14 (1) (2025) 173-182

Unnes Science Education Journal

Accredited Sinta 2

https://journal.unnes.ac.id/journals/usej

Effectiveness of Supplement Apps on Human Auditory System as STEM-Based Learning Media to Enhance Junior High School Students' Analytical Thinking Skills

Muhammad Abdau Yazid✉, Putut Marwoto

DOI: http://dx.doi.org/10.15294/usej.v13i1.20066

Universitas Negeri Semarang, Indonesia

Article Info

Submitted 2025-01-13
Revised 2025-02-26
Accepted 2025-04-28

Keywords

Analytical Thinking Skill; Auditory System; Human; STEM; Supplement Apps

Abstract

The study aims to evaluate the effectiveness of STEM-based learning media, the Supplement Apps Human Auditory System, in enhancing students' analytical thinking skills. This product was developed in Hypertext Markup Language (.html) and follows a quantitative quasi-experimental design with a pre-test post-test nonequivalent control group. The research involved 136 eighth-grade students from a state junior high school 2 Tengaran, Semarang Regency, selected through cluster random sampling to form experimental and control groups. The application integrates Learning Outcomes & Objectives, Materials, Simulations, and Interactive Evaluations and is accessible via https://sahas.nim.my.id/, enabling seamless distribution for instructional use.The paired sample t-test results indicate a statistically significant improvement, with a t-value of 11.92 and an average N-gain score of 0.30 (moderate category). These findings indicate that the Supplement Apps Human Auditory System learning media effectively enhances analytical thinking skills, making it a promising tool for STEM-based education in junior high schools.

How to Cite

Yazid, M. A., & Marwoto, P. (2025). Effectiveness of Supplement Apps on Human Auditory System as STEM-Based Learning Media to Enhance Junior High School Students' Analytical Thinking Skills. *Unnes Science Education Journal*, 14(1), 173-182.

✉ Correspondence Author:
E-mail: abdauyazida@students.unnes.ac.id

p-ISSN 2252-6617
e-ISSN 2502-6232

INTRODUCTION

In the 21st century, efforts to empower and enhance Higher Order Thinking Skills (HOTS) have become one of the primary focuses in educational goals for students (Billah, et al., 2019; Shukla et al., 2016). Strong HOTS abilities support discovery capabilities and the problem-solving process (Jaenudin et al., 2020). In addition to evaluation and creation skills, Analytical Thinking Skills (ATS) are a critical component of HOTS (Anderson et al., 2001; Billah et al., 2019).

ATS (Analytical Thinking Skills) serves as a key driver in advancing students' thinking and preparing them for future challenges(Peters et al., 2019). These skills are highly relevant to efforts aimed at improving PISA scores, where students are assessed based on their ability to solve real-world problems (Heffington et al., 2023). Research indicates that students with strong ATS tend to achieve higher PISA scores (OECD, 2019). In the PISA assessment, students are evaluated on their ability to apply knowledge and skills to solve real-world problems, making ATS essential for addressing these challenges (Fatimah et al., 2018).

ATS (Analytical Thinking Skills) is a cognitive skill that supports decision-making abilities, as well as students' future educational and career success (Hollett at al., 2022). ATS has a positive impact and is closely linked to scientific process skills and critical thinking (Demir, 2022; Inayah et al., 2023). Therefore, empowering and enhancing students' ATS is essential for schools, as it can ultimately contribute positively to improving student achievement (Theabthueng et al., 2022; Ramadani, et al., 2021). Analytical thinking skills consist of three primary aspects or indicators: differentiating, organizing, and attributing (Anderson & Krathwohl. 2001; Billah et al., 2019; Suyatman et al., 2021). The differentiating indicator refers to the skill of distinguishing parts of an entity from a particular perspective; the organizing indicator involves building systematic relationships; and the attributing indicator is the skill of determining and understanding viewpoints (Billah et al., 2019).

There are various ways to enhance students' Analytical Thinking Skills (ATS), one of which is through the use of Interactive Learning Media (ILM) (Maison et al., 2022). Efforts to improve students' ATS can be facilitated by utilizing ILM (Febliza et al., 2023; Blyznyuk & Kachak., 2024). Learning media serve as essential tools to support students' success in understanding the abstract characteristics of science, which often require models of the objects being studied (Mahfudz & Billah. 2020). ILM has proven effective because it enables students to engage directly in the learning process, such as designing projects, testing hypotheses, and drawing conclusions (Putra & Salsabila, 2021). Furthermore, modern education is expected to adapt to technological advancements. Technology used in learning can also improve the quality of education and enhance students' psychomotor skills (Maulidiyah et al., 2022).

One of the science topics at the junior high school level that requires experimental activities is the study of the human auditory system. This topic demands analytical skills to understand the scientific concepts within it. Achieving the learning objectives for the human auditory system cannot be separated from active learning activities rather than relying solely on lectures. The use of conventional methods often causes students to feel bored during the learning process, reducing their motivation to learn (Pradana et al., 2020).

STEM-based learning (Science, Technology, Engineering, and Mathematics) can enhance students' analytical thinking skills, especially in science subjects, which require students to conduct experiments to understand the material, such as the human auditory system (Wahyuni, 2021). The STEM approach in education aims to develop STEM-literate students—those equipped with the knowledge, attitudes, and skills to identify questions and problems, explain natural phenomena, design solutions, and draw evidence-based conclusions in STEM contexts (Halawa et al., 2024). STEM-based learning also provides opportunities for students to improve their performance, which in turn enhances their critical and analytical thinking skills (Muttaqiin, 2023).

Observations conducted at Junior High School 2 Tengaran in January 2024 revealed that students still struggle with analyzing story problems, with more than 50% finding it difficult to understand science material, particularly when questions require applying concepts to real-world situations. This indicates that rote learning still dominates, limiting students' ability to connect concepts with everyday phenomena. Contributing factors include insufficient practice during lessons, the complexity of the material, and the limited use of interactive learning media (ILM). Additionally, approximately 63% of students reported difficulty in solving problems that test their analytical thinking skills.

Therefore, this study aims to determine the effectiveness of STEM-based learning media, Supplement Apps Human Auditory System, in

enhancing Junior High School students' analytical thinking skills. This study hypothesizes that students using the SAHAS application will show a significant improvement in their analytical thinking skills compared to those using conventional learning methods. Despite the growing interest in interactive learning media, previous research has predominantly focused on theoretical approaches or other sensory systems, leaving a gap in the application of STEM-based media for the human auditory system in middle school education (Widya et al., 2024). The novelty of this research lies in integrating auditory system knowledge with STEM principles to create an innovative learning tool that enhances students' critical analytical thinking. Furthermore, this research is urgent due to the increasing need for developing students' analytical skills in the digital era, where such skills are essential for their success in future science and technology careers.

METHOD

This study is quantitative quasi-experimental research design with a pre-test post-test nonequivalent control group design. The research subjects consist of 136 eighth-grade students from state junior high school 2 Tengaran, Semarang Regency, selected through cluster random sampling to determine two class groups: the experimental group and control group (Khoiroh et al., 2019). Both groups received lessons on vibrations and waves, specifically focusing on the human auditory system. However, the difference in treatment lies in the learning approach. The experimental group engaged in both theoretical and practical learning using the Supplement Apps Human Auditory System (SAHAS) learning media. Control group received instruction using conventional teaching aids, primarily PowerPoint slides.

In the control group, lessons were predominantly delivered through the lecture method, and due to limited school resources, only a few students took turns conducting hands-on activities related to the human auditory system. In contrast, students in the experimental group had direct access to the SAHAS learning media, enabling them to explore the subject matter individually using computers or smartphones.

The SAHAS learning media product was implemented and tested on the experimental class and the control class. In the next stage, the large-scale trial was conducted by science teachers and students of Junior High School 2 Tengaran. Respondents for this trial were selected using purposive sampling, a sampling technique based on specific criteria for 8th grade students. This research design employed the One Group Pre-Posttest design model (Febliza et al., 2023). The pre-test was designed to determine the initial level of the respondent's analytical thinking skills. The test consisted of 12 mixed questions of multiple choice and essay. The post-test was structured similarly to the pre-test, which facilitated comparison of results after the experimental part of the study (Song & Cai, 2024).

The normality test was conducted to determine whether the data distribution aligned with the expected distribution. Meanwhile, the homogeneity test was performed to evaluate the similarity of variances among populations following a normal distribution (Demir & Süleyman, 2022). The results of the Kolmogorov-Smirnov test indicated a significance value ($p = 0.08$) > 0.05, suggesting that the data were normally distributed. On the other hand, the homogeneity test using Levene's method yielded a significance value ($p = 0.336$) > 0.05, indicating that the data were homogeneous. The next step involved conducting a Paired Sample t-test for both the control and experimental classes. A difference was observed between the average pretest and posttest scores. The N-gain test was employed to measure the improvement in students' critical thinking skills before and after the intervention (Dewi, 2019), with the results categorized into three levels, as follows:

Table 3. Gain value classification

Average Gain	Criteria
$0.70 < g \leq 1.00$	High
$0.30 < g \leq 0.70$	Midium
$0.00 < g \leq 0.30$	Low

RESULT AND DISCUSSION

Application Products

The result of this study is the development of an interactive learning media (ILM) named Supplement Apps Human Auditory System or SAHAS for grade VIII junior high school students. This product can be accessed via the link https://sahas.nim.my.id/. as shown in Figure 1. The application uses the Hypertext Markup Language (HTML) format, so it does not require storage space on computers or mobile devices. Once students access the link provided by the teacher, they can immediately start using the SAHAS application. Although the application can be run offline, it is recommended to use it online because it contains instructional videos and interactive

features that require an internet connection.

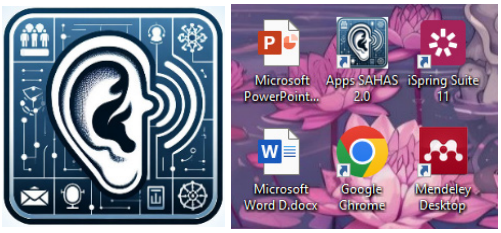

Figure 1. SAHAS Application Icon and the Display of the SAHAS Application Icon on the Desktop Screen

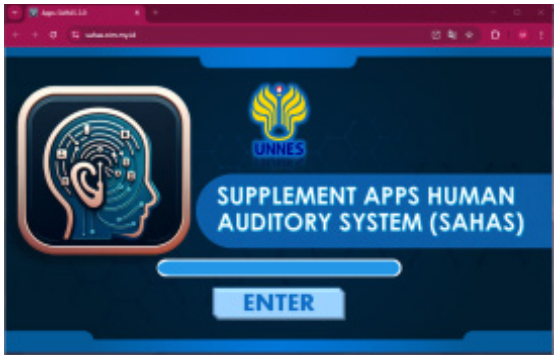

Figure 2. SAHAS Application Display Accessed on a Computer

After students access link provided by the teacher, the SAHAS application display will appear in browser as in Figure 2. When students press "ENTER" button, main menu page will appear as in Figure 3. The main menu contains CP and TP, Materials, Simulations, and Evaluation.

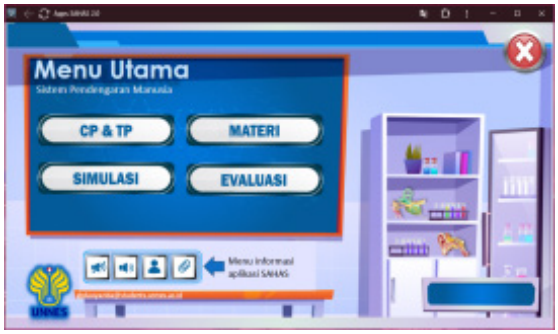

Figure 3. Main menu Display on the SAHAS Application

The SAHAS learning media information and navigation buttons are shown in Figure 4. Before students or SAHAS application users explore all the features in application, they must understand the signs and navigation buttons to facilitate interaction with the application. Apart from that, there are also codes that function as menu signs that contain analytical thinking indicators.

Figure 4. Information display of buttons and navigation of the SAHAS application

SAHAS learning media contains learning materials in the "MATERIALS" menu. The menu contains learning material for grade 8 junior high school, namely introduction to vibrations and waves, parts of the ear organ, learning videos, teaching modules, and STEM student worksheets. Material for introducing wave vibrations and parts of the human ear can be accessed offline, but learning videos, modules and student worksheets can only be accessed online. The material menu display is shown in Figure 5.

The 'MATERIALS' menu presents content in a structured format, combining explanatory texts with high-quality images and diagrams to enhance comprehension. The introduction to vibrations and waves includes interactive illustrations demonstrating wave motion, while the section on ear organs provides labeled diagrams with clickable descriptions. Videos, accessible online, are embedded with checkpoints where students answer brief quizzes to reinforce key concepts before proceeding.

Figure 5. Material menu in SAHAS application

The SAHAS learning media includes several menus with features specifically designed to support the learning process and development of students' analytical skills. These menus are marked with letter codes corresponding to each analytical thinking indicator. The codes include: the letter "A" for the differentiating indicator, as shown in Figure 6; the letter "B" for the organi-

zing indicator, as shown in Figure 7; and the letter "C" for the attributing indicator, as shown in Figure 8. These markings make it easier students to learn and sharpen their analytical thinking skills by utilizing the SAHAS learning media.

Each analytical thinking indicator (A for Differentiating, B for Organizing, and C for Attributing) is visually represented within the application as clickable icons next to relevant learning materials. For example, in the 'Differentiating' section, students are prompted to compare auditory organs through an interactive drag-and-drop exercise. The 'Organizing' section includes a mind-mapping tool where students categorize auditory components, while the 'Attributing' section presents case studies where students identify possible causes of hearing disorders.

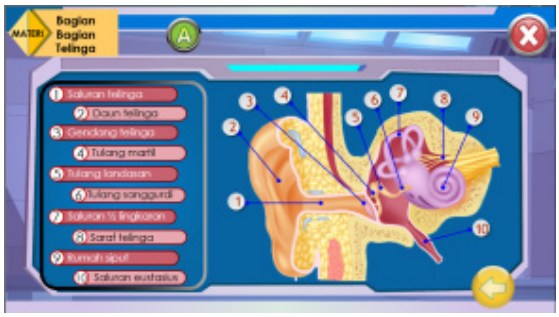

Figure 6. Example SAHAS application display differentiating organs and functions

Figure 7. Example of the SAHAS application display Organizing organs when hearing sounds

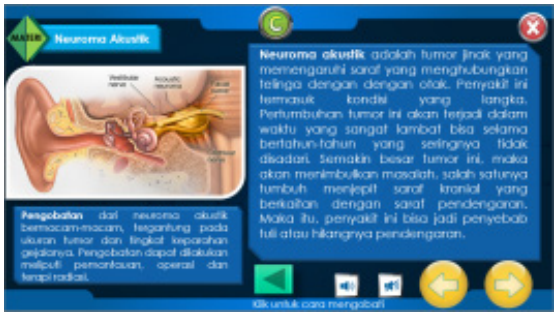

Figure 8. SAHAS application Linking Hearing Organ Disease, Causes and How to Treat It

The SAHAS learning media is also equipped with interactive simulations and evaluations containing questions and games designed for students. The simulations in the learning media are developed using the iSpring Suite 11 (Mardiansyah et al., 2023). These simulations and evaluations are designed to be interactive, enhancing students' engagement in the learning process and potentially having a positive impact on their responses to learning (Hulwani, et al. 2021). The visuals of the simulations and evaluations are shown in Figure 9 and Figure 10.

Figure 9. Example of a simulation display in the SAHAS application, simulating listening process

The interactive simulations, built using iSpring Suite 11, allow students to manipulate variables such as sound frequency and amplitude to observe their effects on hearing perception. For instance, in one activity, students adjust the intensity of a sound wave and visualize how it travels through different parts of the ear. The system provides instant feedback by explaining the physiological response of each organ involved in the auditory process. The evaluation includes gamified quizzes, where students can earn points by correctly answering conceptual questions, reinforcing their understanding in an engaging way.

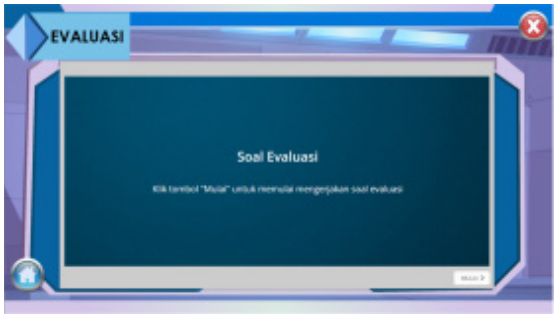

Figure 10. Evaluation display on the SAHAS application which can be done online or offline

Media Effectiveness

This study measures the effectiveness of the STEM-based learning media Supplement Apps Human Auditory System on students' analytical skills through large-scale testing. The research involved 168 eighth-grade students. The testing process included pretests and posttests conducted in four classes, with the results analyzed using a paired sample t-test and N-gain test to evaluate the improvement in students' analytical thinking skills (Sulistyanto, et al. 2022).

The testing phase of the learning media's effectiveness was conducted by administering pretests and posttests in four classes at the school. Subsequently, learning activities were implemented using the Supplement Apps Human Auditory System STEM-based learning media, followed by administering posttest questions to the students. The pretest and posttest results were then analyzed using the paired sample t-test. The paired sample t-test requires data to be normally distributed and homogeneous. The results of paired sample t-test analysis are presented in Table 5.

Table 5. Paired sample t-test results

Test	Mean	t	df	Sig. (2-tailed)
Pretest-Posttest	64.99	11.92	135	0.000

In addition to conducting a paired sample t-test to compare learning outcomes between the control and experimental classes, this study also analyzes each indicator of students' analytical thinking skills. This approach is essential for gaining a deeper understanding of how students process information and solve problems. According to research by Hidayah et al (2023), analytical thinking skills consist of three main indicators:

(1) Differentiating—the ability to break down a structure or data into smaller components;
(2) Organizing—the ability to identify elements-using various numbers and symbols; and
(3) Attributing—the ability to determine the source or cause of information based on data interpretation and analysis.

By analyzing each of these indicators, the study provides a more comprehensive insight into the effectiveness of the implemented learning media (Hidayah et al., 2023). Data from the paired sample t-test for the analytical thinking indicator are shown in Table 6.

Tabel 6. Paired sample t-test results for analytical ability indicators

Class	Analytical Ability Indicator	t_{table}	t_{count}
Experiment 1	Differentiating	1.30	6.79
	Organaizing		7.90
	Atributing		8.65
Experiment 2	Differentiating	1.30	6.40
	Organaizing		3.65
	Atributing		3.33

The STEM-based learning in this study is demonstrated in the first session, where students engage in learning using student worksheets provided by the teacher. The first experiment aims to help students understand the characteristics of longitudinal and transverse waves in order to comprehend the nature of sound. This first experiment emphasizes the science aspect by focusing on understanding wave properties and distinguishing between longitudinal and transverse waves.

The technology aspect is integrated through the use of the STEM-based SAHAS application and the internet as learning resources and tools for representing waveforms. The engineering component involves designing a wave demonstration using a slinky or spring as a visual aid, helping students understand how these tools illustrate physics theories. The mathematics aspect is applied in measuring or calculating wave characteristics (such as wavelength or frequency when applicable). This activity provides students with direct experience in understanding wave concepts through simple observational tools, strengthens their analytical skills, and fosters a deeper understanding through visual demonstrations (Cahya & Sucahyo, 2021).

The second experiment in the student worksheet is designed to help students investigate and explain that sound requires a medium to propagate. This second experiment emphasizes the science aspect by helping students understand the concept that sound needs a medium to travel and explaining the phenomenon of sound propagation based on the properties of particles in a medium. The technology component is integrated through the use of a small electric bell and a simple vacuum chamber to illustrate the experiment. The STEM-based SAHAS application and the internet serve as references for additional information. The engineering aspect involves designing a simple experiment using available ma-

terials to demonstrate the differences in sound transmission through various media. The mathematics component is applied in calculating differences in sound intensity based on qualitative observations.

This experiment combines theoretical concepts with real-world applications to prove that sound cannot propagate in a vacuum, providing practical insights that can be scientifically understood. This learning approach demonstrates that the integration of STEM in science education effectively enhances 21st-century skills among students, including critical thinking, creativity, and problem-solving abilities (Muttaqiin, 2023).

The third experiment, as outlined in the student worksheet, aims to identify the conditions required for sound to be heard by conducting a listening experiment using different media. This experiment emphasizes the science aspect by studying the characteristics of sound in different media (air, water, and metal) and explaining how the medium affects the speed and intensity of sound. The technology component involves using simple tools (such as a metal spoon) to generate sound in different media.

The engineering aspect focuses on designing a simple experiment to explore the interaction of sound with various media and analyzing the results to support or refute the proposed hypothesis. The mathematics component is applied in comparing the speed of sound in different media based on distance and time measurements. This practical activity encourages students to think critically by connecting observed phenomena with scientific theories. The role of the STEM-based learning media Supplement Apps Human Auditory System in this experiment is to serve as a learning reference and supplementary resource to stimulate students' analytical and critical thinking skills through structured teaching modules and student worksheets.

The results of the paired sample t-test (Table 6) indicate that the t-value for the differentiating indicator is 6.79 in Experimental Class 1 and 6.40 in Experimental Class 2. These values demonstrate that the STEM-based learning media Supplement Apps Human Auditory System effectively enhances students' analytical thinking skills, particularly in the differentiating indicator. Students' ability to differentiate analytically improves after completing the learning process, especially when using the learning media in sections labeled with code A in Figure 7.

Furthermore, based on the results of the paired sample t-test analysis for the organizing indicator, the t-value is 7.90 in Experimental Class 1 and 3.65 in Experimental Class 2. These values indicate that the STEM-based learning media Supplement Apps Human Auditory System effectively enhances students' analytical thinking skills, particularly in the organizing indicator. The organizing aspect of analytical thinking can be improved through learning activities that incorporate various interactive features, such as simulations, educational videos, and evaluation questions. This learning approach encourages students to systematically structure and organize the information they acquire, particularly in sections or menus labeled with code B, as shown in Figure 8.

The results of the paired sample t-test analysis for the attributing indicator show that the t-value is 8.65 in Experimental Class 1 and 3.33 in Experimental Class 2. These values indicate that the STEM-based learning media Supplement Apps Human Auditory System effectively enhances students' analytical thinking skills, particularly in the attributing indicator. In the context of analytical thinking, attributing refers to the ability to determine the cause or origin of a phenomenon or event from both internal and external perspectives. This indicator is often associated with students' ability to evaluate, analyze, or infer the reasons behind something based on available data or evidence. The Supplement Apps Human Auditory System STEM-based learning media emphasizes this attributing indicator in the sections labeled with code C, as shown in Figure 9.

The results of the paired sample t-test (Table 6) show that the t-count values for the differentiating, organizing, and attributing indicators for degrees of freedom (df) 33 in each class are greater than the t-table values (t-count > t-table), with a significance value (2-tailed) of 0.000 (Sig < a). This indicates a difference between the pretest and posttest results for each analytical thinking indicator, suggesting an improvement after the implementation of STEM-based learning media.

This learning media is equipped with a teaching module and student worksheets that have been specifically designed to align with STEM-based learning. The way to find out the increase in analytical thinking skills is by the N-gain test. The results of the calculation using the N-gain test to measure the increase in analytical thinking skills are shown in Table 7.

Tabel 7. Results of N-gain test analysis for analytical thinking skill

Class	Analytical Ability Indicator	N-Gain
Experiment 1	Differentiating	0.28
	Organaizing	0.41
	Atributing	0.40
Mean		0.35
Experiment 2	Differentiating	0.29
	Organaizing	0.26
	Atributing	0.22
Mean		0.26

The results of the paired sample t-test are also supported by the N-gain test analysis (Table 7) showing that the increase in analytical skills in experimental class 1 is categorized as "medium" with an average N-gain value of 0.35, while in experimental class 2 it is in the category "low" with an average N-gain value of 0.26. The overall average of the experimental class is 0.30, which is in the "medium" category (appendix 26). This shows that learning media has a positive impact on students' analytical abilities, although the level of success is different in each class (Kurniawan & Oky, 2014).

The improvement in analytical skills obtained from the N-gain test results aligns with research indicating that STEM-based learning is effective in enhancing higher-order thinking skills, such as analysis, evaluation, and creation (Li et al., 2020). STEM-based learning that integrates interactive technology, such as the Supplement Apps Human Auditory System learning media, can facilitate the understanding of complex concepts through simulations, animations, and immersive learning experiences (Kelley & Knowles, 2016). By presenting engaging audio-visual content, this media enables students to understand abstract concepts more easily and apply them in real-world contexts.

The results of this research are also supported by other studies which show that technology-based learning approaches can increase students' interest, understanding of the material and analytical thinking skills (Saputra et al., 2021; Wicaksono et al., 2022). STEM-based applications provide interactive and challenging learning experiences, so that students are actively involved in the learning process. However, the differences between experimental class 1 and experimental class 2 show that the effectiveness of learning media can be influenced by other factors, such as students' initial abilities, teacher teaching methods, or learning environment conditions (Chai et al., 2021). Therefore, further research is needed to explore these factors and optimize the implementation of STEM-based learning media.

Overall, this research succeeded in showing that the STEM-based Supplement Apps Human Auditory System learning media had a positive impact on improving students' analytical skills, especially on human auditory system material. The implementation of this media can be used as a learning innovation to support the development of critical and analytical thinking skills in the 21st century education era

CONCLUSION

The effectiveness of this learning media in improving students' analytical skills is based on the results of the paired sample t-test which shows a t value of 11.92, indicating a significant difference between the control class and the experimental class. The average N-gain value of 0.30 shows an increase in the medium category. These results prove that the learning media developed is able to support STEM-based learning optimally and can be an effective tool in improving students' analytical skills.

REFERENCES

Anderson, L. W., & Krathwohl., D. R. (2001). *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives. 1st Ed*. New York: Longman.

Billah, A., Khasanah, U., & S. Widoretno. (2019). Empowering Higher-Order Thinking Through Project-Based Learning: A Conceptual Framework. *AIP Conference Proceedings 2194(020011)*:1–7. https://doi.org/10.1063/1.5139743.

Blyznyuk, T., & Kachak, T. (2024). Benefits of Interactive Learning for Students' Critical Thinking Skills Improvement. *Journal of Vasyl Stefanyk Precarpathian National University*, 11(1), 94–102. https://doi.org/10.15330/jpnu.11.1.94-102

Cahya, R. E., & Sucahyo, I. (2021). Pengembangan LKPD simulasi Wave on String untuk pembelajaran gelombang stasioner di SMA. *PENDIPA Journal of Science Education*, 5(3), 366–371. https://doi.org/10.33369/pendipa.v5i3.15063

Chai, C. S., Jong, M. S. Y., Yin, H. B., & Chen, M. (2021). Trends and issues of technology-enhanced learning in STEM education. *Journal Computers & Education*, 167. https://doi.org/10.1016/j.compedu.2021.104128

Demir, E. (2022). An Examination of High School Students' Critical Thinking Dispositions and Analytical Thinking Skills. *Journal o Peda-*

gogical Research, 6(4), 190–200. https://doi.org/10.33902/JPR.202217357.

Demir, & Süleyman. (2022). Comparison of Normality Tests in Terms of Sample Sizes under Different Skewness and Kurtosis Coefficients. *International Journal of Assessment Tools in Education,* 9(2), 397–409. https://doi.org/10.21449/ijate.1101295

Dewi, C. A. (2019). Improving creativity of prospective chemistry teacher through chemoentrepreneurship oriented inquiry module on colloid topics. *Journal of Physics: Conference Series*, 1156(1). https://doi.org/10.1088/1742-6596/1156/1/012017

Fatimah, A. W. N., Suryani, N., & Yamtinah, S. (2018). The Development of Critical Thinking Test Based on Higher-Order Thinking PISA Version in the Historical Learning at Senior High School. *International Journal of Multicultural and Multireligious Understanding*, 5(2), 136. https://doi.org/10.18415/ijmmu.v5i2.132

Febliza, A., Afdal, Z., & Copriady, J. (2023). Improving Students' Critical Thinking Skills: Is Interactive Video and Interactive Web Module Beneficial? *International Journal of Interactive Mobile Technologies*, 17(3), 70–86. https://doi.org/10.3991/ijim.v17i03.34699

Halawa, S., Lin, T. C., & Hsu, Y. S. (2024). Exploring instructional design in K-12 STEM education: a systematic literature review. *International Journal of STEM Education*, 11(1). https://doi.org/10.1186/s40594-024-00503-5

Heffington, D. V., & Coady, M. R. (2023). Teaching higher-order thinking skills to multilingual students in elementary classrooms. *Language and Education*, 37(3), 308–327. https://doi.org/10.1080/09500782.2022.2113889

Hidayah, S. N., Fauziyah, N., & Suryanti, S. (2023). Analisis Kemampuan Berpikir Analitis Peserta Didik dalam Menyelesaikan Soal Numerasi. *Jurnal Inovasi Pendidikan Matematika*, 4(1), 83–95.

Hollett, E., & Cassalia., A. (2022). *Convergent Thinking for Advanced Learners, Grades 3*–5. London, UK: Routledge.

Hulwani, A. Z., Pujiastuti, H., & Rafianti, I. (2021). Pengembangan Media Pembelajaran Interaktif Android Matematika dengan Pendekatan STEM pada Materi Trigonometri. *Jurnal Cendekia : Jurnal Pendidikan Matematika,* 5(3), 2255–2269. https://doi.org/10.31004/cendekia.v5i3.717

Inayah, N., & Lubab., A. (2023). Enhancing Analytical Thinking Skills and Scientific Attitudes of Prospective Science Teacher Students through Pre-Practicum Virtual Simulation." *Edusains.* 15(2), 176–85. https://doi.org/10.15408/es.v13i2.35431.

Jaenudin, R., Chotimah, U., Farida, & Syarifuddin. (2020). Student Development Zone: Higher Order Thinking Skills (HOTs) in Critical Thinking Orientation." *International Journal of Multicultural and Multireligious Understanding. IJMMU*, 7(9), 11–19. https://doi.org/10.18415/ijmmu.v7i9.1884.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, 3(1). https://doi.org/10.1186/s40594-016-0046-z

Khoiroh, N., Munoto, & Anifah, L. (2019). Pengaruh Model Pembelajaran Blended Learning Dan Motivasi Belajar Terhadap Hasil Belajar Siswa. *Sustainability (Switzerland)*, 11(1), 1–14. http://scioteca.caf.com/bitstream/handle/123456789/1091/RED2017-Eng-8ene.pdf?sequence=12&isAllowed=y%0Ahttp://dx.doi.org/10.1016/j.regsciurbeco.2008.06.005%0Ahttps://www.researchgate.net/publication/305320484_SISTEM_PEMBETUNGAN_TERPUSAT_STRATEGI_MELESTARI

Kurniawan, M., & Oky, D. N. (2014). Implementation of Android-Based Mobile Learning Application as a Flexible Learning Media. International Journal of Computer Science Issues, 11(3), 168–174. https://doi.org/10.25147/jtiik.201965994.

Li, Y., Wang, K., Xiao, Y., Froyd, J. E., & Nite, S. B. (2020). Research and trends in STEM education: a systematic analysis of publicly funded projects. *International Journal of STEM Education*, 7(1). https://doi.org/10.1186/s40594-020-00213-8

Mahfudz, A. Z., & Billah., A. (2020). The Development of Android-Based Learning Media on Vibrations and Waves Topic for Junior High School Students. *Journal of Physics: Conference Series*, 1567(04200, 1–6. https://doi.org/10.1088/1742-6596/1567/4/042009.

Maison, M., Kurniawan, D. A., Wirayuda, R. P., & Chen, D. (2022). Process Skills-Based E-Module: Impact On Analytical Thinking Skills. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, 8(1), 23–34. https://doi.org/10.21009/1.08103

Mardiansyah, M., Zen, Z., Bentri, A., & Supendra, D. (2023). Pengembangan Media Pembelajaran Menggunakan Ispring Suite pada Mata Pelajaran IPA Kelas VIII SMP. *Jurnal Family Education*, 3(1), 37–42. https://doi.org/10.24036/jfe.v3i1.82

Maulidiyah, U., Wahyuni, S., & Ridho, Z. R. (2022). Pengembangan Media Pembelajaran Interaktif Berbasis Articulate Storyline Untuk Meningkatkan Keterampilan Komunikasi Siswa Smp Kelas Vii Pada Materi Pencemaran Lingkungan. *LENSA (Lentera Sains): Jurnal Pendidikan IPA*, 12(2), 115–124. https://doi.org/10.24929/lensa.v12i2.239

Muttaqiin, A. (2023). Pendekatan STEM (Science, Technology, Engineering, Mathematics) pada Pembelajaran IPA Untuk Melatih Keterampilan Abad 21. *Jurnal Pendidikan Mipa*, 13(1), 34–45. https://doi.org/10.37630/jpm.v13i1.819

OECD. (2019). *Programme for International Student As-*

sessment (PISA).

Peters-burton, E. E., & Stehle, S. M. (2019). Developing student 21 st Century skills in selected exemplary inclusive STEM high schools. *International Journal of STEM Education*, 1, 1–15.

Pradana, I., Setyosari, P., & Sulthoni, S. (2020). Pengembangan Multimedia Pembelajaran Interaktif Berbasis Android Pada Mata Pelajaran Ilmu Pengetahuan Alam Materi Cahaya. *JINOTEP (Jurnal Inovasi Dan Teknologi Pembelajaran): Kajian Dan Riset Dalam Teknologi Pembelajaran,* 7(1), 26–32. https://doi.org/10.17977/um031v7i12020p026

Putra, A. D., & Salsabila, H. (2021). Pengaruh Media Interaktif Dalam Perkembangan Kegiatan Pembelajaran Pada Instansi Pendidikan. *Inovasi Kurikulum*, 18(2), 231–241. https://doi.org/10.17509/jik.v18i2.36282

Ramadani, A. S., I Supardi, Z. A., & Hariyono, E. (2021). Studies in Learning and Teaching Studies in Learning and Teaching Profile of Analytical Thinking Skills Through Inquiry-Based Learning in Science Subjects. *SiLeT*, 2(3), 45–60. https://scie-journal.com/index.php/SiLeT/article/view/83

Saputra, A., Dewi, I. R., & Putra, Z. H. (2021). The influence of STEM-based learning on students' higher-order thinking skills. *Journal of Physics: Conference Series*. https://doi.org/10.1088/1742-6596/1882/1/012098

Shukla, D., & Dungsungnoen., A. P. (2016). Student's Perceived Level and Teachers' Teaching Strategies of Higher Order Thinking Skills; A Study on Higher Educational Institutions in Thailand. *Journal of Education and Practice*, 7(12), 211–19.

Song, H., & Cai, L. (2024). Interactive learning environment as a source of critical thinking skills for college students. *BMC Medical Education*, 24(1), 1–9. https://doi.org/10.1186/s12909-024-05247-y

Sulistyanto, H., Kusuma, I. W., & Suryani, N. (2022). Education Application Testing Perspective to Empower Students' Higher Order Thinking Skills Related to The Concept of Adaptive Learning Media. *Indonesian Journal on Learning and Advanced Education (IJOLAE)*, 4(3), 257–271.

Suyatman, Saputro, S., Sunarno, W., & Sukarmin. (2021). Of student analytical thinking skills in the natural sciences by implementing problem-based learning model. *Journal of Educational, Cultural and Psychological Studies*, 2021(23), 89–111. https://doi.org/10.7358/ecps-2021-023-suya

Theabthueng, P., Khamsong, J., & Worapun, W. (2022). The Development of Grade 8 Student Analytical Thinking and Learning Achievement Using the Integrated Problem-Based Learning and Think-Pair-Share Technique. *Journal of Educational Issues*, 8(1), 420. https://doi.org/10.5296/jei.v8i1.19711

Wahyuni, T. (2021). Supervisi Klinis oleh Kepala Sekolah guna Meningkatkan Kompetensi Guru dalam Mengelola Administrasi Kelas di SD Negeri 42 Ampenan. *Jurnal Paedagogy*, 8(2), 264. https://doi.org/10.33394/jp.v8i2.3561

Wicaksono, E., Santoso, H. B., & Maharddhika, I. G. (2022). Interactive multimedia-based learning to improve critical thinking skills in STEM education. *Journal of STEM Education: Innovations and Research*, 23(2), 45–57. https://doi.org/10.1187/jstem.2022.0457

Widya, W., Mujtahid, Z., Muliaman, A., & Hidayat, A. T. (2024). Needs analysis of interactive STEM-based multimedia to enhance literacy and 21 st -century skills Analisis kebutuhan multimedia interaktif berbasis STEM untuk meningkatkan literasi dan keterampilan abad ke-21. 07(November), 590–599. https://doi.org/10.24042/ijsme.v5i1.23709