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The Development STEM-based Students' Worksheets to Foster Collaborative Skills in Biology Learning

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ABSTRACT

Mastery of 21st century skills is essential for preparing students to adapt and compete in the era of globalization and technological advancement. One of the most important skills is collaboration, which involves the ability to work effectively in teams through active participation and effective communication. Preliminary research conducted through questionnaires and observations indicated that students' collaboration skills had not yet reached the optimal level based on the established indicators. This study aimed to determine the feasibility of a Science, Technology, Engineering, and Mathematics (STEM)-based Student Worksheet for Grade XI biology learning. This development research employed the ADDIE model. Data were collected through interviews, observations, and questionnaires. The sample consisted of 36 students from Class XI-8 at SMA Negeri 1 Guntur, selected through cluster random sampling from nine Grade XI biology classes. The results showed that the STEM-based Student Worksheet was highly feasible for learning, as indicated by evaluations from media experts (89%), content experts (81%), methodology experts (91%), biology teachers (88%), and students (90%). The implementation results revealed that 89% of students demonstrated very good collaboration skills, 8% good collaboration skills, and 3% fairly good collaboration skills, with collaboration indicator achievement ranging from 95.14% to 96.53%. These findings indicate that the developed STEM-based Student Worksheet is feasible for use and has the potential to facilitate students' collaboration skills in senior high school biology learning. This study contributes to the development of STEM-based instructional materials that support collaboration skills, while future research should examine its effectiveness through more in-depth observations and larger sample sizes.

Keywords: Biology, Collaboration skills, Student Worksheet STEM

Introduction

Mastery of 21st-century skills is crucial in preparing students to adapt and compete amidst the challenges of globalization and rapid technological advancement. According to the 21st Century Partnership Learning Framework, the essential skills students need to acquire include critical thinking, creativity, communication, and collaboration (Greenstein, 2012). Collaboration is one of the fundamental elements, involving the ability to work effectively in teams through clear communication and active participation. Firman et al. (2023) state that collaboration skills are essential competencies that individuals must possess in order to cooperate effectively, foster tolerance within a team, and enhance decision-making abilities to reach mutual agreements. For students, these skills serve as the foundation for group work during the learning process, which can become a valuable asset in facing real-world competition. Well-developed collaboration can significantly contribute to improving students' competitiveness.

Several studies have demonstrated the importance of collaboration skills within the context of learning. Mawaddah et al. (2022) demonstrated that STEM-based science learning worksheets (LKS) developed using the ASSURE model can significantly enhance elementary students' collaboration skills. The activities within the worksheets were designed to require group work, discussion, and joint problem-solving, which proved effective in improving indicators of collaboration such as active participation, responsibility, flexibility, and mutual respect. Similarly, a study by Cholis and Yulianti (2020) showed that the implementation of STEM-based physics learning significantly improved high school students' collaboration skills. In this study, students in the experimental class experienced an increase in collaboration scores from 50% to 90%, with an N-Gain score of 0.81, categorized as high. Statistical tests also revealed a significant difference between the experimental and control groups, confirming that the STEM approach can effectively facilitate the development of collaboration skills. Adhiati et al. (2023) also reported that students' collaboration skills improved after the use of STEM-based worksheets (LKS) during learning activities. Meanwhile, a study by Aini and Kuendo (2023) showed that the implementation of the STEM approach in learning significantly enhanced students' collaboration skills, with a post-test mean difference of 7.816 points between the experimental and control groups. The activities within the worksheets encouraged students to participate actively, share ideas, and make joint decisions, thereby effectively supporting the development of collaborative abilities.

In reality, the collaboration skills of students at SMA Negeri 1 Guntur are still considered to be in the low category. This is evidenced by the questionnaire results, where the positive responses scored 38.75%, while the negative responses scored 39.37%. Direct classroom observations of students' collaboration skills also showed a score of 38.46%. According to Sufajar and Qosyim (2022), these observation and questionnaire results fall into the "less collaborative" category. Interviews with teachers revealed that classroom learning still tends to rely heavily on lectures and individual assignments. There is currently no availability of innovative student worksheets that can support collaboration skills at SMA Negeri 1 Guntur. The absence of such worksheets may limit opportunities for student cooperation and contribute to the low level of collaborative skills.

Student Worksheets are one of the instructional tools used in the learning process. In general, worksheets function as learning materials that support or complement the lesson plan. According to Hamdani (2011), student worksheets consist of printed sheets containing information or questions that students are required to respond to. STEM-based student worksheets offer distinct advantages in fostering students' collaboration skills, as they are designed to present contextual problems that must be solved through group work. Through the STEM approach, students are not only expected to understand concepts in science, technology, engineering, and mathematics, but also to collaborate in designing solutions, engaging in discussions, dividing tasks, and drawing conclusions together. Ramachandran (2025) explains that the Science, Technology, Engineering, and Mathematics (STEM) approach

encourages students to work in teams through group projects, thereby enhancing communication and teamwork skills. Active learning methods such as discussions and experiments require intensive interaction among students, which helps develop essential interpersonal skills. STEM is an acronym for the disciplines of science, technology, engineering, and mathematics. According to Beers, the STEM approach in education integrates these four disciplines and is considered one of the most effective methods for supporting the development of 21st-century skills (Cholis & Yulianti, 2020). STEM-based Student Worksheets naturally promote collaboration, as they are designed through interdisciplinary activities that require students to work together in solving complex and contextual problems (Bybee, 2013). STEM learning guides students to collaborate in groups as they design solutions, engage in discussions, and divide roles and responsibilities throughout the task completion process (Luthfiyani et al., 2019).

Although previous studies have demonstrated the positive impact of STEM-based learning and STEM-based worksheets on students' collaboration skills, most of these studies focused on examining the effects of STEM implementation rather than developing worksheets that explicitly integrate collaboration skill indicators into each learning activity. In addition, STEM-based worksheets specifically designed to facilitate collaboration skills in senior high school biology learning remain limited. Therefore, this study develops a STEM-based Student Worksheet that systematically incorporates collaborative activities, including role distribution, group problem-solving, project-based tasks, presentations, and reflection activities. This study contributes to the development of a biology worksheet that not only integrates Science, Technology, Engineering, and Mathematics (STEM) components but also embeds collaboration skill indicators throughout the learning process to support the development of students' collaboration skills. Based on the identified gap, this study aims to develop and evaluate the feasibility of a STEM-based Student Worksheet designed to facilitate collaboration skills among Grade XI students in biology learning.

Methods

This research employed a Research and Development (R&D) design to develop and evaluate Student Worksheets integrated with a STEM (Science, Technology, Engineering, and Mathematics) approach at SMA Negeri 1 Guntur during the odd semester of the 2024/2025 academic year. Rather than relying on a generic theoretical overview, the study followed a systematic progression across the five phases of the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model. According to ADDIE Branch (2009), these stages were executed through the following specific research steps:

The analyze phase began with a preliminary study through classroom observations, teacher interviews, student questionnaires, and document analysis, which revealed low student collaboration skills and infrequent *Student Worksheet* usage. To address this, the researcher developed a STEM-based *Student Worksheet* connecting science, technology, engineering, and mathematics via contextual problem-solving to foster teamwork and 21st century skills. From a target population of nine Grade XI Biology classes, a sample of 36 students from Class XI-8 was selected using cluster random sampling.

Design phase in this stage, the initial blueprint of the STEM-integrated *Student Worksheet* was constructed. The STEM design was explicitly embedded into the worksheet activities, requiring students to engage in scientific investigation (Science), utilize technological tools or digital references (Technology), design and construct solutions or models (Engineering), and perform quantitative data analysis or measurements (Mathematics). Alongside the worksheet layout, assessment instruments including validation sheets and observation rubrics for student collaboration were drafted. *Develop phase*, the designed STEM-integrated Student Worksheet prototype was fully produced and subjected to rigorous expert validation. Content validity was established by submitting the product to three expert validators: a media expert, a content expert, and a methodology expert. Expert evaluations involved both quantitative

scoring (using a four-point rating scale) and qualitative feedback (suggestions and revisions), which served as the basis for refining the product before field testing.

Implement phase, the validated and revised STEM-integrated Student Worksheet was implemented in an actual classroom setting with a sample of 36 students from Class XI-8 during one learning session to test its functionality and practicality. Data collection during this stage utilized multiple techniques: (1) Questionnaires: Administered to assess students' readability responses and overall user feedback regarding the Student Worksheet; (2) Observations: Student collaboration skills were assessed using observation sheets. To ensure reliability, assessments were conducted simultaneously by an independent observer using specific behavioral descriptors across four dimensions (collaboration, adaptation, empathy, and compromise), as detailed in Table 1.

Table 1. Matrix of the observation instruments

No	Dimension	Indicators / Behavioral Descriptors	Pre-Research Format	Implementation Format
1	Collaboration	Active participation, mutual support, and creating a conducive environment.	Individual scoring (scale 0-4)	Breakdown into 4 specific behavioral items
2	Adaptation	Active participation, mutual support, and creating a conducive environment.	Individual scoring (scale 0-4)	Breakdown into 4 specific behavioral items
3	Empathy	Respecting diverse ideas and showing care toward peers.	Individual scoring (scale 0-4)	Breakdown into 4 specific behavioral items
4	Compromise	Open discussion to reach agreements and committing to group decisions.	Individual scoring (scale 0-4)	Breakdown into 4 specific behavioral items

Evaluate phase, the data analysis for the development of the Student Worksheet utilized both quantitative and qualitative methods. Qualitative analysis consisted of suggestions and feedback from expert validators, as well as evaluations from biology teachers regarding the developed product. Quantitative analysis involved the calculation of numerical scores obtained from expert validations, teacher assessments, and student readability tests. These results were then calculated using the following formula.

$$Feasibility\ percentage = \frac{Empirical\ score\ (obtained\ from\ validators)}{Maximum\ expected\ score}\ x\ 100$$

The validation questionnaire, biology teacher assessment, and student responses utilized a four-point rating scale, as shown in Table 2. The scoring system followed a rating scale, and the percentage scores obtained from the research were interpreted based on the criteria outlined in Table 3 below.

Table 2. Assessment score

Description	Score
Very good (SB)	4
Good (B)	3
Fairly good (K)	2
Not good (SK)	1

(Akbar, 2022)

Table 3. Percentage criteria

No	Percentage (%)	Criteria	Description
1	00.00% - 20.00%	Not Valid	Not good to be used
2	21.00% - 40.00%	Less valid	Not good to be used
3	41.00% - 60.00%	Fairly valid	Good to be used after major revision
4	61.00% - 80.00%	Valid	Good to be used after minor revision
5	81.00% - 100.00%	Highly valid	Very good to be used

(Akbar, 2022)

Results and Discussion

Product Prototype

Prior to product development, a preliminary analysis was conducted using three primary data collection methods: classroom observations to examine the learning process and students' collaborative skills, an interview with the biology teacher to identify curriculum constraints and instructional needs, and a questionnaire administered to 34 students to thoroughly assess their learning requirements. The analysis revealed a deficiency in students' collaborative skills and the absence of an appropriate student worksheet for biology instruction at SMA Negeri 1 Guntur. Consequently, these findings justified the development of a Student Worksheet specifically designed to support and facilitate the enhancement of students' collaborative skills.

The prototype design of the Student Worksheet was systematically developed, focusing on Grade XI biology material for the first semester, which was carefully selected and integrated with STEM components. Structurally, the worksheet is organized to include brief learning materials for students to read, supporting illustrations, and references. Specifically, the product is developed by integrating the four main STEM components science, technology, engineering, and mathematics into contextually driven project activities related to students' daily lives. Within each STEM element, specific tasks and collaborative activities are embedded to guide students in actively working together with their peers, thereby fostering their collaborative skills.

To achieve this, the learning activity tasks incorporated simple experiments, group discussions, and project-based problem-solving that actively engaged students in role sharing, idea discussion, joint decision-making, and collective task completion (Firman et al., 2023). Following this design phase, the Student Worksheet prototype was validated by three expert lecturers specializing in content, media, and methodology. Additionally, the Student Worksheet underwent readability testing by students and subsequently underwent readability testing by students alongside an evaluation by the biology teacher.

Content Expert Validation

The content validation was conducted by a lecturer of the Vertebrate Zoology course at UIN Walisongo Semarang. The purpose of this validation was to assess the accuracy and relevance of the material presented in the student worksheet (Rochmatin, 2023). The results of the content expert validation are presented in Table 4 below.

Table 4. Results of Content Expert Validation

Aspect	Percentage (%)
Content	92
Material Presentation	75
Language Used in the Material	75
Overall Total	**81**

Based on Table 4, the content expert validation indicates that the developed student worksheet received highly favorable evaluations across all assessed aspects. The content aspect achieved the highest validation score, while material presentation and language aspects also received strong ratings. Overall, the average validity falls into the 'highly valid' category according to Akbar (2022), demonstrating that the worksheet is suitable for use as instructional material without major revisions. The summary of revisions based on the design expert's feedback is presented in Table 5, while the visual changes made to the student worksheet are illustrated in Figures 1 and 2.

Table 5. Summary of Product Revisions Based on Expert Feedback

Suggestions & Feedback	Revision Action Taken
The summary text layout is plain, lacks digital interactive resources, and needs a more structured presentation to support self-directed learning.	Integrated an interactive QR code to embed digital learning resources, redesigned the layout into a cleaner text structure, and added a data table to present cell theories systematically.
The biological text presentation in the summary section lacks hierarchical structure, making long paragraphs difficult for students to scan and navigate.	Added clear and numbered subheadings (e.g., specific physiological systems and disorders) to break down complex text, improving the overall textual organization and readability.

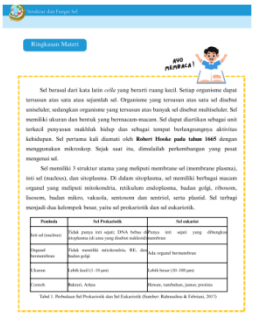

Figure 1. Before revision

Figure 2. After revision

Figure 3. English version

Media Expert Validation

The media validation was conducted by a lecturer of the Instructional Media course at UIN Walisongo Semarang. The media validator evaluated various aspects of the student worksheet, including product presentation such as layout, neatness, dimensions, and design (Ramadhan & Sumarni, 2025). The results of the media expert validation are presented in Table 6 below.

Table 6. Results of media expert validation

Aspect	Percentage (%)
Product Presentation	85
Product Design	95
Language	87
Overall Total	**89**

Based on Table 6, the media expert validation demonstrated high feasibility across all evaluated criteria. Product design achieved the highest evaluation, followed closely by language and product presentation aspects. Overall, the average media validity level falls into the 'highly valid' category according to Akbar (2022), indicating that the developed student worksheet is highly suitable for use as instructional material. Revisions suggested by the media expert included changes to the cover color, concept map, and the use of clearer images.

Revisions suggested by the media expert included changes to the cover color, concept map, and the use of clearer images. A concise summary of these design modifications and the subsequent adjustments made to the Student Worksheet is presented in Table 6. Furthermore, the detailed visual comparison of the layout enhancement, particularly the transition toward high-definition illustrations and collaborative task instructions, is presented in Figure 4 and Figure 5.

Table 7. Summary of product revisions based on expert feedback

Suggestions & Feedback	Revision Action Taken
Modifying the color of the Student Worksheet cover to enhance text readability and replacing the hexagon elements with more appropriate illustrations.	Changed the cover color to maroon to make the text clearly visible and added corresponding illustrations inside the pentagon shapes.
The concept map lacks depth and a clear hierarchical flow between biological concepts.	Redesigned the concept map from a simple linear structure into a detailed horizontal hierarchical layout, adding linking words and specific sub-topic branches to enhance students' conceptual understanding.
The cell illustrations need better clarity, and the task instructions should more explicitly promote active group collaboration among students.	Replaced the three initial figures with two high-definition cell illustrations using updated references, and redesigned the tasks into explicit collaborative instructions that direct students to assign group roles and reach consensus during discussions.

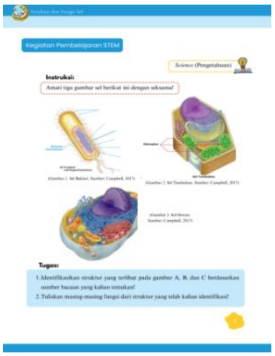

Figure 4. Image before revision

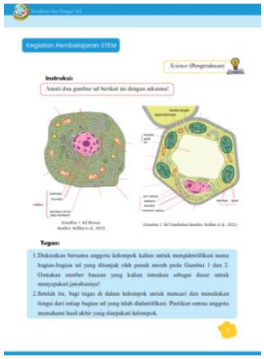

Figure 5. Image after revision

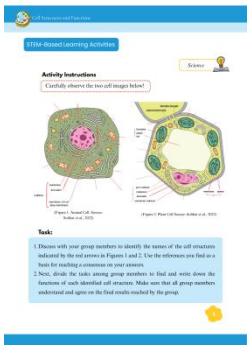

Figure 6. English version

Methodology Expert Validation

The methodology validation was conducted by a lecturer of the Research Methodology course at UIN Walisongo Semarang. The purpose of the methodology expert validation was to evaluate the learning objectives and the extent to which STEM approach aspects had been integrated into the activities within the student worksheet, as well as to assess the potential of those activities in developing students' collaboration skills. The results of the methodology expert validation are presented in Table 8 below.

Table 8. Results of Methodology Expert Validation

Aspect	Percentage (%)
Learning Objectives	87
STEM Integration	100
Collaborative Activities	85
Overall Activities	**91**

Based on the descriptive data presented in Table 8, the methodology expert validation shows highly favorable outcomes across all evaluated aspects. Notably, the STEM integration aspect achieved a perfect score, while learning objectives and collaborative activities also received high ratings. Overall, the average validation score for the methodology falls under the 'highly valid' category according to Akbar (2022), indicating that the developed Student Worksheet is highly suitable for use as instructional material.

Revisions suggested by the methodology expert included modifications to the learning objectives presented in the Student Worksheet to ensure alignment with existing standards. Additionally, the expert provided structural feedback regarding the formulation of questions and task instructions within the student worksheet to stimulate analytical thinking better. A concise summary of these methodological improvements and the corresponding revision actions taken is presented in Table 8. Furthermore, Figures 7 and 8 provide concrete visual examples of the modifications made to one of the points outlined in Table 9.

Table 9. Summary of product revisions based on expert feedback

Suggestions & Feedback	Revision Action Taken
Deconstruct overlapping learning objectives into separate, more operational, and measurable points that incorporate clear contextual cases.	Separated the combined objective regarding the causes and impacts of anemia into two distinct, measurable indicators, and added specific contexts such as 'from a given case' and 'real-world situations'.
Refine the question words to stimulate students' analytical and higher-order thinking skills rather than simple identification.	Modified the interrogative words in the tasks from 'What' to 'How' to prompt deeper conceptual explanations regarding the chemical components of cells.
Simplify over-explained instructional guidelines and correct typographical errors to ensure the text is concise and direct.	Reworded the verbose instructional prompt into two short, direct sentences and corrected the typographical error, making the guidelines clearer for students.

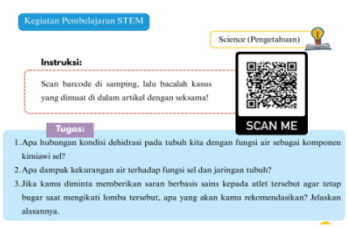

Figure 7. Question Formulation Before Revision

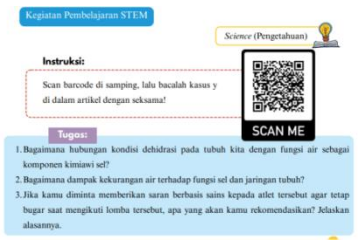

Figure 8. Question Formulation After Revision

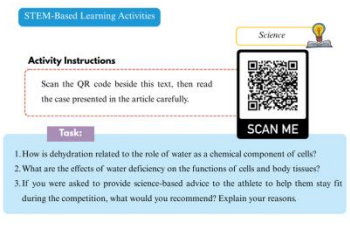

Figure 9. Question Formulation After Revision (in English)

Student Responses and Biology Teacher Feedback

Comprehensive descriptive statistics of students' responses and biology teacher feedback, shown in Table 10, showed that both the biology teacher and students provided highly positive evaluations across all measured aspects. For the teacher's evaluation, the highest scores were achieved in content; content relevance and product; activity presentation, followed closely by product design, STEM integration, collaboration skills, and language. Overall, the teacher's assessment reached a high average percentage.

Table 10. Student responses and biology teacher feedback

Aspect	Teacher Percentage (%)	Student Percentage (%)
Content/Content Relevance	96	90
Language	75	-
Product/Activity Presentation	96	90
Product Design	94	88
STEM Integration	87	-
Collaboration Skills	80	92
Activity Relevance to the Material	-	90
Overall Total	**88**	**90**

On the student side, the response data showed strong satisfaction across all evaluated criteria, particularly in collaboration skills, content relevance, and activity presentation. Overall, this resulted in a high student response average.

According to Akbar (2022), these percentage results fall into the highly practical category, indicating that the developed Student Worksheet is very appropriate and user-friendly for classroom application. The biology teacher gave positive feedback, particularly on the material organization, sequencing, and visual presentation of the student worksheet, stating that it was well-structured and engaging. Furthermore, student feedback indicated that the Student Worksheet was interesting, easy to understand, and facilitated the learning process due to its systematic presentation.

An observation of students' collaboration skills during the readability test was also conducted. This aimed to assess the extent to which the student worksheet supports the development of students' collaborative abilities. The results of the observation are shown in Figure 10 below.

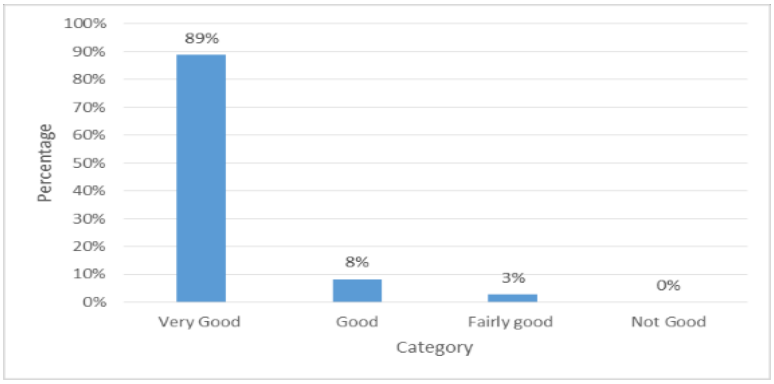

Figure 10. Percentage graph of student collaboration skills observation results

Based on Figure 10 above, the results indicate that the vast majority of students achieved positive ratings in their collaboration skills, with the very good category being the most dominant. Meanwhile, only a small fraction of students fell into the lower categories, and none were recorded in the lowest category. These results were further grouped into four specific collaboration skill indicators, as illustrated in Figure 11.

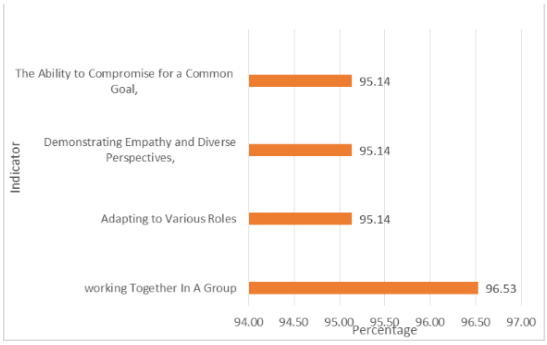

Figure 11. Percentage graph of observation results for each collaboration skill indicator

Figure 11 illustrates that all collaboration skill indicators achieved consistently high results, with the working together in a group indicator peaking slightly above the others. The remaining indicators showed uniform performance levels. The collaboration skill indicators used in this study were adopted from the research by Erviani et al. (2022).

Each collaboration skill indicator assessed during the observation was supported by specific components of the STEM approach, which were systematically integrated into the student worksheet activities. The first indicator, working together in a group, was primarily supported by the engineering (E) component of STEM, in which students were tasked with designing solutions or creating simple products as a team. This required clear task division and organized collaboration. The second indicator, adapting to various roles, was supported by the integration of all four STEM disciplines within the Student Worksheet. The designed activities involved multiple roles based on students' individual strengths, allowing flexible and efficient task allocation without disrupting the problem-solving process. The Student Worksheet also included explicit instructions for role division, such as group leader, recorder, presenter, and data collector, which encouraged students to adapt to assigned or emerging roles actively, making collaboration more structured and effective.

The third indicator, demonstrating empathy and diverse perspectives, is supported by the science (S) component, which emphasizes the processes of observation, discussion, and conclusion drawing. Scientific discussions conducted by students provide space for differing viewpoints while remaining within a framework of logical and collaborative thinking. The fourth indicator, the ability to compromise for a common goal, is closely related to the mathematics (M) component of the STEM approach. Activities involving calculations, data processing, or result analysis encourage students to reach mutual agreements in making appropriate decisions. As a result, compromise becomes an essential element in uniting ideas to achieve accurate and collectively agreed-upon outcomes (Ilma et al., 2024). Based on the observation results presented in Figure 11, it can be concluded that the Student Worksheet developed by the researcher effectively accommodates students' collaboration skills in the Grade XI biology subject matter.

The developed STEM-based Student Worksheet integrates various strategies and features designed to enhance student interaction. One such strategy is group project-based assignments, which make the Student Worksheet more student-centered (Nurwahidah et al., 2021). Students were directed to collaborate in designing, planning, and solving contextual problems related to biology topics. The student worksheet also included structured group work guidelines, clearly defined role responsibilities, and a collaboration observation sheet that served as a tool for both individual and group reflection.

These features not only strengthen the implementation of STEM-based learning but also foster students' abilities to express opinions, listen to peers' ideas, resolve conflicts, and make collective decisions (Sumanti et al., 2025). Therefore, STEM-based learning enhances not only content mastery but also provides meaningful learning experiences that optimally develop collaboration skills (Dewi et al., 2024).

This finding is consistent with research by Mawaddah et al. (2022), which concluded that STEM-based worksheets can enhance students' collaboration skills. The developed worksheets included activities such as experiments, discussions, and demonstrations, providing students opportunities to exchange ideas and perspectives. Research by Aini and Kuendo (2023) also supports the claim that implementing STEM-based learning improves collaboration skills.

Furthermore, Cholis and Yulianti (2020) found that the STEM learning approach provided students with problems to be solved collaboratively through exploratory activities such as discussions and experiments, culminating in the presentation of their work in group reports. Through this approach, students had opportunities to cooperate, actively engage in problem-solving, design and evaluate investigations, and develop inquiry and reflection skills. Thus, this method contributes significantly to the development of students' collaboration skills.

The STEM components integrated into the student worksheet were systematically designed to support learning objectives and foster 21st-century skills, especially collaboration. Each student worksheet activity was structured to reflect the interconnectedness of science, technology, engineering, and mathematics. This integration aims to build contextual and meaningful learning experiences that encourage students to work collaboratively in solving assigned challenges (Kiswari et al., 2023).

Conclusion

The Student Worksheet was designed and developed utilizing the ADDIE development model by integrating the four main STEM components science, technology, engineering, and mathematics presented through problem-based and contextually driven project activities. The feasibility evaluation of the worksheet for Grade XI biology material demonstrated excellent results, yielding scores of 89% from the media expert, 81% from the content expert, and 91% from the methodology expert, thereby placing it in the highly valid category. Furthermore, student responses from the implementation trial in Class XI-8 achieved a score of 90%. In comparison, the biology teacher's evaluation yielded 88%, both indicating that the product is highly practical and appropriate for classroom use. Nevertheless, given the limited scope of this initial trial, further in-depth research is recommended to comprehensively evaluate the worksheet's long-term effectiveness in fostering students' collaboration skills.

Acknowledgement

The researcher would like to express sincere gratitude to the academic advisor and examiners for their valuable suggestions and feedback, which greatly contributed to the refinement of this research. Appreciation is also extended to all members of SMA Negeri 1 Guntur for their support and cooperation throughout the completion of this study.

Generative AI Disclosure

The use of artificial intelligence tools were utilized to translate and adapt certain sentences from Indonesian into formal, academic English, as well as to refine and polish the sentences and paragraphs drafted in this manuscript.

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