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Development of a STEM-Based Physics Instructional Tool to Encourage Students' Collaboration Skills in Inclusive High School

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Abstract: This study aimed to develop and evaluate a STEM (Science, Technology, Engineering, and Mathematics)-oriented physics instructional tool on sound waves to improve collaboration skills in an inclusive high school setting. Using the ADDIE model, the development process included need analysis, instructional design, expert validation, and limited classroom implementation. The product consists of a syllabus, lesson plans, a student module, worksheets, and assessment instruments tailored for diverse learners, including students with Special Educational Needs (SEN). Expert validation involving material, media, and instructional tool reviewers resulted in scores within the "very good" category (average >3.25). Classroom implementation involved 28 students, including one deaf student, who engaged in group-based activities. Student responses showed high acceptance (mean score = 0.74), particularly regarding contextual learning and fair task distribution. Observation using Brookhart's collaboration rubric, showed medium-to-high improvement (average normalized gain = 0.67). Notably, the deaf student actively contributed to group tasks, highlighting the product's inclusivity. These findings suggest that STEM-based instructional tools can effectively support collaborative learning in inclusive physics classrooms. The study recommends further large-scale implementation to validate impact on broader student populations.

Keywords: Collaboration skills; Inclusive high school; Physics instructional tool; Sound wave; STEM

Introduction

The Fourth Industrial Revolution demands human resources who are equipped with 21st-century skills, including critical thinking, communication, creativity, and collaboration (P21, 2019). Advances in science and technology, such as autonomous vehicles, robotics, and artificial intelligence are reshaping industries and redefining the competencies needed to thrive in modern society (Ramlawati & Yunus, 2021). These rapid technological developments not only improve human quality of life and life expectancy, but also raise new challenges in achieving sustainable global development. One of the critical responses lies in the educational sector, which is expected to prepare students with future-ready skills through equitable access and inclusive practices (Adhelacahya et al., 2020; Bao & Koenig, 2019).

Building on this foundation, developing 21st century skills is essential for preparing human resources

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with the knowledge, competencies, and flexibility required to succeed in the current era of globalization (Heryani et al., 2023; Kartika et al., 2023; Nazifah & Asrizal, 2022). The Partnership for 21st Century Learning outlines four essential learning and innovation skills—commonly known as 4C: critical thinking, communication, collaboration, and creativity (P21, 2019). These skills are essential for students to excel both academically and socially in the workplace and broader society. Among these, collaboration plays a central role in shaping students' abilities to interact effectively, solve problems collectively, and take responsibility in group contexts (Fatiin et al., 2024; Yulianti & Anjani, 2020).

Collaboration is defined as the ability to participate in joint activities with mutual respect, effective communication, shared goals, and division of responsibilities (Anugrah et al., 2023; Bella et al., 2024; Khoiriyah et al., 2024). Students with strong collaborative skills can adapt, contribute ideas, and resolve conflicts constructively (Yulianti & Anjani, 2020). However, despite its importance, preliminary observations in one inclusive high school in the Special Region of Yogyakarta reveal that collaborative learning, particularly in physics classes, remains suboptimal. SEN (Special Educational Needs) students are often excluded from meaningful learning interactions. Regular students tend to form exclusive groups, assuming that peers with special needs—such as hearing impairments—will be burdensome and incapable of working together effectively. In group tasks, SEN students are frequently assigned only easy or peripheral roles, with little opportunity for discussion or critical engagement. This passive inclusion undermines the principles of inclusive education, where every student should have equitable chances to participate and succeed.

Ironically, many SEN students express a strong desire to contribute meaningfully to group work and engage in science learning on an equal footing with their peers. This finding is supported by teachers who acknowledge that the lack of inclusive, engaging, and structured learning tools is a significant barrier to equal participation. Moreover, teachers note that abstract topics in physics—such as sound waves—are particularly difficult for SEN students, especially those with hearing disabilities. The absence of contextual and inclusive teaching strategies further reinforces the gap in both collaboration and content mastery.

STEM (Science, Technology, Engineering, and Mathematics)-based learning has emerged as a promising approach to address these challenges. By integrating scientific inquiry, technological design, engineering practices, and mathematical reasoning, STEM learning fosters essential 21st-century competencies, including problem solving, collaboration, and innovation (Alifa et al., 2018; Dea et al., 2024). STEM-based instruction can be designed to reflect real-life contexts, offer differentiated tasks, and promote multi-modal access, which are especially valuable for inclusive classrooms (Nazifah & Asrizal, 2022; Ramlawati & Yunus, 2021; Yulianti & Anjani, 2020). In addition, STEM fosters both hard skills and soft skills that enhance students' readiness to face global competition and technological transformation (Adhelacahya et al., 2020; Khoiriyah et al., 2024).

Despite its potential, STEM-based learning in inclusive physics education is still underutilized, particularly for abstract concepts such as sound waves. Physics instruction often remains traditional and teacher-centered, making it difficult for students—especially those with SEN—to fully grasp and engage with the material. Teachers require innovative learning tools that integrate inclusive pedagogy and active student participation. This necessitates the development of well-structured instructional tools that are aligned with curriculum standards, inclusive principles, and 21st-century learning goals.

Instructional tools—or Subject-Specific Pedagogical (SSP) designs—combine teachers' knowledge of subject matter, curriculum, student conditions, and instructional strategies into a cohesive framework for effective learning (Tyas et al., 2020). In inclusive classrooms, such tools must be specifically crafted to ensure all students, regardless of their learning needs, can access, understand, and engage with the content meaningfully.

Therefore, this study aims to develop a STEM-based physics instructional tool on sound wave material that enhances collaboration skills in inclusive high school settings. The novelty of this research lies in its dual focus: integrating collaboration-promoting strategies into a STEM learning framework; and tailoring the learning tool to support both regular and SEN students in understanding abstract physics concepts. The learning tool includes a syllabus, lesson plan, module, student worksheet, and assessment sheet that are designed to stimulate active participation, peer interaction, and group problem-solving. By applying inclusive STEM learning design, this study seeks to address equity in participation and improve collaboration quality among students in inclusive physics classrooms.

Method

This research employed the Research and Development (R&D) approach using the ADDIE model (Dick & Carey, 1996), which consists of five systematic stages: Analysis, Design, Development, Implementation, and Evaluation. The purpose of this study is to produce a STEM-based physics instructional tool that enhances students' collaboration skills in inclusive classrooms. The ADDIE model stages are illustrated in Figure 1.

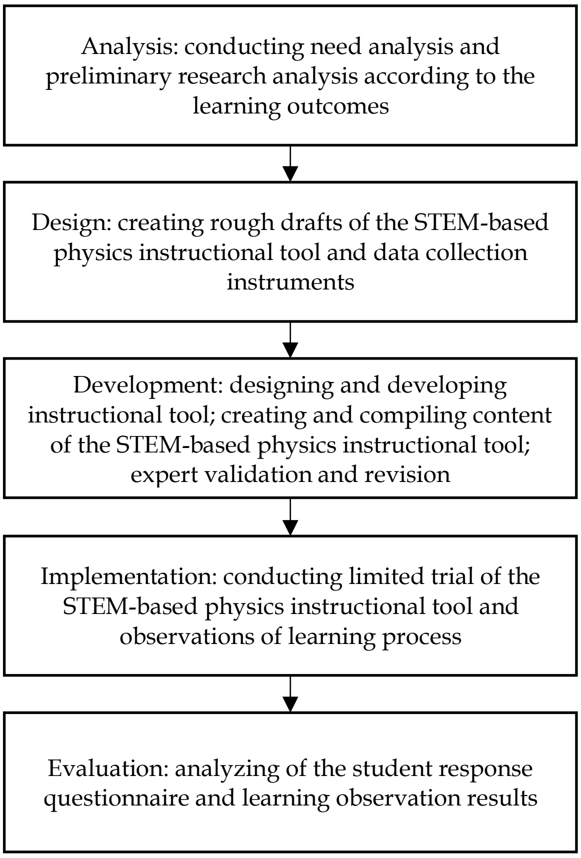


Figure 1. ADDIE model adapted from Dick & Carey (1996)

Research Procedure

In the analysis stage, learning needs were identified through literature review, curriculum analysis, and interviews with physics teachers in inclusive schools. The findings revealed the absence of STEM-based instructional tools and low collaboration, especially among students with special educational needs (SEN). In the design stage, a prototype was developed—including syllabus, lesson plans, modules, worksheets, and assessment sheets—and refined through a Focus Group Discussion (FGD) with teachers.

The development stage involved validation by experts in content, media, pedagogy, and inclusive education to ensure the product's quality and feasibility. During the implementation stage, the tool was trialed with 28 grade XI students, including one deaf student, in an inclusive public high school in Yogyakarta. In the evaluation stage, product effectiveness was assessed based on student responses and observations of collaboration skills during group learning using the STEM-based instructional tool.

Population and Sample

The subjects of this study were grade XI science students learning sound wave material. The population included all grade XI science students at a public inclusive senior high school in the Special Region of Yogyakarta. A purposive sample of one class comprising 28 students—including one deaf student—was selected to represent inclusive learning conditions. In addition, four experts (content, media, instructional tools, and inclusive education) were involved to evaluate the feasibility of the instructional tools. A physics teacher from the inclusive school also provided feedback on the practicality and benefits of the tools in classroom implementation.

Data Colllection Instruments

This study applied three types of checklist-style instruments to gauge both the feasibility and impact of the STEM-based physics tool on students' collaboration skills. First, expert-validation sheets—completed by content experts, media experts, instructional tool experts, and inclusive education practitioners (physics teachers)—confirmed the accuracy, visual quality, and pedagogical suitability of every learning component. Second, a 12-item Guttman questionnaire captured students' perceptions of the lessons. Third, structured observation sheets—adapted from Brookhart (2013) 15-indicator rubric—measured collaboration behaviours (contribution, time management, teamwork, problem-solving, and synthesis). All instruments followed the checklist format (Setyosari, 2012; Riduwan, 2013) and were reviewed by relevant experts before classroom use, ensuring reliable data on both product quality and learning outcomes.

Data Analysis

This study employed both qualitative and quantitative data analysis techniques. Qualitative descriptive analysis was used to interpret expert comments and suggestions on the instructional tool. Quantitative analysis was conducted to determine the validity and effectiveness of the STEM-based physics instructional tool using data from expert validations, student responses, and observation of collaboration skills.

Expert and teacher assessments of the instructional product were analyzed using a mean score formula (Equation 1) and converted into qualitative categories (Very Good to Very Poor) based on Likert scale intervals showed in Table 1 (Widoyoko, 2010). Student response questionnaires were analyzed using the Guttman scale to classify agreement levels (Agree or Disagree), with scores converted accordingly (Table 2). The formula is as follows:

$$\overline{X} = \frac{\sum X}{(Nn)} \quad (1)$$

Where $\overline{X}$ is the mean score of the assessment, $\sum X$ is the number of assessment scores, N is the number of raters, and n is the number of questions.

Table 1. Product Assessment Criteria (Likert Scale) (Widoyoko, 2010)

Mean Score ($\overline{X}$)	Qualitative Criteria
$3.25 < \overline{X} \leqslant 4.00$	Very Good
$2.50 < \overline{X} \leqslant 3.25$	Good
$1.75 < \overline{X} \leqslant 2.50$	Less Good
$1.00 \leqslant \overline{X} \leqslant 1.75$	Very Poor

Table 2. Product Assessment Criteria (Guttman Scale) (Widoyoko, 2010)

Mean Score ($\overline{X}$)	Qualitative Criteria
$0.50 < \overline{X} \leqslant 1.00$	Agree
$0.00 \leqslant \overline{X} \leqslant 0.50$	Disagree

In evaluating collaboration skills before and after the implementation of the STEM-based instructional tool, five observers used a standardized observation sheet with 15 indicators, covering contribution, time management, teamwork, problem-solving, research technique, and synthesis (Brookhart, 2013). The improvement in students' collaboration performance was quantitatively measured using the normalized gain formula (Equation 2) as proposed by Hake (1998).

$$g = \frac{\text{Posttest score} - \text{Pretest score}}{100 - \text{Pretest score}} \quad (2)$$

Table 3. Criteria for Normalized Gain Interpretation (Hake, 1998)

Normalized Gain (g)	Category
$g < 0.3$	Low
$0.3 \leq g \leq 0.7$	Medium
$g > 0.7$	High

The effectiveness of the instructional tool in fostering collaboration was further assessed using normalized gain analysis (Hake, 1998). As shown in Table 3, a normalized gain (g) of less than 0.3 is categorized as low, $0.3 \leq g \leq 0.7$ as medium, and greater than 0.7 as high. This method enabled a comprehensive assessment of the tool's effectiveness in enhancing collaborative behaviors in inclusive physics classrooms.

Result and Discussion

This study developed a STEM-based physics instructional tool to support collaboration skills of students in inclusive classrooms. The syllabus, lesson plan, learning module, student worksheet, and assessment instruments are the components of the learning tool product, as defined by Kementerian Pendidikan RI (2007). In the context of developing STEM-based physics instructional tool to encourage collaboration skills in physics, specifically in sound and wave materials for high school students in inclusive settings, the ADDIE model by Dick & Carey (1996) was adapted.

Product Validation

Quantitative validation was carried out by five experts—comprising specialists in physics content, media, instructional design, and inclusive education. They evaluated the instructional components using a four-point Likert scale. Across components such as the learning module, student worksheet, lesson plan, and assessment instruments, all scores fell within the "very good" category, with average values ranging from 3.45 to 3.65 (see Figure 2). The overall product validation score reached 3.51 out of 4.00, meeting the criteria for high feasibility (Widoyoko, 2010). These results indicate that the tool met essential requirements of content accuracy, media design quality, instructional coherence, and accessibility for students with diverse learning needs.

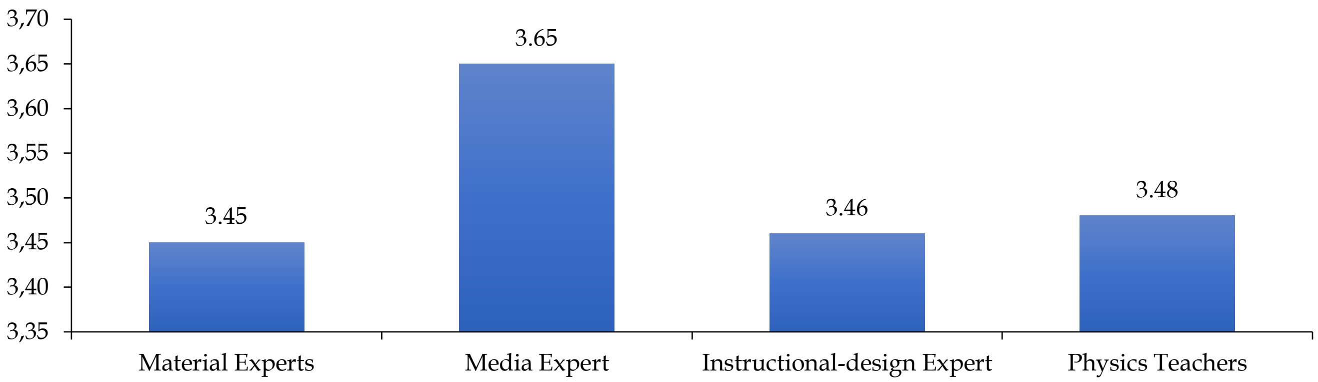


Figure 2. Sonar application in STEM-based learning module

Expert evaluations confirmed that the STEM-based sound-wave package meets professional standards for inclusive physics instruction. Material specialists judged content accuracy, STEM alignment, structure, assessment str3ategies, and language clarity, assigning an overall mean of 3.45 on Widoyoko's four-point scale (Widoyoko, 2010). They recommended broader assessment formats—such as scaffolded short-answer items and visual rubrics, to allow — students with SEN can demonstrate understanding without excessive reading load, in alignment with inclusive assessment practices.

Media experts rated technical layout and graphic quality at 3.65, noting that captions and color cues improve visual access for deaf students, consistent with Universal Design for Learning (UDL) guidelines (CAST, 2024). Their feedback led to revised captions and QR-linked micro-animations in the module and worksheets.

Instructional-design reviewers examined curriculum alignment, activity flow, STEM coherence, and evaluation completeness, returning an average of 3.46. They advised breaking dense activities into shorter blocks and calibrating difficulty to student developmental levels—recommendations supported by Ronfeldt et al. (2015), who emphasize structured collaboration for mixed-ability groups. These revisions improved time-management prompts and embedded "pause-and-reflect" icons.

Finally, inclusive-school physics teachers assessed six dimensions—curriculum fit, material validity, STEM integration, language, technical, and visual design—giving a mean of 3.54. Their classroom-based suggestions ensured local relevance and accessibility, particularly for contextual examples such as recycled-speaker projects (Nazifah & Asrizal, 2022).

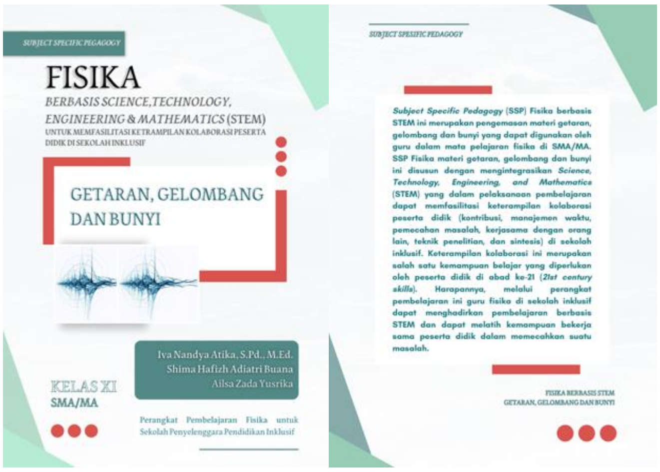


Figure 3. Front and back pages of the STEM-based physics instructional tool

Table 4. Component of the STEM-based Physics Instructional Tool

Components	Description
Syllabus	The syllabus developed contains the title, school information, class/semester, subjects, main material, time allocation, basic competencies, and a table of learning activities that contains learning indicators, expected students' characteristics, assessment techniques and forms, and learning resources.
Lesson Plan	The lesson plans are made for three meetings and derived from the syllabus. The purpose of the lesson plans is to enable learning activities to be more targeted and aligned with the goals and fundamental skills. Lesson plans are created in accordance with Minister of Education and Culture Regulation No. 22 of 2016, which consists of the subsequent sections: lesson plans identity; learning objectives; learning materials; approaches, methods and learning models; students characteristics; instructional media; learning resources; learning activities; and assessment of learning outcomes.
Learning Module	The learning module is a physics module on sound wave material that integrates science (sound wave material), technology, engineering, and mathematics (STEM). To aid students in understanding the information, the module includes videos and graphics bundled in barcode form.
Student Worksheet	STEM-based student worksheet on sound wave material is prepared to encourage collaboration skills among students in inclusive classroom. Observable sound wave phenomena and simple projects that require collaborative work can discovered in the student worksheet.
Assessment Instruments	A cognitive, affective, and psychomotor assessment sheet comprise the instruments. A total of twenty multiple-choice questions can be answered in ninety minutes on the cognitive aspect assessment instrument. As a sort of affective assessment, students examine themselves through self-evaluation. Psychomotor evaluation is carried out concurrently with the use of students' collaboration skills sheets for observation of instruction.

Because every panel produced a mean above the 3.25 "very good" benchmark (Setyosari, 2012), the tool is considered ready for field implementation (Table 1). The polished cover and internal sample pages are shown in Figure 3, illustrating how expert feedback was translated into tangible design enhancements. This multi-layered validation process—spanning content, media, pedagogy, and practitioner lenses—provides a robust foundation for subsequent classroom trials and longitudinal studies of impact on collaboration gains (Brookhart, 2013; Hake, 1998).

The components of the STEM-based physics instructional tool development in this study are listed in Table 4.

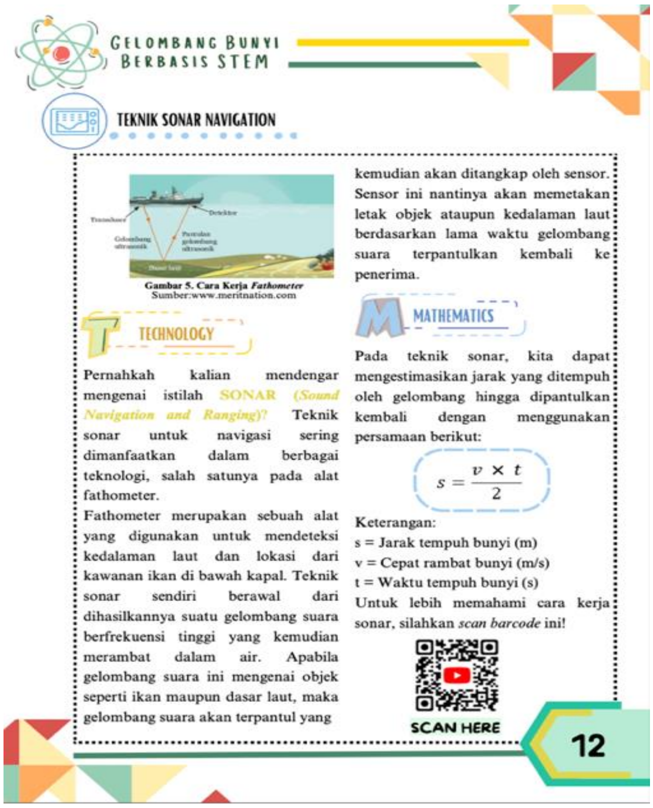
Student Responses

The STEM-based instructional tool was implemented in an inclusive eleventh-grade physics class comprising 28 students, including one deaf learner. Students were divided into five heterogeneous groups to ensure collaborative diversity. The learning process began with individual exploration of the QR-code-accessible learning module, followed by group engagement with structured project worksheets. This blended design facilitated both independent learning and peer collaboration, fostering the development of higher-order thinking and social interaction skills, particularly vital in inclusive environments (Mastropieri & Scruggs, 2004).

Throughout the activity, collaboration skills were assessed using rubric from Brookhart (2013), which includes indicators such as contribution, time management, problem-solving, teamwork, research technique, and synthesis. Observational data showed that all students, including the deaf student, could meaningfully contribute and assume roles within their teams. Students exhibited improved communication and coordination, supported by structured group roles and equitable task distribution.

At the end of the session, students completed a 12-item Guttman-scale questionnaire to evaluate their learning experience. The mean agreement index was 0.74, indicating strong positive responses. Students appreciated the rotation of roles, which promoted fairness and accountability in group work. They also highlighted the real-life relevance of the learning content—such as the sonar navigation example in the module (Figure 4)—and its associated QR video explanation, which helped make the abstract concepts of sound and wave more concrete (Anugrah et al., 2023). Another engaging activity involved constructing a simple sound system using recycled materials (Figure 5), which students found creative and relevant to everyday applications. These hands-on, context-rich tasks encouraged active learning and helped bridge conceptual physics with real-world problem-solving (Honey et al., 2014).

The instructional approach demonstrated not only the effectiveness of STEM integration in supporting conceptual understanding but also in cultivating collaboration among diverse learners. It reflects inclusive education goals and aligns with recent calls for more authentic, accessible, and participatory science learning (UNESCO, 2020).


GELOMBANG BUNYI BERBASIS STEM

TEKNIK SONAR NAVIGATION

Gambar 5. Cara Kerja *Fathometer*
Sumber:www.meritnation.com

TECHNOLOGY

Pernahkah kalian mendengar mengenai istilah SONAR *(Sound Navigation and Ranging)*? Teknik sonar untuk navigasi sering dimanfaatkan dalam berbagai teknologi, salah satunya pada alat fathometer.
Fathometer merupakan sebuah alat yang digunakan untuk mendeteksi kedalaman laut dan lokasi dari kawanan ikan di bawah kapal. Teknik sonar sendiri berawal dari dihasilkannya suatu gelombang suara berfrekuensi tinggi yang kemudian merambat dalam air. Apabila gelombang suara ini mengenai objek seperti ikan maupun dasar laut, maka gelombang suara akan terpantul yang kemudian akan ditangkap oleh sensor. Sensor ini nantinya akan memetakan letak objek ataupun kedalaman laut berdasarkan lama waktu gelombang suara terpantulkan kembali ke penerima.

MATHEMATICS

Pada teknik sonar, kita dapat mengestimasikan jarak yang ditempuh oleh gelombang hingga dipantulkan kembali dengan menggunakan persamaan berikut:

$$s = \frac{v \times t}{2}$$

Keterangan:
s = Jarak tempuh bunyi (m)
v = Cepat rambat bunyi (m/s)
t = Waktu tempuh bunyi (s)
Untuk lebih memahami cara kerja sonar, silahkan *scan barcode* ini!

SCAN HERE

12

Figure 4. Sonar application in STEM-based learning module

Figure 5. Inclusive group work in constructing a recycled sound device

Despite the overall positive reception of the STEM-based instructional tool, students identified time management as a key challenge, particularly during group assessments. This aligns with previous findings that collaborative tasks often require clear structure and time allocation to be effective (Gillies, 2016). The feedback highlights the importance of providing scaffolding strategies to support inclusive student engagement in time-constrained activities. Nevertheless, the consistent 'very good' ratings from both students and expert reviewers indicate that the instructional tool possesses strong pedagogical quality and practical usability in educational settings. Students reported increased confidence in both independent and group learning settings, improved communication skills, and a deeper awareness of how scientific concepts relate to everyday life (Anugrah et al., 2023; Fatiin et al., 2024). These findings support the instructional tool's potential to foster meaningful, inclusive learning environments, particularly in classrooms with diverse learner needs (Brookhart, 2013; Khoiriyah et al., 2024; Nurjanah et al., 2020). By integrating real-world STEM contexts and encouraging collaborative exploration, the tool effectively bridges content mastery with essential 21st-century skills.

Observation of Collaboration Skills

Observation data confirmed that the STEM-based tool substantially boosted collaborative performance. Using Brookhart (2013) fifteen-indicator rubric and documented marked gains in contribution, time-management, problem-solving, teamwork, research technique, and synthesis. Normalised gain values (Hake, 1998) averaged 0.67, signalling medium-to-high improvement; the "team contribution" indicator alone climbed from 48 % before instruction to 86 % after, yielding a high gain of 0.73. Qualitative field notes reinforce these numbers: during a resonance-box investigation, the deaf student spontaneously assumed the role of facilitator, interpreted the waveform in sign language, and was immediately affirmed by peers—clear evidence that multimodal prompts and rotating roles foster genuine inclusion (CAST, 2024). Similar progress was recorded across all five groups, indicating that every learner—including those with special educational needs—could occupy meaningful roles. Such findings echo recent studies showing that structured, diverse teamwork prepares students for an interconnected world and supports global-competency goals (Khoiriyah et al., 2024; Nurjanah et al., 2020). Practically, the results suggest that physics teachers who integrate structured role assignments, hands-on learning aids, and visual supports can foster equitable collaboration while maintaining strong conceptual understanding.

The good effectiveness of the products can be linked to several integrated components. First, the learning activities required students to engage in real-world, interdisciplinary problem-solving activities—such as designing a simple sound system from recycled materials—which fostered shared cognitive responsibility in learning. Second, the implementation of structured role rotation allowed every student, including those with special educational needs (SEN), had the opportunity to take on leadership and technical roles during group work, which is crucial for inclusive engagement. Third, the instructional tool embedded principles from Universal Design for Learning (UDL), such as multiple means of representation (e.g., captioned videos, tactile media, color-coded steps), allowing students with various learning profiles to access the content equitably. These features are consistent with findings from Yulianti et al. (2020), who emphasized the importance of multimodal learning materials in inclusive STEM education. Additionally, real-time formative feedback integrated into the worksheets and modules helped maintain student motivation and guided improvement, in line with the work of Nazifah et al. (2022).

Overall, the results demonstrate that the instructional tool is not only valid but also effective in fostering collaborative learning within inclusive classrooms. These findings align with previous studies by Fatiin et al. (2024) and Ronfeldt et al. (2015) which emphasize the importance of inclusive instructional design and active learning strategies to enhance student collaboration. The findings of this study carry three main implications. First, for classroom implementation, the developed tool provides a practical and ready-to-use model to support inclusive science education. Second, from a policy perspective, the study encourages the broader adoption of inclusive pedagogical strategies that integrate UDL principles and STEM elements. Third, future research should repeat the study in different settings with control groups and delayed tests to improve and refine the instructional model.

However, the study is not without limitations. The small sample size from a single school constrains the generalizability of the findings. Moreover, the absence of a control group limits the capacity to infer causality. Further research involving larger and more diverse populations, randomized controlled trials, and video-based analysis of student collaboration could provide deeper insight into the long-term effectiveness of such instructional tools. Despite these limitations, the current findings suggest that a well-designed STEM-based instructional tool can significantly enhance collaboration skills and learning equity in inclusive physics education. Detailed classroom photograph (Figures 5)provide supporting qualitative evidence of student engagement and inclusion during the learning process.

Conclusion

The results of this study demonstrate that the STEM-based physics instructional tool developed for inclusive classrooms is valid, practical, and effective in enhancing student collaboration skills. Expert validation scores from material, media, instructional design experts, and inclusive school practitioners were consistently above 3.25 on a 4-point scale, placing them in the "very good" category. Student responses, measured through a 12-item Guttman-scale questionnaire, indicated a high level of acceptance with an agreement index of 0.74, reflecting strong engagement with the instructional design. Furthermore, collaboration skill observations using Brookhart's rubric revealed significant improvements, with a normalized gain (g) of 0.67—classified as medium to high. This was particularly evident in indicators such as team contribution, where students—including those with special educational needs (SEN)—demonstrated increased participation and leadership during hands-on group activities. As future research, we suggest involving physics teacher in inclusive schools in planning and teaching classes related to STEM and collaborative learning perspective. Also, since this research was restricted to the deaf, individual differences in the classroom were investigated more. Nevertheless, the usage of STEM-based physics instructional tool can still be modified to meet the demands of the class.

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Conceptualization, direction, funding acquisition, Writing manuscript; editing, I.N.A.; investigation, product development and resources, S.H.A.B. and A.ZY.; Validation, draft review, E.

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Conflicts of Interest
No conflicts of interest are disclosed by the authors.

References

Adhelacahya, K., Said, A. A. N., & Habsari, R. A. (2020). Inovasi Pembelajaran Berbasis Science, Technology, Engineering and Mathematics (STEM) pada Anak Berkebutuhan Khusus di Era Revolusi Industri 4.0. *Jurnal Ilmiah Penalaran dan Penelitian Mahasiswa*, *4*(1), 147–164. Retrieved from https://www.researchgate.net/publication/350660843

Alifa, D. M., Azzahroh, F., & Pangestu, I. R. (2018). Penerapan Metode STEM (Science, Technology, Engineering, Mathematics) Berbasis Proyek untuk Meningkatkan Kreativitas Siswa SMA Kelas XI pada Materi Gas Ideal. *Prosiding SNPS (Seminar Nasional Pendidikan Sains)*, 88–109. Retrieved from https://core.ac.uk/reader/289792260

Anugrah, A., Herlina, K., & Suyatna, A. (2023). Inquiry-Integrated STEM on Electronic Student Worksheet: An Effort to Stimulate Creative Thinking and Collaborative Skills. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *12*(2), 251. https://doi.org/10.24042/jipfalbiruni.v12i2.17306

Bao, L., & Koenig, K. (2019). Physics Education Research for 21st Century Learning. *Disciplinary and Interdisciplinary Science Education Research*, *1*(1). https://doi.org/10.1186/s43031-019-0007-8

Bella, B., Istikomayanti, Y., & Lathifah, A. S. (2024). Validity of Optical Practicum KIT Equipped with Guided Inquiry-Based Worksheet for Madrasah Aliyah Students. *Tarbiyah: Jurnal Ilmiah Kependidikan*, *13*(1), 17–26. https://doi.org/10.18592/tarbiyah.v13i1.10999

Brookhart, S. M. (2013). *How to Create and Use Rubrics for Formative Assessment and Grading*. ASDC. Retrieved from https://ascd.org/books/how-to-create-and-use-rubrics-for-formative-assessment-and-grading?variant=112001

CAST. (2024). *Universal Design for Learning Guidelines version 3.0 [graphic organizer]*. MA: Author.

Dea, P. A., Kaniawati, I., & Eliyawati, E. (2024). STEM ESD-Based Learning with "Arduino Uno-Based Trash Can" to Improve Students' Critical Thinking Skills and Sustainable Awareness in Learning Environmental Pollution. *Jurnal Penelitian dan Pembelajaran IPA*, *10*(1), 114–145. https://doi.org/10.30870/jppi.v10i1.24008

Dick, W., & Carey, L. (1996). *The Systematic Design of Instruction* (4th Ed.). Harper Collin.

Fatiin, J. M., Winarno, N., Samsudin, A., Wahyuningsih, Y., & Nurhaida, P. (2024). Improving Students' Collaboration Skills by Using STEM-Engineering Design Process (EDP) on Motion and Force Materials. *Pillar of PhysicsEducation*, *17*(2), 157–166. Retrieved from https://ejournal.unp.ac.id/students/index.php/pfis/article/view/16170

Gillies, R. M. (2016). Cooperative Learning: Review of Research and Practice. *Australian Journal of Teacher Education*, *41*(3), 39–54. https://doi.org/10.14221/ajte.2016v41n3.3

Hake, R. R. (1998). Interactive-Engagement Versus Traditional Methods: A Six-Thousand-Student Survey of Mechanics Test Data for Introductory Physics Courses. *American Journal of Physics*, *66*(1), 64–74. https://doi.org/10.1119/1.18809

Heryani, T. P., Suwarma, I. R., & Chandra, D. T. (2023). Development of STEM-Based Physics Module with Self-Regulated Learning to Train Students Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 4245–4252. https://doi.org/10.29303/jppipa.v9i6.3578

Kartika, I., Atika, I. N., Widyasari, F. D., & Putranta, H. (2023). Development of Local Wisdom-Based Subject-Specific Pedagogy (SSP) to Improve Students' Scientific Literacy Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 7979–7986. https://doi.org/10.29303/jppipa.v9i10.3969

Kementerian Pendidikan RI. (2007). *Regulation of Minister of Education of the Republic of Indonesia Number 41 of 2007 about Process Standards for Primary and Secondary Education Units, Pub. L. No. 41*. Jakarta: Kementerian Pendidikan RI.

Khoiriyah, S., Wiliyanti, V., & Gunawan, I. (2024). The Influence of The STEM Learning Approach on Students Communication and Collaboration Abilities on Elasticity Materials. *Jurnal Penelitian Pembelajaran Fisika*, *15*, 263–271. https://doi.org/10.26877/jp2f.v15i3.18724

Mastropieri, M. A., & Scruggs, T. E. (2004). *The Inclusive Classroom: Strategies for Effective Instruction*. Upper Saddle River.

Nazifah, N., & Asrizal, A. (2022). Development of STEM Integrated Physics E-Modules to Improve 21st Century Skills of Students. *Jurnal Penelitian Pendidikan IPA*, *8*(4), 2078–2084. https://doi.org/10.29303/jppipa.v8i4.1820

Nurjanah, S., Rudibyani, R. B., & Sofya, E. (2020). Efektivitas LKPD Berbasis Discovery Learning untuk Meningkatkan Keterampilan Kolaborasi dan Penguasaan Konsep Peserta Didik. *Jurnal Pendidikan dan Pembelajaran Kimia*, *9*(1), 27–41. https://doi.org/10.23960/jppk.v9.i1.202003

P21. (2019). *Framework for 21st Century Learning Definitions*. Retrieved from https://static.battelleforkids.org/documents/p21/P21_Framework_DefinitionsBFK.pdf

Ramlawati, R., & Yunus, S. R. (2021). Desain Pembelajaran Inovatif Berbasis Pendekatan STEM. *Prosiding Seminar Nasional Pendidikan IPA II*, 15–22. Retrieved from https://ojs.unm.ac.id/semnaspendipa/article/view/26186/13226

Riduwan, R. (2013). *Belajar Mudah Penelitian*. Bandung: Alfabeta.

Ronfeldt, M., Farmer, S. O., McQueen, K., & Grissom, J. A. (2015). Teacher Collaboration in Instructional Teams and Student Achievement. *American Educational Research Journal*, *52*(3), 475–514. https://doi.org/10.3102/0002831215585562

Setyosari, P. (2012). *Metode Penelitian Pendidikan dan Pengembangan*. Bandung: Rineka Cipta.

Honey, M., Pearson, G., & Schweingruber, H. (2014). STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research. In *70th Annual International Technology Education Association Conference*. The National Academi Press. Retrieved from https://www.nap.edu/catalog/18612/stem-integration-in-k-12-education-status-prospects-and-an

Tyas, R. A., Pujianto, P., & Suyanta, S. (2020). Subject Specific Pedagogy Based on Discovery Learning and Volcanic Eruption Disasters: Does It Affect Students' Concept Mastery? *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *9*(2), 271–283. https://doi.org/10.24042/jipfalbiruni.v9i2.6867

UNESCO. (2020). *Global Education Monitoring Report 2020: Inclusion and Education: All Means All*. https://doi.org/10.4135/9788132108320.n14

Widoyoko, E. P. (2010). *Evaluasi Program Pembelajaran*. Yogyakarta: Pustaka Pelajar.

Yulianti, D., & Anjani, D. (2020). Implementing Physical Learning Based on Momentum and Impulse STEM Materials to Develop Collaboration Skills. *Jurnal Ilmu Pendidikan*, *25*(1), 27. https://doi.org/10.17977/um048v25i1p27-32