Dijk, 2019).

Contextual and place-based science learning has been widely emphasized as essential for fostering meaningful learning and student engagement, particularly within the framework of Education for Sustainable Development (ESD) (Fischer et al., 2022). ESD-oriented learning supports students in developing responsibility and action competence for sustainability by connecting scientific knowledge with real-life environmental challenges (Olsson et al., 2022). Without instructional media that are contextually relevant and pedagogically designed to support collaboration, students may struggle to develop essential 21st-century competencies.

Socioscientific issues (SSI)–based learning has been widely recognized as an effective pedagogical approach for fostering collaboration, argumentation, and decision-making skills in science education. SSI learning engages students in discussions that require the evaluation of scientific evidence alongside social and ethical considerations (Sadler, 2009; Zeidler et al., 2003). Empirical studies further indicate that SSI-based instructional materials can enhance students' collaborative and communication skills through structured discourse and group-based activities (Fadilah et al., 2022)

In addition to collaboration, SSI learning also supports students' cognitive development through questioning and reflective thinking processes. Question-driven activities embedded in SSI contexts encourage students to analyze complex problems and construct reasoned arguments, thereby enhancing higher-order thinking skills (Hariyadi, 2014; Hariyadi et al., 2018). Studies have also shown that SSI-based learning materials, including science textbooks, contribute to the development of creative and analytical thinking by encouraging students to consider multiple perspectives (Budi et al., 2020).

The integration of digital technology and artificial intelligence (AI) into learning media has demonstrated significant potential to enhance instructional quality and student engagement. AI-based learning media enable the efficient development of visually appealing and interactive instructional materials that support students' understanding of complex concepts (Chen et al., 2020). Empirical studies report that AI-assisted platforms facilitate teachers in producing engaging learning media more effectively, thereby supporting classroom instruction (Maulid et al., 2024).

Despite the potential of AI-based media, their effectiveness depends on contextual suitability and pedagogical alignment. Research on digital inequality highlights that differences in students' digital readiness and access to technology may influence the effectiveness of technology-enhanced learning environments, particularly in under-resourced contexts (Pierce & Cleary, 2024; van de Werfhorst et al., 2022). Therefore, AI-based learning media should be designed not only to enhance visual appeal but also to support collaborative learning and remain sensitive to students' socio-ecological contexts (Hariyadi et al., 2025).

Although previous studies have examined SSI-based pedagogy and AI-supported learning media, research integrating both approaches remains limited. Existing studies often focus on SSI instruction without intelligent media support or on AI-based tools that emphasize individual learning outcomes rather than collaborative skills. Moreover, the application of AI-generated learning media within SSI frameworks in coastal school contexts has received little attention, despite the potential of coastal environments to serve as rich socio-scientific learning contexts (Gough, 2017). This study addresses this gap by developing Kling-AI–based learning media integrated with an SSI approach and contextualized to coastal environmental issues. Accordingly, this study aims to develop and evaluate Kling-AI–based socio-scientific learning media in terms of their validity, practicality, and effectiveness in supporting students' collaborative skills in biology learning.

METHODS

Research Design

This study employed a research and development (R&D) design to develop and evaluate artificial intelligence–based learning media for biology learning. The R&D design was chosen because it allows systematic development, testing, and refinement of instructional products to ensure their effectiveness and suitability for educational use (Richey & Klein, 2014). The development process was carried out using the ADDIE instructional design model, which consists of five stages: Analyze, Design, Develop, Implement, and Evaluate. The ADDIE model provides a structured yet flexible framework for guiding instructional media development and has been widely applied in educational technology research (Branch, 2009; Molenda, 2015).

Population and Samples

The characteristics of the research sample are summarized in Table 1, including grade level, number of students, gender distribution, and school context.

Table 1
Demographic Data of Research Sample

Demographic Aspect	Description
Grade level	Grade X
Number of students	22
Gender	10 male, 12 female
School context	Islamic senior high school (Madrasah Aliyah) in a coastal area

As shown in Table 1, the research involved tenth-grade students from an Islamic senior high school located in a coastal area, with a relatively balanced gender distribution. The sample size and school context are considered appropriate for examining the feasibility and initial effectiveness of the developed learning media in a limited-scale trial.

Instrument

The instruments used in this study consisted of four types: media validation sheets, a student response questionnaire, pre-test and post-test questions, and a collaborative skills observation rubric. The media validation sheets were used to assess the validity and feasibility of the developed learning media in terms of content accuracy, visual design, and pedagogical suitability. The student response questionnaire was arranged using a Likert-type scale to measure the practicality and usability of the learning media from students' perspectives. The pre-test and post-test questions were designed to evaluate students' conceptual understanding before and after the implementation of the learning media. Meanwhile, the collaborative skills observation rubric was employed to assess students' collaborative behaviors during learning activities, including participation, responsibility, cooperation, and contribution to problem-solving.

The instruments were developed based on learning objectives and relevant theoretical frameworks commonly used in educational research (Sugiyono, 2019). The construction of the collaborative skills observation rubric referred to the collaboration indicators proposed by Greenstein (2012). All instruments, including the learning materials used during classroom implementation, were validated through expert judgment involving media experts and subject matter experts. The validation results indicated that all instruments were categorized as valid and feasible for use, with minor revisions made based on experts' suggestions, such as improving wording clarity and adding relevant indicators.

Procedure

The research procedure was developed based on the ADDIE instructional design model, which consists of five stages: Analyze, Design, Develop, Implement, and Evaluate, as illustrated in Figure 1.

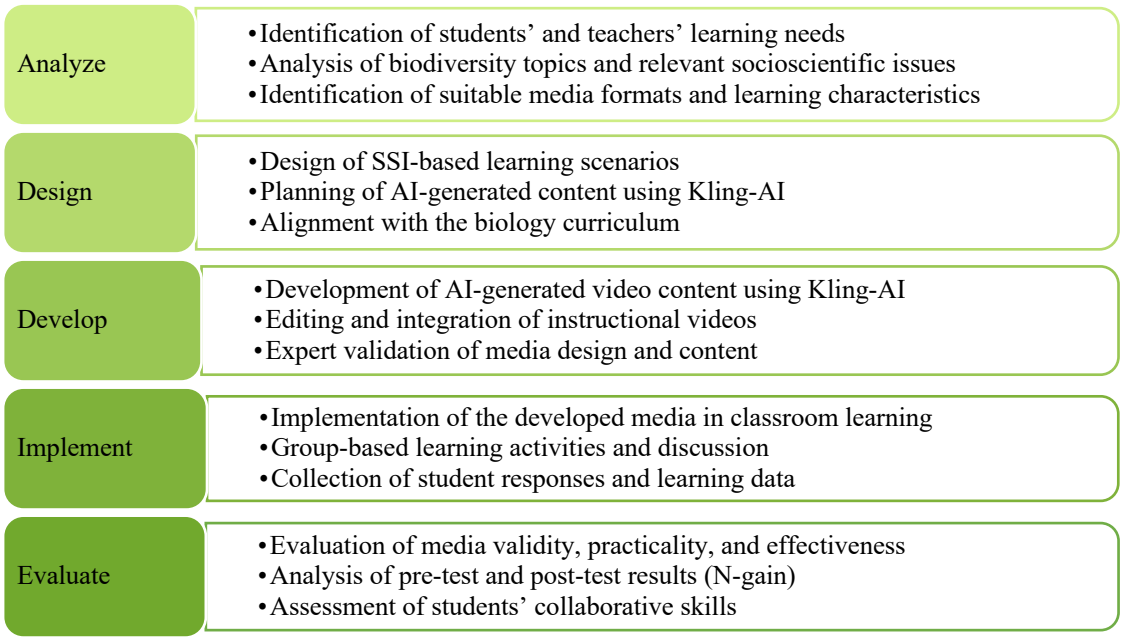

Figure 1. Research procedure based on the ADDIE model

As shown in Figure 1, the analysis stage involved identifying learning needs, student characteristics, and curriculum alignment. The design and development stages focused on planning and producing AI-based learning media using a socio-scientific issues approach, followed by expert validation. The media was then implemented in classroom learning, and its validity, practicality, effectiveness, and collaborative skills outcomes were evaluated.

Data Analysis Techniques

The effectiveness of the developed learning media was evaluated by comparing students' pre-test and post-test scores using normalized gain (N-gain) to determine the level of improvement in learning outcomes (Hake, 1998). Descriptive statistical analysis was employed to analyze expert validation and student response questionnaire data by converting the obtained scores into percentages of the maximum possible score and interpreting them using predefined assessment criteria. In addition, students' collaborative skills were analyzed descriptively using rubric-based scoring to examine collaborative behaviours during learning activities (Wijayanti et al., 2024).

RESULTS AND DISCUSSION

To ensure that the developed learning media were aligned with students' learning conditions and contextual characteristics, an analysis of student needs was conducted at the initial stage of this study. The findings obtained from this analysis informed the subsequent stages of media development. The results of the student needs questionnaire are summarized in Table 2.

Table 2
Student needs questionnaire

Aspect	Yes	No
Do you have difficulty understanding the material on biodiversity?	4.00	18.00
How often do you use digital media in biology learning?	10.00	12.00
Do you find it easier to understand the material when it is presented in the form of images or videos?	16.00	6.00
Do you prefer to study individually rather than in a group?	12.00	10.00
Do you find the current learning methods interesting enough?	20.00	2.00
How often do you engage in discussions about social issues related to biology?	7.00	15.00
Do you feel that you understand biological concepts better by discussing them with friends or groups?	13.00	9.00
Do you find it difficult to collaborate with friends on group assignments?	4.00	18.00
Are you interested in using AI-based learning media in biology lessons?	16.00	6.00

Aspect	Yes	No
Are you more motivated to learn if the learning media has an attractive and interactive appearance?	17.00	5.00
Do you feel you need visual aids to understand the concept of biodiversity?	15.00	7.00
Do you think the use of technology is important in supporting biology learning?	18.00	4.00

Based on the results presented in Table 2, the student needs questionnaire indicates that students require learning media that are interactive, visually engaging, and contextually relevant to their coastal environment. These findings confirm that existing learning resources have not fully accommodated students' learning needs, particularly in supporting collaborative learning activities. This result is consistent with previous studies emphasizing that learning in under-resourced and coastal contexts requires instructional media that align with students' socio-ecological realities to enhance engagement and meaningful learning experiences (Semken & Freeman, 2008; van Deursen & van Dijk, 2019). Therefore, the results of this needs analysis provide a strong foundation for developing AI-based learning media integrated with socio-scientific issues. The results of the student needs analysis served as the foundation for the development of the Kling-AI-based learning media. Following the development process, expert validation was conducted to evaluate the quality, usability, and pedagogical alignment of the media before its application in classroom learning.

Based on this needs analysis, the learning media were subsequently developed to address the identified requirements. The learning media developed in this study were an educational animated video lasting about one minute, designed using the Kling-AI application and adapting the Socio-scientific Issue (SSI) approach. The material presented was related to biodiversity, raising the contextual issue of marine pollution as a real threat to biodiversity. This video serves as a starting point to encourage student collaboration through discussions based on scientific and social perspectives and is further developed through student worksheets. The video is visually designed in the form of animation, with segments and transitions between sections to clarify the narrative flow. It is equipped with subtitles and voice-overs. The animated display allows complex events to be presented in a simpler and easier-to-understand manner. The Kling-AI application is used as the main generator to create visual content, while the editing process is further carried out using the CapCut application, including the addition of graphic elements such as text and other overlays. Following the development process, expert validation was conducted to evaluate the quality, usability, and pedagogical alignment of the media before its application in classroom learning.

Table 3
Validity assessment by media experts

Aspect	Assessment Indicators	Score
Visual Quality	Clear video resolution	3.00
	Text in the video is easy to read and does not overlap with the image	4.00
	Transitions between video segments are smooth and unobtrusive	3.00
Audio Quality	Background music supports the learning atmosphere and does not dominate	4.00
Presentation of Material	Duration is appropriate (not too long/boring and not too fast)	4.00
	Delivered in language appropriate to the cognitive level of the students	3.00
	Video contains real/contextual examples relevant to the material	4.00
Learning Design	Learning objectives are conveyed implicitly and explicitly	3.00
	The video encourages active participation (e.g., prompts for thinking)	3.00
	In line with the learning approach (Socio-scientific issue)	4.00
	Relevant to the learning objectives achieved in CP	3.00
Educational appeal	Interesting video, not monotonous	4.00
	Contains visual or narrative elements that motivate students to learn	3.00
Total		45.00

As shown in Table 3, the results of the media expert validation indicate that the developed Kling-AI-based learning media achieved a high level of validity. This finding demonstrates that the media

meets essential criteria in terms of design quality, usability, and alignment with pedagogical objectives. These results support previous studies which highlight that artificial intelligence–based learning media must be pedagogically aligned and contextually appropriate to ensure instructional effectiveness (Chen et al., 2020; Zhang & Aslan, 2021). Thus, the high validity score confirms that the developed media is suitable for use in supporting biology learning activities. After the media design and technical aspects were validated by media experts, the next stage focused on evaluating the accuracy and suitability of the learning content. Therefore, subject matter expert validation was conducted to ensure that the biological concepts presented in the media were scientifically accurate and aligned with curriculum standards

Table 4
Validity assessment by subject matter experts

Aspect	Indicator	Score
Conceptual Accuracy	Concepts are consistent with theory	4.00
	No misconceptions found	4.00
Curriculum Alignment	In line with CP	4.00
	Supports the achievement of learning objectives (TP)	4.00
	Related to the Pancasila student profile	4.00
Conceptual integration	Providing understanding of the topic	4.00
Socioscientific relevance	The issues raised are relevant to real life and current environmental conditions.	4.00
	Opens up space for ethical, social, and scientific discussions related to human actions towards nature	4.00
	Encourages reflective attitudes and a sense of responsibility towards environmental sustainability	4.00
	Encouraging students to understand conflicting values and different perspectives (e.g., economic, ecological)	4.00
Accuracy of Language & Narrative	Communicative language, unambiguous, and in accordance with EYD	4.00
Total score		43.00

The results of the subject matter expert validation presented in Table 4 indicate that the developed learning media achieved a high level of content validity, with an average validity score of 97.72%, which falls into the very valid category. This finding demonstrates that the biological concepts and socioscientific issues presented in the media are scientifically accurate and appropriate for high school biology learning. This result supports the argument proposed by Zeidler et al. (2003) that SSI-based learning materials must be grounded in sound scientific content to facilitate meaningful reasoning and discussion. In addition, Sadler (2009) emphasizes that accurate scientific content is essential for supporting student interaction and collaborative knowledge construction in SSI-based learning contexts. Following expert validation of both media design and learning content, the developed media was then implemented in a limited-scale trial to obtain initial feedback from students.

Table 5
Limited-scale trial questionnaire before the media was applied in a large class

Aspect	Assessment Indicators	Score
Material	The material presented in the video is clear and understandable	3.00
	The video content is relevant to the topic being studied	3.00
Illustrations	The illustrations in the video are clear	3.00
	The video duration is appropriate, not too long/short	3.00
	Illustrations, graphics, or animations in the video help you understand the material	3.00
	The content in the video does not give rise to multiple interpretations	2.00
	This video makes you more interested in learning about this topic	3.00
Total		20.00

As shown in Table 5, the results of the limited-scale trial questionnaire indicate that students responded positively to the developed Kling-AI-based learning media, with an average response score of 92.22%, categorized as very practical. These results indicate that students perceived the media as engaging, clear, and supportive of collaborative learning activities. This finding is consistent with the study by Scherer et al. (2020), which reports that students' engagement with digital learning environments is strongly influenced by the interactivity and relevance of instructional media. Furthermore, (Semken & Freeman, 2008) argue that contextual learning grounded in students' local environments enhances affective engagement and learning relevance. Following the positive results obtained from the limited-scale trial, the next stage of the study focused on evaluating the practicality of the developed learning media. This stage aimed to examine the ease of use, clarity, and effectiveness of the media when applied in actual classroom settings.

Table 6
Student Media Practicality Questionnaire

Aspect	Class Score
The material presented in the video is clear and understandable	79.00
The video content is relevant to the topic being studied	81.00
The illustrations in the video are clear	83.00
The video duration is appropriate, not too long or too short	81.00
Illustrations, graphics, or animations in the video help you understand the material	81.00
The content in the video does not give rise to multiple interpretations.	80.00
This video makes you more interested in learning about this topic.	82.00
Is the Kling-AI app easy to use?	85.00
Total score	652.00

As presented in Table 6, the student media practicality questionnaire shows that the developed Kling-AI-based learning media achieved a high level of practicality, with an average score of 92.22%, categorized as very practical. These results indicate that students perceived the media as easy to use, engaging, and supportive of collaborative learning activities during biology instruction. This finding is consistent with Scherer et al. (2020), who reported that students' acceptance and effective use of digital learning media are strongly influenced by usability and perceived relevance. In addition, Karişan & Zeidler (2024) emphasize that digital learning environments integrated with SSI can enhance collaborative interaction when designed to facilitate discussion and shared problem-solving. Moreover, the practicality of the developed learning media was also evaluated from the teacher's perspective to obtain a more comprehensive understanding of its classroom applicability.

Table 7
The teacher's response to the practicality of the media

Aspect	Indicators	Score
Ease of use	How easy is this media to access and use by teachers in learning?	3.00
Suitability for learning	Is the content in this media appropriate for the biology curriculum and learning objectives?	4.00
	How effective is this media in supporting student needs?	3.00
Efficiency and practicality	Are the illustrations in this video easy to understand?	3.00
	How easy is this media to integrate with existing learning methods?	3.00
Total score		16.00

The results presented in Table 7 show that the teacher's response to the practicality of the developed learning media yielded an average score of 80.00%, categorized as *practical*. This result indicates that the media is considered feasible and applicable for classroom use, particularly in supporting instructional delivery and student collaboration. These findings align with Zhang & Aslan (2021), who highlight that the effectiveness of AI-supported learning media depends on its alignment and ease of classroom integration. Furthermore, Hwang et al. (2020) emphasize that AI-based instructional tools must support teachers' instructional goals to be effectively implemented in real learning contexts. After the practicality of the developed learning media was confirmed from both student and teacher perspectives, the next stage focused on examining the effectiveness of the media in improving

students' learning outcomes.

Table 8
N-gain analysis of students' learning outcomes

Assessment	Mean score
Pre-test	49.40
Post test	65.22
N-gain	0.33

The results of the N-gain analysis presented in Table 8 indicate that students' learning outcomes improved after the implementation of the Kling-AI-based SSI learning media, with an average N-gain score 0.33 categorized as *moderate*. This result suggests that the developed media was effective in supporting students' conceptual understanding in biology learning. This finding supports Sadler (2009), who states that SSI-based learning can enhance students' understanding by engaging them in meaningful reasoning and discussion of real-world scientific issues. Moreover, Zhang & Aslan (2021) emphasize that digital learning media integrated with appropriate pedagogical approaches can positively influence students' learning outcomes. Beyond cognitive learning outcomes, this study also examined the development of students' collaborative skills as one of the key competencies emphasized in SSI-based learning.

Table 9
Average collaborative skill scores of students per indicator

No.	Collaborative skill indicator	Average score
1	Group involvement	84.27
2	Responsibility in carrying out assigned tasks	80.81
3	Working with colleagues	80.95
4	Contribution to problem solving	81.63
5	Respecting friends' opinions	82.13
Total		81.96

As shown in Table 9, the average collaborative skill scores of students across all observed indicators fall within the good category, with an overall average score of 81.96. These results indicate that students demonstrated positive collaborative behaviors, including participation in discussions, sharing ideas, and engaging in group decision-making activities. This finding aligns with Zeidler et al. (2005), who explain that SSI-based learning environments inherently promote collaboration through discourse and collective reasoning. Besides that, Sadler (2009) highlights that social interaction and peer negotiation are essential components in fostering collaborative competencies in science learning. To provide a clearer picture of students' overall collaborative competence, the level of students' collaborative skill mastery was further analyzed.

Table 10
Level of student collaborative skill mastery

Score Category	Number of Students	Percentage
≥ **71** (achieved)	19.00	86.36%
< **71** (not achieved)	3.00	13.63%
Total	22.00	100.00%

The results presented in Table 10 show that the majority of students achieved a good level of collaborative skill mastery after participating in SSI-based learning supported by Kling-AI media. This finding indicates that the developed learning media effectively facilitated students' ability to collaborate, communicate ideas, and work collectively to address socio-scientific problems. This result is consistent with Sholehah et al. (2022), who reported that SSI-oriented learning encourages shared responsibility and collaborative decision-making among students. Not only that, Yokhebed (2019) emphasizes that collaboration is a core competency required for students to function effectively in 21st-century learning environments.

The findings of this study demonstrate that the Kling-AI–based learning media integrated with the socio-scientific issues (SSI) approach is valid, practical, and effective in supporting biology learning,

particularly in fostering students' collaborative skills. Rather than functioning merely as a medium for content delivery, the developed product serves as a pedagogical trigger that stimulates discussion, shared reasoning, and collective problem-solving through contextual environmental issues.

The high validity scores obtained from both media experts and subject matter experts indicate that the developed media meets essential instructional quality standards. From a media design perspective, the short-duration animated video format, clear visual elements, and structured narrative flow help support students' understanding without increasing cognitive overload. Visual-based learning media have been reported to enhance learners' engagement and meaning-making processes by presenting complex information in accessible and concrete forms (Salehudin et al., 2021). From a content perspective, the integration of biodiversity concepts with marine pollution issues ensures conceptual accuracy while embedding scientific knowledge within authentic and locally relevant contexts. These findings are consistent with previous research emphasizing that effective AI-based learning media must align not only with technical design principles but also with pedagogical and curricular objectives (Chen et al., 2020; Sultana et al., 2021; Zhang & Aslan, 2021).

The practicality results further indicate that the Kling-AI–based learning media is feasible for classroom implementation. Positive responses from both students and teachers suggest that the media is easy to use, engaging, and compatible with existing instructional practices. The concise duration of the video allows flexible integration into classroom learning, particularly as an introductory stimulus for group discussions. This finding aligns with Scherer et al. (2020), who highlight that usability and perceived relevance strongly influence learners' acceptance of digital learning media. In addition, AI-assisted media development has been shown to support teachers in efficiently preparing contextual and engaging instructional resources (Hwang et al., 2020; Maulid et al., 2024).

In terms of effectiveness, the moderate N-gain score indicates that the developed media contributes positively to students' conceptual understanding, although the improvement is not categorized as high. This outcome should be interpreted as a characteristic of the developed product rather than a limitation. The learning media was intentionally designed as a short, discussion-oriented trigger rather than a comprehensive instructional package, placing greater emphasis on collaborative engagement than on intensive cognitive training. Instructional design studies suggest that learning media designed primarily to stimulate interaction and reflection may demonstrate stronger social learning outcomes than immediate cognitive gains (Mang et al., 2021; Sadler, 2009; Sultana et al., 2021). Therefore, the moderate N-gain score remains consistent with the intended pedagogical function of the media.

A key contribution of this study lies in the development of students' collaborative skills. The results show that students demonstrated good levels of collaboration across indicators such as participation, responsibility, cooperation, and contribution to problem solving. These findings support the theoretical framework of SSI-based learning, which emphasizes discourse, argumentation, and collective decision-making as central mechanisms for fostering collaboration (Pitiporntapin et al., 2015; Zeidler et al., 2005). By presenting socioscientific issues grounded in students' coastal environments, the media encourages learners to negotiate diverse perspectives and engage in shared problem-solving processes, thereby strengthening collaborative competencies.

Compared to previous studies that focus primarily on individual cognitive outcomes or text-based SSI materials, this study highlights the potential of AI-generated visual media to support collaborative learning contextually and efficiently. The use of a short animated video generated through Kling-AI distinguishes this study from prior research by demonstrating that AI-based media can function effectively as a collaborative learning catalyst rather than a standalone instructional tool. This finding extends existing research on SSI and digital learning by illustrating how artificial intelligence can be strategically integrated to support 21st-century skills—particularly collaboration—in under-resourced and coastal learning contexts (Karişan & Zeidler, 2024; Yokhebed, 2019).

Overall, the discussion indicates that integrating Kling-AI–based learning media with the SSI approach provides meaningful learning experiences that support both conceptual understanding and collaborative skill development. By aligning AI-generated visualization with socioscientific pedagogy and local environmental contexts, the developed product contributes to more relevant, engaging, and socially grounded biology learning.

CONCLUSION

This study concludes that the Kling-AI–based learning media integrated with the Socioscientific

Issues (SSI) approach is valid, practical, and effective for supporting biology learning, particularly in the context of marine pollution topics. The expert validation results confirm that the developed media meets instructional quality standards, while practicality assessments indicate that the media is feasible and easy to implement in classroom settings. The findings further demonstrate that the developed media contributes positively to students' learning outcomes and plays a significant role in fostering collaborative skills through discussion-oriented and context-based learning activities. The use of a short-duration, AI-generated animated video positions the product as a pedagogical trigger that facilitates socioscientific discussion rather than a comprehensive instructional package, which explains the moderate cognitive gains observed. In general, the integration of artificial intelligence–based visualization with the SSI approach offers a meaningful learning strategy that supports both conceptual understanding and the development of essential 21st-century skills, particularly collaboration, in coastal and under-resourced educational contexts.

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