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Development of Interactive Learning Media Crossword Puzzle Integrated Virtual Laboratory in Science Learning Vibrations and Waves Material

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Abstract: Learning media is an essential component in supporting learning objectives. Teachers are expected to make optimal use of these media. This research aims to develop interactive learning media through crossword puzzles integrated with virtual laboratories that are valid, practical, and effective. This research is included in the type of development research that refers to the ADDIE model Research and Development Model: Analysis, Design, Development, Implementation, and Evaluation. The tools used in this research are the validation sheet, learning process implementation observation sheet, student response questionnaire, student activity observation sheet, and learning outcomes test. The research results show that the interactive crossword puzzle integrated virtual laboratory learning media is categorized as valid, practical, and effective because the combination of learning and games provides a deep and enjoyable learning experience for users. Meanwhile, the virtual laboratory allows experiments to be conducted virtually so that they can be accessed anytime and anywhere.

Keywords: Crossword Puzzle; Interactive learning media; Vibration; Virtual laboratory; Waves

Introduction

The swift advancement of science and technology demands that we prepare ourselves to navigate global transformations, especially in education. Education plays a vital role in developing the era of Society 5.0, especially in improving the quality of human resources. Schools and teachers also play an essential role in Society 5.0. In the face of Society 5.0, the latest ideas are needed to address existing challenges. The concept of independent learning in the Merdeka Curriculum is part of Society 5.0. Society 5.0 uses technology to solve society's problems. The idea of self-regulated learning is used in Merdeka Belajar, which allows students to learn at their own pace while the teacher acts as a facilitator (Nurhayati, 2023). Learning activities focus not only on one source, such as books, but educators expand their reach by obtaining information from a variety of sources. The same goes for the use of media in learning. In general, the application of technology in education, such as the use of interactive multimedia, can create a more exciting learning experience, involve various senses, and encourage students to engage actively in the learning process (Sumarsono et al., 2024). Teachers need to be creative in developing learning media and adapting them to the needs of their students. Inappropriate selection of media in learning activities makes students tend to be less focused and quickly bored during the learning process, which has the effect of a lack of understanding, showing a passive attitude in the learning process, which has an impact on low student learning outcomes. Incorporating learning media into the educational process can spark new interests, inspire and energize learning activities, and impact students

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psychologically (Oemar, 2011). A good learning process must include interactive, fun, challenging, and motivating aspects and provide more space for students to cultivate creativity and independence in alignment with their talents and interests.

As an educator, you need to be able to present more innovative learning media. Innovative and creative learning media is one of the most essential factors in achieving learning goals. In the current development of learning media, especially in science learning. The presentation of science material needs to be structured using media to make learning more enjoyable. Children often like pictures. Based on experience, students enjoy learning when presented with colorful photographs and visualized in a realistic form.

Utilizing media in learning can boost students' motivation, making them more engaged and helping them better comprehend the material (Jannah et al., 2020; Ardana et al., 2021). Interactive learning media can capture the interest of students, is easy to use for elementary school students, and facilitates the learning process for teachers (Arifin et al., 2021; Biassari et al., 2021). Therefore, it is shown that using interactive learning media in learning process activities is very important to expand knowledge and facilitates teachers in delivering material effectively. By using these media, students will understand the material more quickly, which can enhance students' skills and academic performance (Rosa et al., 2023)

Choosing learning media is not easy because you have to consider the condition of students and the learning material to be taught. Likewise, it isn't easy to understand scientific concepts and their application, so the media is needed to collect knowledge and encourage students. To address this issue, the use of interactive learning media is essential, which presents teaching material in two or three dimensions in the form of video, images, animation, and audio learning. This learning media simulates a phenomenon based on learning materials and quizzes by filling in science learning puzzles from paper-based to virtual, then delivered as an application. One of the learning media is a crossword puzzle, a supporting learning application. Crossword puzzle learning media is a structure of review text in the form of a crossword puzzle, which can promote students' interest and participation in the learning process (Zulfikri, 2017). Crossword puzzles make subjects attractive without eliminating the essence of learning. They can create exciting conditions that make students interested and enthusiastic about learning. They are also easy to understand, not dull, and easier to remember the material explained (Hisyam, 2007). Using crossword puzzle media can help students recognize and remember previously learned terms by using the instructions given in each box. Through this game, students are required to answer questions according to the number of boxes available, which can effectively stimulate their interest in learning and provide an intellectual challenge (Marlina et al., 2021).

In addition to crossword puzzle media, virtual lab media is another learning innovation that can be integrated into learning to engage students in active learning. The virtual lab was developed as an alternative to manipulating the presentation of materials that are difficult to handle in traditional laboratories and to present abstract visual concepts. The advantages of virtual laboratories include the ability to manage content similar to natural conditions, visualization of complex material, resolution of resource limitations, personalization of learning, reduced risk of workplace accidents, and time flexibility. Types of virtual laboratories that can be developed for online hands-on learning include video, web, and distance-based laboratories (Subekti et al., 2022). There is empirical data in several areas of science education showing that the use of virtual laboratories produces comparable levels of learning to traditional hands-on laboratories (Stahre et al., 2019; Moosvi et al., 2019). Virtual laboratories are increasingly recognized as effective for improving student learning outcomes. According to (Abdjul et al., 2019), virtual laboratories provide a more in-depth and interactive learning experience for students. By using advanced simulation and visualization technology, virtual laboratories allow students to perform experiments and observations without the limitations of space and time. This improves their understanding of abstract scientific concepts and enriches their practical skills in applying theory in real-world contexts. Thus, virtual laboratories are not only a complement to modern education but also a necessity to prepare students for the learning challenges of the 21st century.

Virtual laboratory provides students with a more immersive and interactive learning experience. Using advanced simulation and visualization technology, this lab allows students to conduct experiments and observations without space and time constraints. Virtual laboratories enhance understanding of complex scientific concepts and enrich students' practical skills in applying theory to the real world. In addition, students can experiment multiple times as necessary (Papaconstantinou et al., 2020). Virtual laboratories also allow students can learn at their own pace since they have the flexibility to prepare and conduct experiments whenever and wherever they choose (Byukusenge et al., 2022). Virtual laboratories offer additional benefits, such as reducing unnecessary investments and avoiding economic losses by preventing damage to non-essential laboratory equipment (Checa et al., 2022). The use of

virtual laboratories supports the development of critical thinking, innovation, and teamwork skills, which are highly valued in today's job market (Lynch & Ghergulescu, 2017). In addition, virtual laboratories can replace natural laboratories to prove chemical concepts, theories, and laws in the modern era (Lestari et al., 2023). Virtual laboratories offer many advantages over traditional physical laboratories. These include reducing safety issues, increasing student confidence, and providing more efficient use of time for work practices with accurate results (Wahyuni & Atun, 2019). This advantage is very beneficial for educational institutions, especially those that do not have adequate laboratory facilities (Maryuningsih et al., 2019; Rana et al., 2023).

The development of interactive learning media, such as crossword puzzles integrated with virtual laboratories, is significant in improving the quality of education. These media make the learning process more exciting and enjoyable and encourage students to participate in learning actively. By experiencing hands-on activities, students can make the new knowledge they learn meaningful and relevant to everyday life (Masril et al., 2018).

With crossword puzzles, students can better understand and remember key concepts, while virtual laboratories allow them to conduct hands-on experiments in a safe and controlled environment. This combination also supports independent learning, allowing students to learn at their own pace and according to their needs. In addition, using technology in learning helps students prepare for the challenges of the modern world while enhancing their problem-solving skills and creativity through interactive learning experiences. Based on the above explanation, it is essential to research learning media development to strengthen education through interactive learning media crossword puzzle integrated virtual laboratory in science learning material vibrations and waves.

Method

This research is included in the type of development research; in this case, what is being developed is the development of interactive learning media crossword puzzles integrated with virtual laboratories in science learning about vibrations and waves. The learning development model used in this research refers to the ADDIE model (Sivasailam et al., 2016), which consists of five stages: Analysis, Design, Development (includes validation testing, limited testing, or extensive testing), Implementation, and Evaluation. Branch has flow chart of the ADDIE model as a learning system design in Figure 1.

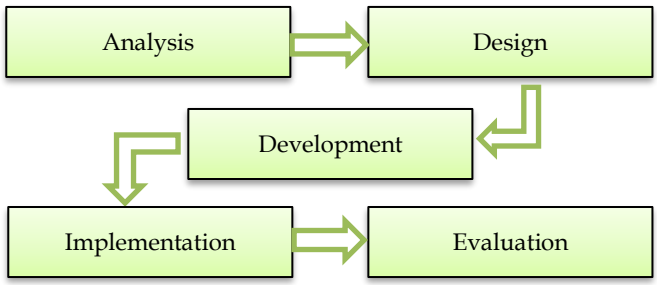


Figure 1. Flow chart of the ADDIE Development Model

This research will be conducted in the odd semester of the academic year 2023/2024 at MTS Alhuda, Gorontalo City. The instruments used in this research are the validation sheet, learning process implementation observation sheet, student response questionnaire, student activity observation sheet, and learning outcomes test. Data analysis in this research uses quantitative descriptive analysis, describing quantitatively the quality of the development of learning media, interactive learning media, crossword puzzles, and integrated virtual laboratories in science learning with vibration and wave material. Includes validity, practicality, and effectiveness. The analysis used in this research is described as follows.

Analysis of the validity

The validator expert writes his assessment of the interactive crossword puzzle integrated virtual lab learning media on the validation sheet. Two validators perform this validation, and a conclusion is drawn from the results of the two validators' review. Analyzing the validation of learning media is used to check whether the data resulting from the validation of the learning media under development are suitable to proceed to the next stage. The formula used in validation is Aiken concerning (Arikunto, 2010). The developed interactive learning media can be used if it meets valid or very valid criteria based on expert assessments.

Analysis of the practicality

The practicality of interactive learning media includes using the developed interactive learning media. The practicality analysis developed in this research was obtained based on student responses and the study of implementation in learning. Student response data was obtained from a questionnaire that analyzed percentages and qualifications to conclude whether the developed interactive learning media received a good response from students. The evaluation of the student's responses is carried out by comparing the given average total score with the criteria (Sukardi, 2013). The developed interactive learning media are practical from the point of view of student responses if 75% of the students are in

the good and very good categories. The practicality analysis is also based on data analysis resulting from observations of learning implementation. The analysis of learning implementation consists of two options: implemented or not implemented. The assessment of learning implementation is carried out by trying the average total score given with the criteria referred to in (Sukardi, 2013). The developed interactive learning media are said to be practical from the point of view of learning implementation if 75% of them are in the good and very good categories.

Analysis of effectiveness

In this analysis, the interactive learning media that is developed will be obtained from the results of observing students in learning. Following the learning process during two sessions, observing students' activities was analyzed and interpreted by interpreting the results of the average total score obtained using the criteria (Sukardi, 2013). Student learning outcomes are said to be complete if they meet the minimum completeness criteria value of learning outcomes completeness value. Student activities are effective in learning if 76% of students are in the good and very good categories.

Result and Discussion

This development research aims to create a product through interactive learning media. Crossword puzzles, an integrated virtual laboratory, have been developed. This research aims to allow researchers to see how the virtual laboratory integrated crossword puzzle learning media based on local wisdom in science learning with vibration and wave material is valid, practical, and effective. The images in the learning media are displayed appropriately according to the material, making learning more interesting for students. The research method used is research and development using the ADDIE development model, which consists of four stages: Analysis, Design, Development, Implementation, and Evaluation.

In the first stage, analysis, the researcher carried out the pre-research stage through interviews with educators in MTS Al-Huda, Gorontalo City. Based on interviews with educators, it is known that educators only use textbooks in learning activities and do not use interactive learning media, and even practical activities still need to be implemented. This problem is a factor in students' need for more interest and understanding of learning. Next, the researcher made observations on the students. The observation results show that students often feel bored in science learning because much of the material presented is abstract, so many students still don't understand it. Teachers use only textbooks as teaching materials, and practical activities are rarely used. The results are then analyzed so that it is considered necessary to develop interactive learning media so that students feel happy in learning activities, and it is essential to add learning activities that are combined with games to make learning more enjoyable. It is hoped that these learning media can help improve students' understanding of the material because it is in the media. Interactive learning includes pictures, videos, games, and problems commonly encountered in everyday life are presented.

The second stage, namely the design stage, designs interactive learning media, which will be used for vibration and wave material, to produce first draft. In preparing the learning media framework, there is a display design, namely, the preparation of the material, concept maps, and data used as essential references in the arrangement of each stage of the material. Using a concept map, each topic prerequisite for the following material is placed in the appropriate position. This helps to build a structured and gradual understanding for students because they can logically follow the development of concepts from basic to more complex (Munawwarah et al., 2022). Virtual laboratory, which can be done online anywhere and at any time, the results of practical activities in interactive learning media can be directly uploaded to the learning media. Games can be in the form of crossword puzzles or learning media equipped with games to fill in crossword puzzles related to vibration and waves. Crossword puzzles can be used in productive learning for students without losing the learning content. Even an educational game strategy like puzzles can create active student participation. At this stage, the tools to be used are also developed.

The third stage, the development stage, was conducted through expert validation by two validators to assess the validity of the first draft of the crossword puzzle integrated virtual lab interactive learning media. After the expert validation, improvements were made according to the validator's suggestions and input and then reorganized into a second draft, where the interactive learning media was declared very effective and suitable for learning. In addition, the interactive media was tested on a limited basis with 15 students to see the readability of the interactive media that was validated by the validator. Interactive media are validated by considering various elements such as construction, content, readability, language, and appearance. The validator provides suggestions and input regarding the designed interactive media during this validation process in Table 1.

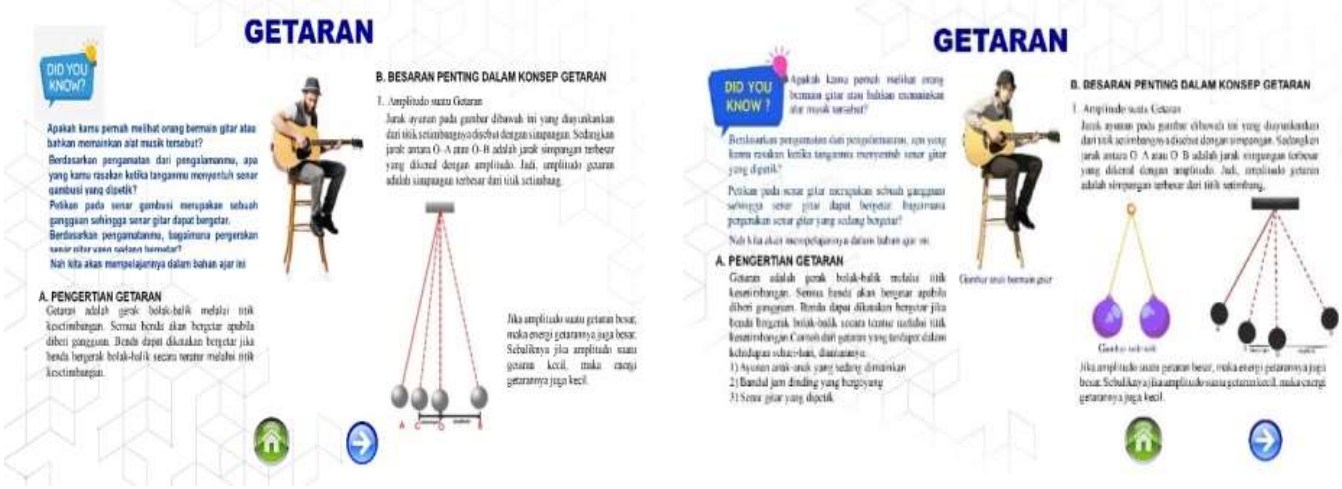
Table 1. Validator Suggestions for Interactive Learning Media

Validator	Revised aspects	Pre-revision suggestions	After review
1	Design aspects	Addition of instructions for application use	Added instructions on how to use the program
	Aspect of appearance	Use personal documentation on interactive media that is either derived from documentation or created by you. And if you use someone else's documentation, add references.	The images and videos in the interactive learning media will come from your own editing, and references will be added.
2	Aspects of readability and aspects of appearance	Consistent font size in interactive media content because writing is still closed	The size of letters in interactive learning media was consistent.

Based on the results of Table 1, there are several suggestions from the material validator to make changes to the latest images or their modifications, add references when using other people's data, and improve the layout of the writing. Several modifications of learning media before and after revision for all suggestions and input from material validators are shown in Figure (2)-(5).

Before revision After revision

Figure 2. Modification of correction of the most recent changes to the image or your own modifications



Before revision After revision

Figure 3. Modification of correction of recent changes to the image or your own modifications and a good layout

Before revision After revision

Figure 4. Modification of changes were made to the images and layout of the text to make them easier to read

Before revision: None (-) Before revision: None (-)

After revision After revision

Figure 5. Modifications of (a) Addition of instructions for application use, and (b) References added

The following validation is the validation of the materials used. Validating the materials used is important in ensuring that the information presented in a context or product is accurate, relevant, and valuable for the stated purpose. Here are some suggestions from validators regarding the materials used: Ensure that the information source used is trusted and has a good reputation in its field so that the information presented is valid and trustworthy, and consider the relevance of the material to the goals you are trying to achieve.

The results of the materials and media expert validation of the learning media developed are shown in Table 2.

Table 2. Validation Results

Assessment	Validity Score	Criteria
Results of the validation by media experts	3.85	Very valid
Validated by materials experts	3.89	Very valid
Average score of the validation	3.87	Very valid

Based on Table 2, the average value of the validation results is 3.87 and is included in the category "very valid," so the learning media can be used with slight improvements. The evaluation results of these two validators show that the developed interactive learning media are good and can be used in the learning process.

The fourth stage is implementation, which is carried out using interactive learning media and tested on students in the school where the research is carried out. The trial was conducted by researchers who carried out the teaching and learning process using interactive learning media. The study was conducted with a limited trial of 15 students. The trial was conducted to determine the quality of the product, in this case, the interactive crossword integrated virtual laboratory learning media that will be developed, and the student's responses to this media. This trial is to see the practicality and effectiveness.

The results of observations of learning implementation and students' responses when using the crossword puzzle interactive learning media integrated

with the virtual laboratory can assess the practicality of the crossword puzzle interactive learning media integrated with the Virtual Laboratory.

Implementation of learning activities means following the lesson according to the planned syntax, with a description for I (Implemented) and NI (Not Implemented) in Table 3. During two sessions, observers see the implementation of a lesson. In a limited study, 15 students were observed.

Table 3. Implementation of the Learning Process

Learning Activities	Meeting 1 (%)		Meeting 2 (%)	
	I	NI	I	NI
Preliminary Activities	81.15	18.85	100	0
Core activities	92.31	7.69	100	0
Closing Activities	82.21	17.79	100	0
Average	85.22	14.78	100	0
Implemented aspects average				92.61

The results of learning implementation show in Table 3, on average 14.78% of the indicators still need to be implemented at the first session. This is because some students need to familiarize themselves with the learning media developed, so they need a lot of time to adapt. In the second session, all the indicators were well implemented because the students had adapted to the developed learning media, and the researchers had prepared the lesson well. This aligns with the view Yusuf (2018), that teachers must prepare thoroughly, understand all the material presented, and provide clear examples.

The average percentage of implementation results in 2 sessions obtained a score of 92.61% with the criteria "very good." Based on these criteria, it can be concluded that learning with the integrated virtual laboratory crossword puzzle interactive learning media developed is classified as practical because the learning media developed by the learning planned by the researcher and the learning media used are easy to understand for teachers and students. A learning tool is said to be practical if it is by the learning plan designed by researchers, is easy to use in practice for teachers and students, with the assumption that the material is easy to understand (Irawan & Hakim, 2021).

Student responses to learning activities using the developed interactive crossword puzzle integrated virtual laboratory learning media were obtained through a response questionnaire. Product development is then evaluated based on student responses using a questionnaire based on four evaluation aspects, namely usefulness, ease of use, ease of learning, and satisfaction. The questionnaire consists of 22 statements and four indicators in Table 4 by providing a rating of each statement on a Likert scale according to (Sukardi, 2013).

Table 4. Average percentage of student Responses

Indicator	Percentage (%)	Categories
Usefulness	90.00	Very good
ease of use	89.72	Very good
ease of learning	90.00	Very good
Satisfaction	90.42	Very good
Average for all indicators	90.03	Very good

Table 4 shows the average percentage of student responses. First, based on the usefulness indicator, the average percentage of student responses was 90.00 (very good); second, based on the usability indicator, the average percentage of student responses was 89.72 (very good); third, based on the ease of learning indicator, the average percentage of student responses was 90.00 (very good). Fourth, based on the satisfaction indicator, the average percentage of student responses was 90.42 (very good). The average percentage of all evaluation indicators obtained a percentage value of 90.03 (very good). This shows that the development of crossword puzzles as an interactive learning media integrated with Virtual Laboratory received a positive response from students. This can be seen from the average of the students' responses from all indicators, which obtained results with very good criteria so that the developed learning media is beneficial in learning, easy to learn, easy to use, and gives satisfaction to students in its users.

The effectiveness of the integrated virtual laboratory crossword puzzles interactive learning media was assessed by observing student activities in the learning process using the developed interactive learning media and student learning outcomes. Assessment of student activities was conducted by three observers over two sessions during the learning process using the integrated virtual lab interactive crossword puzzle learning media. The observers' assessment is done by completing the student activity observation sheet. The student activity sheet assesses eight indicators: observing, listening to learning objectives, formulating problems, formulating hypotheses, designing experiments, conducting experiments to obtain data, collecting and analyzing data, and drawing conclusions. This indicator is adapted to the learning syntax of guided inquiry that has been previously designed in Table 5.

The results of the evaluation in Table 5 are all indicators of students' activity in learning activities received the highest average score, and the average percentage of all indicators was 88.67%. This shows that the student's activities are classified as "very good."

Table 5. Observations of the Activities of the Students

Indicator	Percentage of student activity (%)		Average (%)
	Meeting 1	Meeting 2	
Observations	92.50	95.21	93.86
Attention to student learning goals	91.66	94.66	93.16
Formulate the issue	89.12	93.33	91.23
Formulation of hypothesis	81.66	90.23	85.95
Experiment Design	89.12	91.12	90.12
Conduct experiments for data collection	84.01	86.12	85.07
Data collection and data analysis	83.35	84.17	83.76
Make conclusions	85.83	86.67	86.25
Average of all indicators			88.67

Thus, the developed interactive crossword-integrated virtual lab learning media is effective. The next was a learning outcomes test carried out on 15 students, where 13 met or exceeded the minimum completion criteria. In comparison, two other students scored below the minimum completion criteria or had yet to exceed the minimum completion criteria. Thus, the percentage of students who complete the course is 86.67%. From these results, the developed learning media meets the effectiveness requirements because most students can reach or exceed the set standards. This learning media is very good because, through interactive learning, it is able to cover students' learning styles. After all, interactive learning is combined into one media, starting from text, images, audio, music, animated images, or videos into one unit so that the learning media can display more abstract material. According to research conducted by Sudirtha et al. (2021), the visual learning style is highly preferred by students when participating in online learning through social media. These findings underscore the importance of understanding students' learning styles when designing interactive media. Based on this, interactive learning can actively involve students in learning and impact students' motivation and interest in learning.

This is supported by research Trimansyah (2021), which shows that interactive media refers to interaction or dialog between teachers and students using various specific media. Interactive media, such as learning videos, have attracted students to pay attention to explanations, which seem more straightforward to understand than listening to teachers' lectures (Yusi, 2019). Interactive media encourages students to participate actively in learning. This occurs in the interactions between students and learning media and between students and teachers (Rosamsi et al., 2019). In addition to the benefits for students, the interactive press makes it easier for teachers to deliver material more efficiently.

According to Rosa et al. (2023), using interactive learning media can increase students' motivation to learn, make it easier for teachers to convey information, and create a more supportive learning atmosphere. On the other hand. Reseach from Wulandari (2020) emphasized that multimedia-based interactive learning media can increase students' interest in learning. Several studies emphasize using different applications and technologies in developing interactive media. For example, Sari et al. (2023) found that using images and animations in educational games can increase students' motivation to learn mathematics. In addition, Ardana et al. (2021) emphasize the importance of interactive media with interactive buttons to get students more involved in the learning process.

Interactive learning media allows students to participate actively in the learning process, making them more motivated and interested in what they are learning. It also refers to instructional choices actively programmed and managed by students to make learning more meaningful and satisfying.

The learning media developed includes games like crossword puzzles, making learning fun. The crossword puzzle learning development packages the learning of vibrations and waves into a game so that learning becomes fun and refreshes the brain in thinking because it is combined into games so that learning feels fun. Children still like to play, so combining games into learning makes learning fun, not monotonous. This is supported by research from Alfiansyah et al. (2023), namely that this crossword puzzle learning media makes it easier for students to understand content that is considered problematic. This media facilitates student activities and makes it easier for teachers to explain topics. This medium also adds new nuances to the learning process. Provide an educational game atmosphere so that learning is not monotonous.

The results of research conducted by Malihah & Jamaludin (2023) show that using learning media such as crossword puzzles can increase students' interest in learning and provide them with challenges. In addition, research by Agustin et al. (2021) found that crossword puzzles can increase student activity and learning outcomes because a calm and clear mood helps to strengthen memory. In addition, Pratiwi (2022) research results show that crossword puzzle learning media can help students understand the material better and improve their learning outcomes.

Crossword puzzle learning media is very effective in helping students understand the subject matter so that learning becomes fun. Students can use crossword puzzles to sharpen their critical and creative thinking

skills while remembering important information more easily. These activities make learning more interactive and encourage collaboration between students when they work in groups. In addition, crossword puzzles can increase learning motivation because students feel challenged to solve each problem. In this way, students' learning outcomes can be significantly improved because they are more involved and active in learning.

This media also includes the virtual laboratory PhET Simulation, tailored to the learning objectives so that students no longer need to search for how to use the virtual laboratory. Still, it has been embedded directly by the teacher in the media. Virtual laboratories can help students interact with learning media, which is like doing practical work in the real world. So that teaching media is integrated with. Virtual laboratories can enhance mastery of concepts from material explained in the press, then applied in virtual laboratories, so students' understanding becomes profound and meaningful. The fifth stage is evaluation. In this stage, an evaluation process of the developed media is carried out to improve and perfect the developed product. The evaluation results show that the developed interactive crossword puzzle integrated virtual lab learning media can be used successfully.

Conclusion

The conclusion is that the interactive learning media in the form of a crossword puzzle integrated with the Virtual Laboratory shows a very good validity with an average value of 3.87. Its practicality is also demonstrated by the percentage of learning implementation reaching 92.61% and an average student response of 90.03%, so teachers and students can easily understand and use the media. In addition, this media effectively increases activity and learning outcomes, with an average student activity score of 88.67% and student completion of 86.67%. Integrating various media such as text, images, audio, and virtual lab simulations provides an in-depth and enjoyable learning experience suitable for different student learning styles. Interactive learning media crossword puzzles integrated virtual laboratory in science learning, the vibration and wave material developed is categorized as valid, practical, and effective because the combination of education and games provides users with a deep and enjoyable learning experience. Crossword puzzles challenge students to use their knowledge in an interactive and interesting context. At the same time, the virtual lab allows experiments to be performed directly so that they can be accessed anywhere, anytime.

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All authors contributed to writing this article.

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Conflicts of Interest
The authors declare no conflict of interest

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