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Sound Wave Digital Learning Material Integrated Augmented Reality and CTL Model to Promote Students' 21st Century Skills

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ABSTRAK

Proses pembelajaran seharusnya mampu mengembangkan keterampilan abad ke-21 siswa. Kenyataanya keterampilan abad ke-21 siswa masih rendah. Keterampilan abad 21 yang perlu dikembangkan pada siswa adalah kemampuan 4C, diantaranya: berpikir kritis dan berkomunikasi. Tujuan dari penelitian ini untuk menganalisis hasil analisis kebutuhan, hasil uji validitas, dan hasil uji praktikalitas bahan ajar digital untuk menunjang peningkatan keterampilan pada abad 21 siswa. Jenis penelitian yang digunakan adalah R&D dengan model Hannafin dan Peck. Subjek dalam penelitian ini adalah siswa kelas XI. Instrumen yang digunakan yaitu angket, soal tes, dan penilaian kinerja untuk menganalisis kebutuhan siswa; lembar validasi produk untuk menentukan validitas produk; dan lembar praktikalitas produk untuk menentukan kepraktisan penggunaan produk. Analisis data yang digunakan dalam penelitian ini yaitu analisis statistik deskriptif. Uji validitas dilakukan menggunakan rumus Aiken's V. Hasil analisis validitas menunjukkan bahwa rata-rata nilai validasi bahan ajar digital AR-CTL dalam kategori yang valid. Nilai analisis praktikalitas bahan ajar digital AR-CTL dalam kategori yang praktis.

ABSTRACT

The learning process should be able to develop students' 21st century skills. In fact, students' 21st century skills are still low. Skills in the 21st century that need to be developed by students are 4C abilities, including: critical thinking and communication. The purpose of this research is to analyze the results of the needs analysis, the results of the validity test, and the results of the practicality test of digital learning materials to support the improvement of students' 21st century skills. The type of research used is R&D with the Hannafin and Peck model. The subjects in this study were students of class XI senior high school. The instruments used are questionnaires, test questions, and performance assessment to analyze student needs; product validation sheets to determine product validity; and product practicality sheets to determine the practicality of product use. The data analysis used in this research is descriptive statistical analysis. The validity test data analysis was conducted using Aiken's V formula. The validity analysis results show that the average validation value of AR-CTL digital learning materials is in the valid category. The practicality analysis value of AR-CTL digital learning material is in the practical category. So, it can be concluded that the augmented reality digital learning material integrated with the CTL model are valid and practical to promote students' 21st century skills.

1. INTRODUCTION

Globalization has affected all human aspects in life including education. In the era of globalization, various basic Students must acquire certain skills, especially skills of 21st century. Skills of 21st century are the skills needed by a person to successfully face increasingly complex challenges, especially to succeed in a career and socialize in the world of work (Jayadi et al., 2020; Redhana, 2019). Skills of 21st century are the skills needed for students to participate actively, effectively, and successfully acquire academic fields, communicate, problem-solving competencies, and filter detailed information (Hidayatullah et al., 2021; Kasuma et al., 2022). The steps to achieve 21st century learning goals are broad knowledge, critical thinking, communication, collaboration, the ability to innovate, and literacy. Thus, skills of 21st century can answer the challenges of globalization. Learning implementation should be able to develop the skills in 21st century by students. New standards are needed so that students may master creative thinking abilities, flexible problem solving, teamwork, and innovation in the twenty-first century (Y. Asrizal & Usman, 2022; Maulidah, 2019). Students must have 21st century skills, particularly 4C skills such as critical thinking, creative thinking, cooperation, and communication (Mardhiyah et al., 2021; Novisya & Desnita, 2020). A student-centered learning approach, also known as Student Center Learning, is also integrated into 21st century learning.

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Student-centered learning is anticipated to encourage students to actively participate in the development of knowledge, attitudes, behavior, and comprehensiveness. This technique provides opportunities and facilities for students to create their own knowledge in order to get a thorough understanding, which can improve students' learning quality (Mohamadi, 2018; Wati & Widiansyah, 2020). Teaching and process of learning according on children's needs is the definition of student-centered learning approach. This shows that learning should consider the wants and needs of children to increase the learning quality. To realize this, was needed that can guide students to be active in learning. Digital material of teaching that can support this are digital learning material. The first theoretical is digital learning materials. Digital learning materials are materials or resources that are systematically arranged to assist students and teachers in carrying out the learning process. Digital learning materials consist of learning materials that are systematically arranged to achieve learning objectives presented or published in electronic format (Fanani et al., 2022; Ridho et al., 2020). The stage of preparing learning materials depends on the characteristics of the material to be developed in learning activities. There are several scopes of learning materials, including the following: 1) title, class, semester, and identity of the author, 2) core competencies and basic competencies, 3) achievement indicators, 4) learning materials, 5) exercise questions, 6) competency test, 7) reference (Bosica et al., 2021; Siagian et al., 2019).

The ideal conditions expected have not been in similar with the real situation in the field. According on the initial research results, there were problems in physics learning, especially the low skills of 21st century of students. The first real condition is that the use of physics digital learning material in schools is still low and there is no CTL integrated digital learning material. The second real condition related to critical thinking and communication skills of grade XI students is still in the low category, namely with a value of 51.32 and 50.78. This is in similar with research which says that students lack thinking activities to solve a problem, and also the lack of interaction between fellow students in the learning process so that it does not lead to discussion or friendship between fellow students which can increase students' thinking activities. Student communication is also unskilled due to the frequent use of local languages and low mastery of science vocabulary (Mahdalena & Daulay, 2020; Mukaromah & Wusqo, 2020). The third real condition is related to sound wave material, namely students have difficulty understanding sound wave concepts (Dwipangestu et al., 2018; Krismandana & Wibowo, 2020). The fourth real condition is related to student outcomes in learning, seen from the average odd semester midterm exam of students in class XI MIPA 5, which is 32.91 and is in the category was low.

The solution to fix this issue is the creation of augmented reality digital learning material integrated with the CTL model to increase skills in 21st century by students. The utilization of technology and information in education provides space for students to get subject matter interactively and independently. Interactive learning can be presented in the shape of so that we can accessed easily on smartphone devices. This is in similar with analytical research on the development of CTL and MI-based modules on sound waves (Krismandana & Wibowo, 2020). The second research entitled the development of AR training media high school students' abstract skills of critical thinking in magnetic field material (Rizti Yovan & Kholiq, 2021). Third, a research entitled the development of a physics module assisted by AR technology on sound wave material for SMA / MA class XI (Khunaeni et al., 2020). Fourth, a research entitled the development of a learning book equipped with AR on the subject of sound and optical waves (Bakri, 2018), Fifth, a research entitled modules equipped with AR technology (Chaeranti et al., 2018). The five studies developed AR material in learning, applied them to SMA / MA students, measured the validity and AR material practicality of learning, trained students' skills of critical thinking, and students' concept mastery. This previous research is the basis for conducting this research.

From the problem solution that has been stated, there are three theoretical studies needed to solve the problem. The first theoretical research is about digital learning material. Digital learning material is a product of advances in digital technology. The technological advancement results allow the interaction of text, sound, images, animations and videos that can be presented through the use of computers with the help of tools / applications (Marjuni & Harun, 2019; Rachmadtullah et al., 2018). Multimedia is able to provide a rich learning experience and positive value for students. The presence of digital learning material is expected to be able to support students in line with technological advances, so it needs to be continuously developed and pursued. Digital learning material as material of teaching has many contributions for students in the process of learning. These contributions include: 1) effectively developing students' imaginative power; 2) able to convey the historical message of an event visually; 3) able to arouse students' enthusiasm for learning; 4) able to visualize activities and objects that occurred in the past. Digital learning material can also stimulate students' minds, so that learning becomes more real for students. Digital learning material can assist pupils in repeating content that is not understood at any time or place (Kurniawti et al., 2019; Winatha et al., 2018). Therefore, the use of digital learning material greatly supports students in learning both in direct learning and independent learning.

The second theoretical research relates to augmented reality (AR). AR is a technique that can transform two-dimensional or three-dimensional virtual things into real-world objects and then project them in real time. AR technology in education can help students visualize abstract material in 3D, making the information easier for students to understand (Blankenberg et al., 2021; Nincarean et al., 2019). AR can be used to assist visualize abstract

notions in order to better grasp and structure an item or model. AR technology can also increase visual spatial intelligence and increase student outcomes in learning. Therefore, the use of AR has the potential to overcome many student problems in the process of learning and AR technology is also able to increase students' imagination. So, combining AR and smartphones can offer students experience and apply scientific knowledge with new technology (Ahied et al., 2020; Sahin & Yilmaz, 2020).

The third theoretical research relates to the Contextual Teaching and Learning or CTL model. CTL is a learning model that utilizes everyday experiences to increase students' skills of critical thinking. The CTL model links the material learned with students' real life every day, both in the family, school, and community environment with the aim of finding the meaning of the material for their lives. This learning model motivates students to take responsibility for their learning (A. Asrizal et al., 2018; Ismatunsarrah, 2020). One part of a productive and responsible learning strategy is that meaningful activities build on students' prior knowledge and experience (Darling-Hammond et al., 2020). The CTL model has components to create meaningful learning. The components of CTL are part of the 4Cs which are the basic skills of the 21st century. These components are constructivism, discovery, questioning, learning communities, modeling, reflection, and authentic assessment. These components are in similar with the demands of the 21st century, namely student-centered learning. The CTL model has several advantages, including being meaningful and real learning and learning is more productive and fosters concept reinforcement (Darling-Hammond et al., 2020; Ponidi, 2021). Students' cognitive abilities can be honed by using the CTL model so that students' skills in the 21st century can be improved and learning objectives can be met.

Based on the background that has been stated, digital augmented reality (AR) learning materials for sound waves integrated with the CTL model need to be done. This is in line with the real conditions in the field which show that the use of digital learning materials is still low and has not integrated the CTL model. In addition, the results of critical thinking and communication skills of students are also still low. The purpose of this study is to reveal the results of preliminary research, reveal the results of the validity test, and reveal the results of the practicality test of the digital learning materials produced. The novelty in this research is the utilization of technological advances to improve students' 21st century skills, especially critical thinking and communication skills. in addition, this research also uses CTL models that can increase student activeness and independence.

2. METHOD

This research can be included into research and development method. The research and development conducted produced a product in the shape of digital learning material augmented reality sound waves integrated with the CTL model to increase students' skills of critical thinking and communication. In developing digital learning material integrated with the CTL model, the Hannafin and Peck model was applied (Boangmanalu et al., 2018). The Hannafin and Peck model is a product-oriented procedure as the basis of research, for example digital learning material (Sumarmi et al., 2023). The Hannafin and Peck paradigm is divided into three stages: needs analysis, design, and development and implementation. Data collection in the research used several instruments. First, a questionnaire of teachers' constraints on the utilization of ICT in material of learning. This questionnaire was given to 2 high school physics teachers. Second, performance assessment questions given to students to measure students' critical and creative skills of critical thinking. Third, document analysis in the shape of physics lesson plans of teachers to analyze objectives of learning and settings. Fourth, student learning outcome documents to analyze student knowledge. Fifth, the validation sheet of digital learning material. The validity instrument contains 5 assessment components, namely material substance, design of learning, appearance, software utilization, and AR-assisted CTL integration. Sixth, the practicality sheet of digital learning material according to students. The practicality instrument consists of an assessment of the components of benefit, ease of use, attractiveness of presentation, clarity, and integration of AR-assisted CTL.

The technique for data analysis used in the research is technique of descriptive analysis, namely by describing the needs analysis results, validity test analysis, and practicality test analysis in the shape of tables or graphs. The assessment in this research used a Likert scale with a score of 1-5 with the following conditions: 5 means Very Good, 4 means Good, 3 means Fair, 2 means Less, and 1 means Very Less. The validity test results were then analyzed using the Aiken's V formula with expert validation categories ≥0.6 categorized as valid and <0.6 categorized as invalid (Azwar, 2015). The practicality test results were analyzed descriptively quantitatively with the category 80 to 100 is very good, 66 to 79 is good. 56 to 65 is sufficient. 40 to 55 is less, and 30 to 39 is a failure (Arikunto, 2019).

3. RESULT AND DISCUSSION

Result

First result in this research is need analysis. There are four result in need analysis. First result is the problem of using ICT for physics learning in schools. Data collection techniques and instruments used are

questionnaire instruments. The questionnaire was filled by two physics teachers of SMA Negeri 8 Padang. According on the questionnaire obtained results the results that the learning conducted in SMA Negeri 8 Padang in class XI has not been integrated with digital technology. The lack of active participation of students and tend to only pay attention to the teacher's explanation with the help of printed material of learning provided is the result of teacher-centered learning. According on the questionnaire results with physics teachers, Teachers face a number of challenges while teaching the physics process of learning. The obstacles are expressed directly by physics teachers presented. Some learning problems obtained from the teacher questionnaire as in Table 1.

Table 1. Analysis of Technology Use Issues results

Teachers' Difficulty on ICT Utilization	Value
Difficulty in Creating ICT-Based learning material	82
Difficulty in Mastering ICT-Based learning material	72
Difficulty in Mastering Software	80
Difficulty s in Creating ICT-Based learning material with Software	80
Difficulty in Using ICT-Based learning material in learning	80

Data in Table 1 shown that teachers experience obstacles to the ICT used in learning material. According to the data analysis, the teacher's constraints on the ICT used in learning material are in the 72-82 value range. The analysis results show that teachers are very constrained in making ICT-based learning material, namely with a value of 82 in the category was high. Teachers' constraints in mastering software, constraints in making ICT-based learning material with software, and constraints in using ICT-based learning material in learning are in the category was high with a value of 80. From the data obtained, we got conclusion that teachers feel constrained and have difficulty in utilizing ICT in learning material.

This research also analyzed student characteristics. Analysis of student characteristics was obtained through a questionnaire to students. There are 3 indicators of student characteristics presented, namely: 1) student background, 2) student interest, 3) student motivation, and 4) student learning style. Data on student characteristics were obtained from the questionnaire analysis results by class XI students. The analysis results of student characteristics shown in Figure 1.

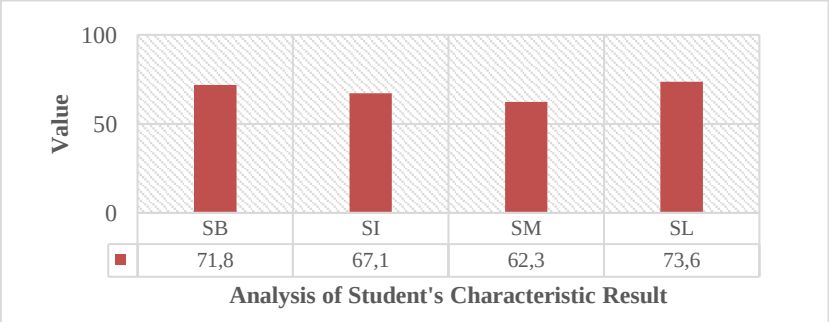

Figure 1. Analysis of Student's Characteristic Result

Data in Figure 1 shown how the characteristics of students of class XI IPA SMAN 8 Padang in physics learning. According to the data, we can explained that the three indicators are in the insufficient category where interest in learning and motivation to learn scored 67 and the highest score is learning style with a score of 78. While students' learning styles get higher scores but are also still classified as less. This can be interpreted that the internal factors of students have not helped the physics process of learning in order to obtain maximum results.

The third needs analysis is the analysis of learning settings. The learning setting analysis results were obtained according on the physics teacher's lesson plan which included introductory activities, core activities, and closing activities. The learning setting analysis results is shown in Figure 2.

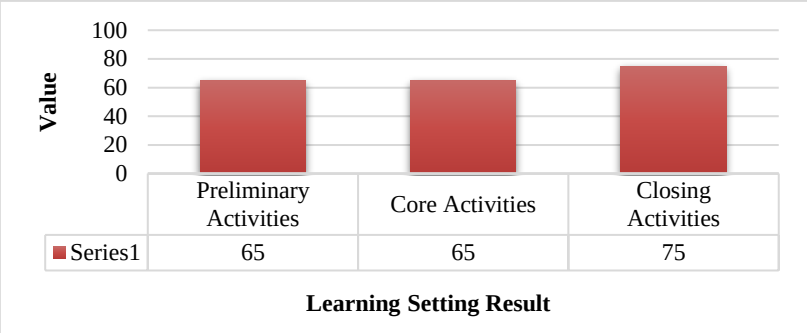

Figure 2. Analysis of Learning Settings Result

Figure 2 has shown the analysis results by physics teacher learning settings which include introductory activities, core activities, and closing activities. Preliminary activities are in the category in good with a score of 84. Core activities and closing activities are in the sufficient category with scores of 79 and 76, respectively. The average analysis of learning settings is in the sufficient category with a value of 79.7. This shows that the learning setting at SMAN 8 Padang is quite in similar with the ideal learning implementation. However, it is necessary to increase and increase the core activities and closing activities to maximize the learning implementation.

The fourth result of this research is the analysis of student outcomes in learning. Analysis of initial abilities assessed are critical skills of critical thinking and communication. Analysis of critical skills of critical thinking obtained from test questions. Analysis of communication skills is obtained from performance assessment. student outcomes in learning were seen from the midterm exam students results in class XI MIPA 5 SMAN 8 Padang. The analysis results are according on descriptive statistical parameters. According on the initial observation during the research, the value of critical thinking, communication, and students' knowledge, as shown in Table 2.

Table 2. Statistic Parameter Values for Need Analysis Data

Statistic Parameter	Critical Thinking	Knowledge	Communication
Number of students	34	34	34
Average	51.3	32.91	50.8
Mode	45	33	53
Median	45	31	51.5
Lowest Score	35	20	40
Highest Score	70	85	67
Range	35	65	27

Data in Table 2 explained that the skill critical thinking and communication average of 34 students in class XI MIPA 5 SMAN 8 Padang is 32.91 which is in the less category. The lowest value of student outcomes in learning is 20, while the highest value of student outcomes in learning is 85. Critical skills of thinking are 51.32 which is in the deficient category. Meanwhile, communication skills were observed when students presented their group practicum results. Students' communication skills obtained a score of 50.78 which is in the deficient category. The skills of 21st century assessment results show that skills in 21st century by students are still low. According on the data obtained, we got conclusion that students face difficulties in learning.

The next result in this research is the result of product validation. Digital learning material that have been developed are then validated by experts to reveal the validity of the digital learning material developed. The validation instrument used has assessment components which include material substance (MS), design of learning (LD), visual communication (VK), software utilization (SU), and AR-assisted CTL integration (CU). The product validation results shown in Figure 3. Data in Figure 3 was data of validation results for digital learning material according on five validity components can be explained. The five components, namely material substance, design of learning, display of digital learning material, software utilization, and AR-assisted CTL assessment are in the category was valid with a range of Aiken's V values from 0.78 to 0.91. The average result of Aiken's V analysis according on five components is 0.81 with category was valid. This shows that the validity of digital learning material for sound waves integrated with the CTL approach is in the category was valid and feasible to use in learning. Indicators of material substance components consist of 1) correctness, 2) depth, 3) currentness, and 4) readability. The indicator analysis results on the material substance component are in the value range 0.78-

1.00 with an average of 0.91 which is in the category was very high. The design of learning component indicators consist of 1) title, 2) objectives of learning, 3) material, 4) sample questions, 5) exercises, 6) compilers, and 7) references. The analysis results for indicators on the design of learning component are in the value range 0.84-1.00 with an average of 0.81 which is in a category was very high.

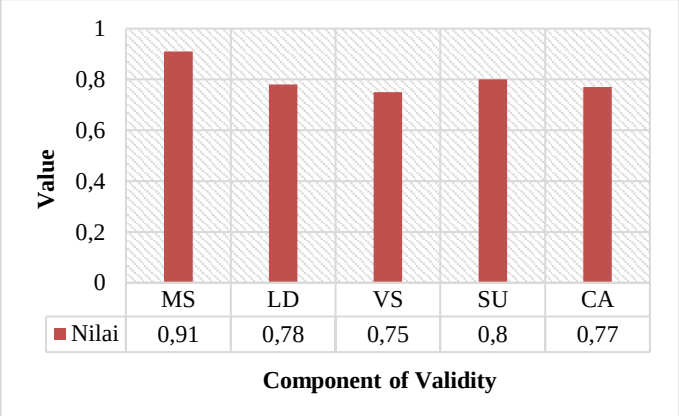

Figure 3. The Average of the Component Validity Test of Digital Learning Material

Indicators of visual communication components consist of 1) navigation, 2) typography, 3) media, 4) color, 5) animation, 6) simulation. The analysis results for indicators on the visual communication component are in the value range 0.78-1.00 with an average of 75 which is in the category was high. Indicators on the software utilization component consist of 1) interactivity, 2) supporting software, and 3) originality. The analysis results for indicators on the software utilization component are in the value range of 0.73-0.85 with an average value in the category was high of 0.80. Indicators on the AR-assisted CTL assessment component consist of 1) contextual nature and 2) contextual components. The analysis results for indicators on the CTL assessment component are 1.00 and 0.86 with an average value in the category was high.

This digital learning material is containing text, images, and videos. Digital learning material consists of cover, material, learning video, worksheet, evaluation, and AR camera. These menus will make it easier for students to use. The following AR digital learning material display designed shown in Figure 4.

Figure 4. (a) AR Digital Material Teaching Cover Display, (b) AR Digital Material of Teaching Main Menu Display

Figure 4 is a cover design and menu on digital learning material. The cover menu contains the identity of digital learning material in the shape of titles and names of authors, the material menu contains sound wave learning material equipped with KD and objectives of learning, the learning video menu contains learning videos related to sound wave material in everyday life, the worksheet menu contains student worksheets to increase the skills in 21st century by students, the evaluation menu contains questions according on material that students have learned before, and the AR camera menu to display 3D sound wave videos by scanning the code. Similar to research findings, the level of digital technology maturity in instructors and pupils is sequential, beginning with

caring, literacy, capability, creativity, and critical use of digital technology. All of these maturity levels are considered low. As a result, many training and learning innovations related to the linking of digital technology mastery competencies must be expanded.

Last result in this research is practicality test. The research results after the product has been validated, then the student practicality test is conducted to reveal the product practicality that has been developed. The practicality instrument used has assessment components which include benefits (BF), ease of use (EU), attractiveness of presentation (AP), clarity (CL), integration of AR-assisted CTL (CI), and software use (SU). The analysis of each component of practicality shown in Figure 5.

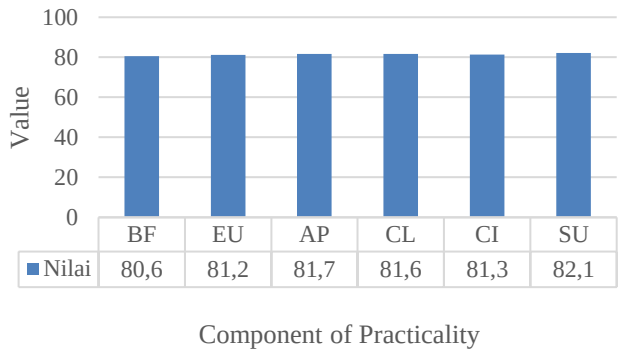

Figure 5. The Average Value of the Component Practicality Test of Digital Learning Material

Data in Figure 5 explained that the practicality test results for digital learning material are in a category was high with a range of value is 80.6 to 82.1. The average analysis of the practicality test results for digital learning material are in the category in very good with a value of 81.42. Indicators in the benefits component consist of 1) can be used to achieve objectives of learning, 2) can be used anywhere and anytime as needed, 3) can be used as a learning resource, 4) can be used to accelerate mastery of physics material, 5) can be used to stimulate curiosity, and 6) can be used to control learning activities. The analysis results for the benefits component are in the excellent category, namely with a value of 80.6. Indicators in the easy-to-use component consist of 1) making it easier to understand learning material, 2) making it easier to apply physics concepts in everyday life, 3) making it easier to carry out experiments, 4) digital learning material are easy to implement, and 5) making it easier to master technology. The analysis results for the easy-to-use component are in the category in very good with a value of 81.2.

Indicators in the presentation attractiveness component consist of 1) attractive cover, 2) attractive illustration display, 3) attractive concept images and videos, 4) attractive content display, 5) attractive color combination on the cover, 6) activities on interesting worksheets, and 7) attractive toolbar and background colors. The analysis results for the presentation attractiveness component are in the category in very good with a score of 81.70. Indicators on the clarity component consist of 1) the objectives are clear, 2) the material is clear, 3) the information is clear, 4) the work step activities are clear, 5) real-world phenomena are clear, 6) the instructions given are clear, and 7) the use of writing fonts is clear. The analysis results for the clarity component are in the category in very good with a value of 81.6. Indicators on the integration component of AR-assisted CTL consist of 1) CTL steps and 2) CTL components. The analysis results for the AR-assisted CTL integration component were in the category in very good with a score of 81.3. Indicators in the software use component consist of the ease of software used in making digital learning material. The analysis for results the software use component were in the category in very good with a value of 82.1.

Discussion

From the data analysis that has been done, four results can be stated from the preliminary research at SMA Negeri 8 Padang. First, the analysis of the problem of using ICT in schools is quite high Second, the analysis of student characteristics found that the motivation, interest, and learning style of students are in the less category. This can be interpreted that the internal factors of students have not helped to obtain maximum results. Third, the analysis of skills in 21st century by students found that students' initial critical thinking and communication skills were in the low category. This is due to the teacher who still dominates the process of learning so that students lack thinking activities and interaction between fellow students (Astuti et al., 2021; Musnar Indra D, 2020). Finally, the analysis of student outcomes in learning found that daily tests and midterm exam results were in the poor category. This is because most students cannot connect what they have learned with how that knowledge is used so that students have difficulty understanding the concept of material. In

addition, low outcomes in learning are also caused by poor quality learning (Haya et al., 2022; Tarigan et al., 2019). According on the initial research results at SMA Negeri 8 Padang, we got conclusion that teachers and students need the development of digital learning material AR sound waves integrated with CTL models to increase the skills in 21st century by students.

Validation of AR digital learning material was conducted by three physics lecturers as experts. The validity results obtained are divided into five assessment components, namely material substance, visual communication display, design of learning, software utilization, and CTL assessment. According on data analysis validation of digital learning material developed, the validation results were obtained in a category in very good with an average value of 80. The results obtained illustrate that digital learning material have fulfilled all indicators developed in the validation of digital learning material. This is in similar with several studies. First, the research states that the product in the shape of an augmented reality-based physics module has been successfully developed with valid (Laksono & Wibowo, 2022; Purwandari et al., 2021). Second, material of learning get good validation scores from media experts and material experts so that they can be said to be suitable for the process of learning. Third, digital learning material on direct electricity material are suitable for use because the validation test results are included in the category was very valid. Products that have been valid can be tested for the products practicality that have been developed (Ilahi et al., 2021; Nalasari et al., 2021).

The digital learning material practicality is seen from the assessment that has been done by students of class XI MIPA SMA after using this digital learning material in learning. The digital learning material practicality test results are in the very practical category. This shows that digital learning material is useful, easy to use, the presentation is interesting, clear, and has integrated AR and CTL models. The practicality results for this digital learning material are helped by the research results which states that the material of learning developed have benefits for students as users, provide ease of use, and make learning time effective (Irhandayaningsih, 2020; Nida et al., 2021). In addition, previous study found there was an increase in student activity from the previous 72% to 90% (Nur et al., 2020). Furthermore, the product design assessment results conducted by students through aspects of ease of use, ease of determining concepts, learning independence, efficiency, and attractiveness are on average in a very practical interpretation.

The findings obtained in the field that skills in 21teachibfst century by students are low are due to the material of learning used that have not been integrated with the CTL model. In addition, the utilization of technology in schools is not optimal so that the material of learning used in schools has not utilized technology. The limitation in this development is that the digital learning material in the shape of AR digital learning material integrated with the CTL model developed are limited to sound waves. In addition, digital learning material in the shape of AR digital learning material integrated sound waves CTL model are limited to skills of critical thinking and communication skills. Digital learning material in the shape of AR digital learning material have several advantages, namely AR digital learning material makes learning more effective and efficient. digital learning material in the shape of AR digital learning material developed can be used online and can be used on smartphones of teachers and students. Future researchers who will continue this research are expected to complete the shortcomings in this study, such as digital learning material available in all physics materials and test the effectiveness of using this learning material to students.

4. CONCLUSION

Based on the research and discussion results, four conclusions can be stated. First, the needs analysis obtained results as a guideline for developing learning material show that students' skills of critical thinking, creative thinking, and knowledge are still low. Second, the design of electronic learning material developed contains sound wave material integrated with CTL to increase students' critical and creative skills of critical thinking. learning material can be used by teachers and students using their respective smartphones anywhere and anytime. Third, the validity of digital learning material for sound waves integrated with the CTL approach with smartphones is in the category was valid. Digital learning material are valid in five components, namely material substance components, visual communication displays, design of learning, software use, and CTL assessment. Fourth, the practicality value of using digital learning material for sound waves integrated with the CTL approach with smartphones is in the category in very good in five components, namely the benefit component, ease of use, presentation attractiveness, clarity, and cost-effectiveness. Thus, the digital learning material for sound waves integrated with the CTL approach with smartphones to increase students' critical and creative skills of critical thinking are valid and very practical to use in the process of learning to increase students' critical and creative skills of critical thinking.

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