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Heat E-Teaching Material Assisted by Augmented Reality and CTL Model to Promote Students' 4C Skills

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ABSTRAK

Abad 21 menuntut siswa untuk beradaptasi dan memanfaatkan kecanggihan teknologi yang berkembang. Pembelajaran abad 21 yang diharapkan yaitu keterampilan 4C untuk menhadapi tantangan global. Keterampilan berpikir kritis dan berpikir kreatif siswa pada pembelajaran fisika masih rendah. Solusi dari permasalahan tersebut yaitu siswa membutuhkan media ajar yang lebih interaktif agar dapat meningkatkan minat belajar, bahan ajar digital dengan Augmented Reality terintegrasi model CTL menjadi solusi permasalahan tersebut. Tujuan penelitian ini untuk menentukan analisis kebutuhan, validitas dan praktikalitas penggunaan bahan ajar digital dengan AR terintegrasi model CTL untuk meningkatkan keterampilan berpikir kritis dan kreatif siswa. Jenis penelitian ini adalah Research and Development dengan model pengembangan Hannafin and Peck. Instrumen pengumpulan data meliputi instrumen analisis kebutuhan, lembar angket validasi dan lembar angket praktikalitas. Teknik analisis data yang digunakan adalah statistik deskriptif, kualitatif, dan kuantitatif. Berdasarkan data yang dianalisis terdapat tiga hasil penelitian. Pertama, hasil penelitian analisis kebutuhan yang menyatakan masih rendahnya berpikir kritis dan kreatif siswa. Kedua, hasil validasi produk dengan kategori valid. Ketiga, hasil praktikalitas produk dengan kategori sangat praktis. Disimpulkan bahwa bahan ajar elektronik kalor berbantuan Augmented Reality dan model CTL dapat digunakan dalam pembelajaran. Implikasi penelitian, dengan bahan ajar elektronik berbantuan AR model CTL, guru diharapkan mampu memotivasi, membimbing dan mengarahkan siswa dalam membangun keterampilan 4C.

ABSTRACT

The 21st century requires students to adapt and utilize the growing sophistication of technology. The expected 21st century learning is 4C skills to face global challenges. Students' critical thinking and creative thinking skills in physics learning are still low. The solution to the problem is that students need more interactive teaching media in order to increase interest in learning, digital teaching materials with Augmented Reality integrated CTL models are the solution to the problem. The purpose of this study was to determine the needs analysis, validity and practicality of using digital teaching materials with AR integrated with CTL models to improve students' critical and creative thinking skills. This type of research is Research and Development with the Hannafin and Peck development model. Data collection instruments include needs analysis instruments, validation questionnaire sheets and practicality questionnaire sheets. The data analysis techniques used are descriptive, qualitative, and quantitative statistics. Based on the data analyzed, there are three research results. First, the results of needs analysis research which stated that students' critical and creative thinking was still low. Second, the results of product validation with the valid category. Third, the results of product practicality with a very practical category. It is concluded that electronic teaching materials for heat assisted by Augmented Reality and CTL models can be used in learning. Research implications, with electronic teaching materials assisted by AR CTL model, teachers are expected to be able to motivate, guide and direct students in building 4C skills.

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1. INTRODUCTION

Learning in the 21st century is experiencing fundamental changes by applying technology to the learning process. The learning process must be able to develop students' 21st century skills. The expected 21st century skills are learning to think critically, creatively, collaborate and communicate (Marlina & Jayanti, 2019; Sugiyarti & Arif, 2018). Critical thinking skills are a thinking process carefully and not just accepting other people's argument by involving reasoning, analysis, and being easy to fix problems (Ana et al., 2022; Sugiyarti & Arif, 2018). Meanwhile, the skills of creative thinking are an ability that is useful for creating something new (Marlina & Jayanti, 2019; Sugiyarti & Arif, 2018). Critical thinking and the skills of creative thinking are an important part of learning that needs to be given to students in the curriculum (Marlina & Jayanti, 2019). The learning in 21st century and independent curriculum has emphasized student-centered learning. The principle of learning in 21st century is student-centered learning or learning that requires students to be active collaboratively and connect it to the real context (Asrizal et al., 2018; Xhomara, 2022). Learning in 21st century requires students to have critical thinking and skills of creative thinking. Critical thinking skills need to be improved so that students can think and analyze in solving a problem (Ana et al., 2022; Sugiyarti & Arif, 2018). Then skills of creative thinking also need to be improved so that students can be more creative in generating an idea and can be applied in real life (Harjono et al., 2022; Sugiyarti & Arif, 2018). Critical thinking and skills of creative thinking can be can be improved through the Information and Communication Technology (ICT) utilization in learning.

Utilization of ICT is very important in learning in 21st century and independent curricula. The usage of ICT in the twenty-first century and the autonomous curriculum necessitates instructors' ability to employ technology in learning as well as new student-centered learning practices (Khahro & Javed, 2022; Supiyati et al., 2023). Learning by utilizing ICT can also make students more active thereby encouraging interaction between students and teachers during learning (Almazroa & Alotaibi, 2023; Kennedy, 2023). Therefore, the use of ICT in learning can help improve the effectiveness, efficiency and quality of learning (Asrizal et al., 2023; Saxena, 2017). The use of ICT also provides benefits for teachers in developing teaching materials, many schools have provided teaching materials to support teaching activities and to overcome problems or obstacles that exist in learning activities (Goh & Sigala, 2020; Nurkhodri & Dafit, 2022). Teaching material using ICT should be applied in physics learning. ICT teaching materials need to be applied in physics learning to create active, interactive, and learning was meaningful. ICT teaching material have several advantages, namely: providing convenience in learning, encouraging student interest and activeness when learning and facilitating the assessment of learning progress (Asrizal et al., 2022; Kingsley & Ugwu, 2019). Therefore, ICT teaching materials in learning can facilitate students in improving their thinking skills (Asrizal et al., 2022; Iwan & Suyatna, 2018).

However, the reality on the ground has not met expectations. This is known from the results of initial research conducted at SMAN 15 Padang. Problems that occur in the field show that students' critical thinking and creative thinking skills are still low, as can be seen from the tests given in the form of essays. Critical thinking skills with an average score of 50 and students' creative thinking skills with an average score of 51. This is in line with several studies that show students' critical thinking and creative thinking skills are still low. The first research stated that students' critical thinking skills were in the low category. Students experience difficulties because there is no supporting practicum so that students can understand physics concepts and students' lack of understanding of physics concepts that exist in everyday life (Bugg, 2020; Yusuf, 2022). The second study explained that students' creative thinking abilities were in the low category. Students' creative thinking abilities are still low because when asked, students experience problems, namely not having the ability to develop their thinking patterns so that when answering various questions given by the teacher, they only do what the teacher exemplifies (Inaya & Setiyawati, n.d.; Meitiyani et al., 2022; Warsah et al., 2021). The third research explains that in the learning process, the teaching materials used have not been able to improve students' 4C skills (Nurhalimah et al., 2024; Nurhayati et al., 2024).

The development of electronic teaching materials can overcome these problems. There are three researchers who have offered solutions for developing electronic materials for teaching. First, research entitled Other researchers also researched CTL-based physics e-modules using the Kvisoft flipbook maker application to increase high school students' scientific literacy (Ramdani et al., 2021; Velychko et al., 2021). Second, research entitled developing flip book-based electronic materials for teaching to improve student learning outcomes Third, research entitled CTL-Based Physics E-Module using the Kvisoft Flipbook Maker application to increase the scientific literacy of SMA/MA students (Ramdani et al., 2021; Velychko et al., 2021). These three studies developed e-module products and electronic materials for learning, applied to SMA/MA students, measuring student learning outcomes and students' scientific literacy levels. This previous research is a fundamental source for conducting this research, because the three studies discuss

electronic teaching materials and the CTL model. Researchers will develop AR-CTL ectonics teaching materials with updates that have not been available to previous researchers.

The development of teaching materials carried out by several previous researchers had several limitations. The use of digital materials for teaching by adding Augmented Reality (AR) technology equipped with the Contextual Teaching and Learning (CTL) Model is a solution to this problem. AR technology will make physics learning more real and the CTL model will connect physics learning with students' daily lives. This research has three differences from previous research. The first difference is that electronic teaching materials are developed with the help of Augmented Reality (AR). The second difference is that the electronic teaching materials developed also integrate CTL which connects learning with the real world. The third difference is that this research is aimed at stage F students. This research is new from previous research. The first novelty lies in the teaching materials developed in the form of electronic teaching materials which are accessed on cellphones in the form of applications. These two electronic teaching materials are made interactive by adding video, audio, 3D images and physical simulations which can make it easier for students to understand the material provided, making it easier for students to understand the material offered.

There are three theories related to the development of electronic teaching materials. First, a theoretical review of solutions related to electronic teaching materials. Electronic teaching material are a change from printed teaching material using technology that helps students gain actual, contextual, interactive and flexible learning experiences with science and technology development. The presence of digital teaching materials cannot be separated from advances in information technology through the features contained in applications for making electronic teaching materials that present interactive learning so that students' enthusiasm increases to learn them (Alenezi, 2020; Divayana et al., 2019). Teaching material are packaged in digital form to make access easier for students them because they use software and get them without spending money (Anderson & Rivera-Vargas, 2020; Khasani et al., 2019). Digital teaching material consist of various series of learning activities to achieve objectives of learning. The use of digital teaching material in learning is to assist teachers in encouraging students' knowledge and abilities (Asrizal et al., 2023; Nurhasnah et al., 2020). Electronic teaching material is arranged systematically, meaning that the teaching material are in similar with the goals, needs and learning characteristics that have been previously determined so that they can train student independence (Asrizal et al., 2018; Elvisa & Rifai, 2021).

The second theoretical overview of the solution concerns Augmented Reality. One of the uses of technology in the educational sector is the application of Augmented Reality technology in the educational sector. Augmentend Reality is a collaboration of 2D and 3D virtual objects in a technology and is projected into a real environment in real time (Hamzah et al., 2021; Tools et al., 2023). AR is also a technology capable of incorporating two-dimensional or three-dimensional virtual objects into real, projectable environment. The use of AR can help students understand concepts, stimulate students to discover concepts and interpret material with a three-dimensional view, create interactive media and an interesting and fun learning environment (Du et al., 2020; Hakim, 2018).

The third theoretical research on the solution is related to the CTL model. The learning model is an important component that supports the success of the learning process (Al-Adwan et al., 2021; Asfar et al., 2023). CTL is a process of learning that relates everyday life to the material being studied by students so that it helps students to understand a material (Khalim, 2023; Samsudin et al., 2023). The main goal of CTL is to help students in the right way to attach meaning to student learning at school. When students find meaning in learning, students will remember what they have learned (Agusti et al., 2023; Hyun et al., 2020). CTL constructivism, discovery, inquiry, learning community, modeling, reflection, and genuine evaluation are the seven components (Ghonivita et al., 2021; Hulaimi, 2019). Several reasons CTL can be successful in learning because according to students' daily lives, the CTL approach is able to associate new information with existing knowledge, according to the way nature works, so that the application of CTL is expected to make learning more effective and efficient (Afni & Hartono, 2020; Risan et al., 2021).

Based on the statement above, it is necessary to develop digital materials for teaching with AR integrated with the CTL model to improve students' critical and creative thinking skills. The use of AR-assisted electronic teaching materials and CTL models will improve students' critical and creative thinking skills due to linking learning with the real world. In addition, these AR-assisted electronic teaching materials will improve students' knowledge, attitudes and skills because they are in accordance with 21st century learning. This research is needed to develop interesting and interactive teaching materials in the learning process. The interactive process is very necessary because it can clarify a material being taught through interesting video, audio and 3D image displays. This study has several objectives, namely determining the results of the needs analysis, determining the results of the validity test, and determining the results of the practicality test of the use of integrated heat electronic teaching materials with the AR-assisted CTL model.

2. METHOD

Research was done by researchers is research and development. Development research is a research type that is used in the manufacture of a product and is then tested for the validity and practicality of the product being developed. The aim of research and development in education is not only to test theory, but also to enable students to use the products developed more effectively in schools, thereby broadening their knowledge (Kwangmuang et al., 2021; Sugiyono, 2019). The Hannafin & Pack design model according consists of three steps which can be seen in Figure 1.

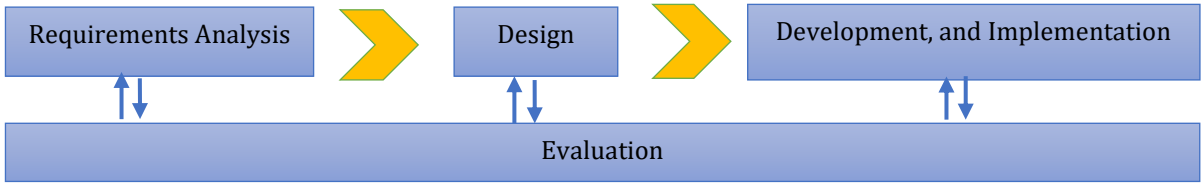

Figure 1. Hannafin & Pack Design Model Steps

There are two research subjects in this study. First, the validation test subjects were 3 lecturers from the Physics Department, FMIPA UNP. The two practicality test subjects were one class of phase F students, namely 30 students from Padang 15 State High School.

Researchers used data collection instruments in the form of questionnaires. The first is a questionnaire about the obstacles physics teachers have in utilizing ICT in teaching materials. This questionnaire was given to 2 physics teachers, consisting of indicators: obstacles to mastering software, making electronic teaching materials with software, and obstacles to using teaching materials in learning. Second, performance assessment questions were given to thirty students to measure students' critical and creative thinking abilities. Third, document analysis in the form of physics teacher teaching modules to analyze learning objectives and settings. This analysis is guided by the audience, knowledge abilities, attitude abilities, skill abilities, conditions and degrees. Fourth, document student learning outcomes to analyze student knowledge seen from the semester assessment results. Observations of learning settings are guided by Minister of Education and Culture Regulation Number 22 of 2016. Fifth, validation questionnaire sheets and practicality questionnaires for electronic teaching materials. Analysis of data collection methods in the first stage of research is needs and context analysis. Researchers used data collection instruments in the form of questionnaires. The first is a questionnaire about the obstacles physics teachers have in utilizing ICT in teaching materials. This questionnaire consists of indicators: barriers to mastering software, barriers to creating digital teaching materials with software, and barriers to using digital teaching materials in learning. Second, this student characteristics questionnaire was distributed to 30 students at stage F. This student characteristics questionnaire consisted of four components, namely background, learning interest, learning motivation, and student learning style. third, performance assessment questions are given to students to measure students' critical and creative thinking abilities. Fourth, document analysis in the form of documenting student learning outcomes to analyze student knowledge. Fifth, document analysis in the form of physics teacher teaching modules to analyze learning objectives and settings. sixth, validation questionnaire sheet and practicality questionnaire for digital teaching materials.

The second stage of research is the design of integrated CTL heat electronic materials of teaching assisted by AR. Activities that have been carried out research software that will be used in electronic teaching material. Activities that have been carried out include designing electronic teaching material. Electronic teaching material use unity software, blender software, and PhET simulation software. The material chosen in this electronic teaching material is the research of the influence of heat and heat transfer in everyday life, which includes a material's thermal properties, heat capacity, and conductivity. In making electronic teaching material, the learning model is integrated, namely the CTL model. The structure of electronic teaching material made consists of covers, instructions for using materials of teaching, objectives of learning, objectives of learning, materials of teaching, worksheets, videos, sample questions, evaluation questions, AR cameras and references.

The third phase is development and implementation. This activity is carried out after the electronic teaching materials have been designed. At this development and implementation stage, product validity and practicality tests are carried out. The product validity test aims to find out whether the digital teaching materials being developed are valid or not. The instrument used consists of several components, namely

material substance, learning design, appearance, use of software, and CTL integration. Validation of product validity instruments is carried out on a limited basis, namely by supervisors. Next, a validity test was carried out on three validators, namely physics lecturers at Padang State University. Furthermore, the electronic teaching materials were refined according to the validator's suggestions and input. A practicality test was carried out which aims to determine the level of practicality of the product. The practicality test questionnaire according to students is prepared according to the components that have been determined in the use of electronic teaching materials. These components include: usability, ease of use, attractiveness, clarity, AR-assisted CTL integration, and software use.

Data analysis techniques used in research are descriptive statistics to analyze needs, validity test analysis, and practicality test analysis in the form of tables or graphs. Teacher problems analysis connected to the use of ICT in physics materials of teaching, students' skills analysis and knowledge is presented in tabular form. Student characteristics analysis, objectives of learning, learning settings, validity tests and practicality tests are presented in graphical form. The assessment of this research used a Likert scale with a score of 1-4 with the following conditions: 4 Strongly Agree, 3 Agree, 2 Disagree, and 1 Strongly Disagree. 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. The practicality test results were analyzed descriptively quantitatively, categories 80 to 100 were very good, 66 to 79 good, 56 to 65 sufficient, 40 to 55 not good, and 30 to 39 failed.

3. RESULT AND DISCUSSION

Result

Based on the data that has been analyzed, there are three research results according to the stages of the Hannafin & Pack design model, namely the needs analysis results, validity, and practicality. The first needs analysis is an problems using ICT analysis. The instrument used was a questionnaire given to 2 physics teachers. Some of the teacher's problems in using ICT in materials of teaching shown in Table 1.

Table 1. Results of the Teacher Problems Analysis Connected to the use of ICT in Teaching Material

Information	Mak
Dificulty in making electronic teaching material	83
Dificulty in software understanding	72
Dificulty in making electronic teaching material with software	68
Dificulty in using electronic teaching material in learning	83

Based on Table 1, it can be described that teachers experience obstacles to the use of ICT in teaching materials. Based on the data from the analysis of teachers' obstacles to the use of ICT in teaching materials, they are in the range of scores from 68 to 83. The results show that the analysis shows that teachers are very constrained in making electronic teaching materials and constrained in using teaching materials in learning, namely with a score of 83 in the high category. Obstacles in creating digital open materials include difficulties in creating learning objectives, creating learning indicators, and relating the material to real world contexts. On the other hand, obstacles in using electronic teaching materials in learning include difficulties when managing students, difficulties when teaching, and difficulties in presenting digital teaching materials in learning. Obstacles in mastering software and obstacles in creating digital open materials with software are with scores of 72 and 68 in the sufficient category. Obstacles in mastering software and creating digital open materials with software include difficulty using Unity software, Blender software and Phet simulation. From the data obtained, it can be concluded that teachers feel constrained and have difficulty using ICT in teaching materials.

The second needs analysis is an analysis of students' critical thinking abilities, students' creative thinking abilities, and students' knowledge. Students' critical thinking and creative thinking abilities are obtained from the work assessment sheet, while students' knowledge scores are seen from the mid-semester assessment. This analysis aims to determine the value of students' critical thinking abilities, creative thinking abilities and knowledge. Analysis of critical thinking abilities (KBS) and creative thinking abilities (KBF) as well as student knowledge can be seen in Table 2.

Table 2. Statistical Parameter Values for Data on Students' Critical Thinking Skills and Skills of Creative Thinking and Knowledge

Statistical parameters	KBS	KBF	Knowledge
Average	50	51	55
Mode	48	45	60

Statistical parameters	KBS	KBF	Knowledge
Median	52	50	55
Lowest value	28	40	25
The highest score	72	70	70
Range	44	30	45

Based on Table 2, it can be explained that the lowest scores for assessing students' skills, creative thinking and knowledge separately are 28, 40 and 25 respectively. While the highest scores are 72, 70 and 70 respectively. The average critical thinking ability scores students' ability is 50, students' creative thinking ability is 51, and students' knowledge is 55. This shows that the average value of students' critical thinking abilities, creative thinking and knowledge is in the low category. The range of scores from the assessment of students' critical thinking abilities, creative thinking and knowledge is 44, 30 and 45 respectively. The scores that often appear in the assessment of students' critical thinking abilities, creative thinking and knowledge are 48, 45 and respectively. 60. The median scores from research on students' critical thinking abilities, creative thinking and knowledge are 52, 50 and 55. Based on these three assessments, it can be seen that students' critical thinking abilities, creative thinking abilities and knowledge have not reached the expected outcome criteria so there is a need for renewal in learning so that the results are more optimal and in line with expectations.

The third needs analysis is a student characteristics analysis. The instrument used was student characteristic questionnaire sheet. Student characteristics analysis has 4 components, namely: background (BG), interest in learning (IL), learning motivation (LM), and learning style (LS). Based on a questionnaire to students of class XI stage F at SMAN 15 Padang, the student characteristic analysis values results are in the range of 65 to 70. The student background indicators are in the medium category with a value of 65. Meanwhile the indicators of interest in learning, learning motivation, and student learning styles are in the good category, namely with consecutive values of 67, 68 and 70. This can be interpreted that the student's internal factors that do not support the physics process of learning lie in the student's background.

The objectives of learning analysis is the fourth needs analysis. The physics instructor teaching modules analysis yielded the objectives of learning results analysis for three physics resources. The instrument chosen is determined by the compatibility of the ABCD structure with the objectives of learning established by the teacher. The indicators of objectives of learning that are assessed consist of audience (AC), knowledge ability (KA), attitude ability (AA), skill ability (SA), condition (CD) and degree (DR). Based on the analysis of learning objectives, it was found that the scores were in the range of 50 to 83. The results for the audience component and knowledge ability were in the very good category with a score of 83, this is because the learning objectives were mostly aimed at students and focused on students' knowledge with appropriate operational verbs. . The results for attitude and degree abilities are in the good category with a score of 75, this is because there are some learning objectives that do not include student attitudes during the learning process and do not include several criteria for learning success for each indicator. The results for skills and condition abilities are in the sufficient category with scores of 50 and 63, this is because learning has used an innovative learning model but has not been in accordance with the learning steps.

The fifth needs analysis is a learning settings analysis which is guided by Permendikbud Number 22 of 2016 concerning the process of learning activities that take place in class. The learning setting analysis is seen from the implementation of the teaching modules that have been made by the teacher. The learning activities carried out include preliminary activities (INA), core activities (COA), and closing activities (PKB). Based on the results of the analysis of physics teachers' learning settings which include preliminary activities, core activities and closing activities. The preliminary activity is in the very good category with a score of 83, however there is a weakness in this activity, namely the lack of motivation to learn in students. The core learning activities are in the good category with a score of 70, but here there are shortcomings, namely the learning model used does not match the steps and some skills in the material do not yet exist. The closing activity was in the good category with a score of 75, in this activity there were shortcomings, namely that several learning activity plans for the next meeting were not informed. The average analysis of learning settings is in the good category with a score of 76. This shows that the learning settings are in accordance with the implementation of ideal learning. However, there needs to be several improvements and improvements to the core activities and closing activities so that the implementation of learning is more optimal and in line with expectations.

The further research results are product descriptions. The product developed is a CTL integrated AR assisted hot digital teaching material. Digital teaching material is designed based on the structure of written teaching material. The following is the cover for digital teaching material which shown in Figure 1.

Figure 1 (a) Cover Display of Electronic Teaching Material (b) Electronic Materials of Teaching Menu Display

At the beginning of this teaching material there is a cover containing the title, class, and author. The title section describes the AR-CTL electronic teaching material that will be studied in class XI even semester students. On the cover of this electronic teaching material there is a play button to select the material to be studied and a button to exit the menu. At the bottom of the cover is the name of the maker of the AR-CTL electronic materials of teaching. Then the menu on this electronic teaching material contains material which includes the identity of digital materials of teaching for learning purposes, the flow of objectives of learning, a description of the material which contains material using the CTL model, examples of questions and summaries. Furthermore, the menu on this digital teaching material contains videos regarding learning materials, student worksheets containing practicum through phet and direct, as well as exercises and an AR camera that will display AR images.

Digital teaching material are validated by three experts to determine the validity of electronic teaching material. The validation results were obtained from the validator's assessment of the CTL integrated AR-assisted electronic heat teaching material product using a validation instrument sheet. The validation instrument used consisted of assessment components, namely material substance (MS), design of learning (LD), display (AP), software utilization (SU) and CTL integration (CI). Based on the data analysis in the figure, we known that the validation value of all components is in the valid category, namely from 0.80 to 0.93. The average value of the analysis results of the five components of validation of digital materials of teaching according to experts is 0.84 which is included in the valid category. The substance of material component have four indicators, includes: 1) correctness, 2) depth, 3) contemporary, 4) readability. The validation results for the substance of the material varied from 0.75 to 0.92. The score given from the validator for all materials substance component can be classification as valid. The design of learning component consists of six indicators, namely 1) title, 2) objectives of learning, 3) materials, 4) sample questions, 5) exercises, 6) references. Validation results for design of learning vary from 0.67 to 1.00. The value given from the validator for each design of learning component is categorized as valid.

The display component consists of six indicators. The six indicators are 1) navigation, 2) typography, 3) media, 4) color, 5) animation, 6) simulation. Validation results for views vary from 0.67 to 0.92. The value given by the validator for each display component is categorized as valid. Thus the display of digital heat materials of teaching makes it easier for students to run them with clear navigation displays, clear display of images according to the material, as well as AR videos and animations that can motivate student learning. The software utilization component consists of software indicators and authenticity. Validation Results The use of software is assessed to vary between 0.83 to 1.00. Overall the use of software in electronic materials of teaching is in the valid category. Thus, the use of software in digital materials of teaching can be used to add AR images, videos and animations. The components of CTL integration with the help of AR consist of constructivism, inquiry, asking, learning communities, modeling, and reflection. The CTL integration assessment results were between 0.83 and 0.92. Overall, the integrated AR CTL-assisted digital heat materials of teaching already contain CTL indicators with valid categories.

AR-CTL-assisted electronic heat teaching material is produced in such a way as to be of high quality, so the validator provides various suggestions for product improvement. Advice given by several validators is in the form of input given by the validator on the quality of the product being developed. There are some key suggestions from the validator. First, writing on digital teaching material is enlarged and correcting writing that is still wrong. Second, the specific heat table must be made not in the form of pictures. Third, adapt the evaluation questions to the objectives of learning. Fourth, the images contained in electronic materials of teaching include references. The suggestions given by the validator are used as a first step in improving electronic teaching material.

Improvements to electronic teaching material were carried out according to the validator's suggestion. Improve writing on electronic teaching material by increasing the size of the writing and correcting the wrong words. Improvements to image form creation heat tables to table that have already been created or typed. Refinement of objectives of learning questions adapted to the operational verbs used. Adding a reference at the bottom of the digital teaching material image. Improvement of electronic materials of teaching is intended so that electronic teaching material can be declared valid in their use.

Products that are already valid are then carried out practicality tests on students to get the practicality of the products that have been developed. The practicality instrument used consists of components useful (SF), easy to use (EU), interestingness (AR), clarity (CR), AR assisted CTL integration (CI), software use (US). Based on the data analysis the practicality component is in the category was very good with a score range of 89 to 94. The average practicality test results from electronic materials of teaching are in the category was very good with a score of 91. The scores given by students to the practicality test sheet instrument state that electronic materials of teaching integrated AR-assisted hot CTL practically used in physics learning. Useful component indicators consist of 1) can be used to achieve objectives of learning, 2) improve the quality of learning, 3) foster interest and motivation to learn, 4) can give users freedom, 5) can make learning activities more interesting, interactive and reduce the amount of research time, 6) to train critical and skills of creative thinking with a variety of trying activities. The useful component analysis results are in the category was very good, with a range of 85 to 92. The easy-to-use component indicators consist of 1) simple display, 2) easy-to-understand button functions, 3) make it easier for students to remember physics material, 4) can improve students' ICT abilities, 5) can more easily master physics, 6) can control learning activities. The component analysis results that are easy to use are in the category was very good, namely from the range of values 89 to 93.

The indicators of the attractiveness component consist of 1) attractive design, 2) provision of interesting color and letter combinations, 3) attractive slide space, 4) Images, videos and animations become the main attraction of learning, 5) Experimental activities can attract students' interest to be active, 6) scores on exercise activities can attract students to answer correctly. The attractiveness component results analysis are in the category was very good with a value range of 90 to 95. The indicators for the clarity component consist of 1) the language used is clear and informative, 2) the instructions for use are clear, 3) the design is simple and clear, 4) the material presented is in similar with scientific principles of physics, 5) examples of questions and clear discussion, 6) evaluation clear and in similar with the indicators. The clarity component analysis results were in the category was very good, with a range of 88 to 93. The indicators of the AR-assisted CTL integration component consist of 1) constructivism activities that can develop thinking power, 2) inquiry to improve critical thinking skills, 3) develop curiosity, 4) community learning activities by carrying out simple experiments with groups or discussing problems, 5) presents the model as a real example of learning, 6) reflects. The AR-assisted CTL integration component analysis results are in the category was very good, with a range of 89 to 91. The component indicators of software use consist of 1) application-based unity software and slide display space, 2) blender software for designing 3D images, animations, and running videos 3) simulation PhET software. The analysis results of the use of the software are in the category was very good, with a value range of 89 to 97.

Based on the research results it is known that the electronic teaching material developed are stated to be valid and practical to improve students' critical and skills of creative thinking. Which states that electronic-based materials of teaching can be used as an alternative choice of providing a stimulus to improve critical thinking skills. The electronic teaching material developed are integrated with the CTL model and stimulate students to have students' critical and skills of creative thinking. Through the CTL component in electronic teaching material, students can discover physics concepts for themselves and relate them to the real world. Presentation of material that contains videos, images and AR animations can attract students' interest in understanding the material. electronic teaching material are made interactive in the evaluation section which displays scores in order to attract students' interest in answering correctly. The inquiry process and learning community train students to think critically and creatively. electronic teaching material are provided in an application so that teachers and students can access them via smartphones. Namely the development of digital materials of teaching based on discovery learning with AR to improve critical thinking skills in science material.

Discussion

The results of the first needs analysis showed that there were problems with learning. These problems include Physics learning materials in schools not utilizing technology, and Physics learning materials not being integrated with models. This results in the learning objectives of 21st century education not being achieved properly. Several problems show the need for new solutions and innovations to support learning. In line with research results which prove that we are entering a new era, the learning process in

schools requires new innovations to support the learning process. One of them is the development of electronic materials (Cahyati et al., 2022; Gómez-Galán, 2020). By using electronic materials in teaching, students and teachers can save time in carrying out learning, save costs, reduce paper use, and master technology according to the demands of 21st century education (Matthew et al., 2018; Rodrigues et al., 2021).

The results of the second needs analysis show that students' critical and creative thinking abilities are still low as seen from the students' essay tests. This is because teachers still dominate the learning process so that students lack thinking activities and interaction between fellow students (Coman et al., 2020; Heilporn et al., 2021). The results of the third needs analysis relate to student characteristics. Student characteristics can influence student learning outcomes later. By knowing the characteristics of students, teachers can choose the right learning resources, the right way of learning, and organize the class so that learning is more effective (Rasmitadila et al., 2021; Sumardi et al., 2020). The results of this analysis are one of the reasons why it is important to develop electronic teaching materials for teaching with Augmented Reality that are integrated with the CTL model.

The results of the fourth analysis show that the learning activities designed by the teacher are not in accordance with the applicable curriculum guidelines. The learning activities described consist of opening activities, core activities and closing activities. In core activities the teacher has implemented a learning model but has not been able to make students active in learning. This is because teachers still forget several steps in the model applied, resulting in learning becoming monotonous and boring. At the closing event there was no explanation regarding the activities for utilizing the material that had been studied. Learning activities need to be designed well so that educational goals can be achieved. Directly involving student activities can provide learning experiences for students (Almulla, 2020; Reeve & Shin, 2020). One solution that can provide students' learning experience is by providing learning resources such as this research, namely by developing products, in the form of AR-assisted electronic teaching materials and CTL models in the form of applications that can be accessed via smartphone.

The results of further research show that the validation of hot electronic teaching materials assisted by AR and CTL models to improve students' critical and creative thinking skills is declared valid and practical. These results are in line with previous research which states that teaching materials are said to be valid if they meet the criteria for good quality teaching materials based on the results of a validator questionnaire which shows that the teaching materials developed have good material validity, media and linguistic aspects and can be used (Istyadji et al., 2022; Zendrato et al., 2022). The designed electronic teaching materials are made as interesting and interactive as possible by adding video, animation, AR camera technology, experiments using phEt simulations, and CTL models that are appropriate to the 21st century and the applicable curriculum. The teaching materials developed have the advantage of being able to visualize learning material through videos, realizing abstractions of physics concepts in the form of images, and can be used for independent research.

Furthermore, the practicality of digital teaching materials is shown from the assessments carried out by Phase F high school students after using these digital teaching materials in learning. The practicality test results for digital teaching material are in the very practical category with a score of 91 in the category was very good. This shows that digital teaching material are useful, easy to use, attractive, clear, and cost-effective. The practicality of digital teaching material results are supported by research results which state that the developed teaching material have benefits for students as users, provide ease of use, and make learning time effective (Nida et al., 2021; Sayaf et al., 2021). This research focuses on developing electronic teaching materials, namely hot materials assisted by Augmented Reality and CTL models for students' critical and creative thinking, these are the findings of this research. Hot material is very suitable for studying with AR because it can display material in 3D so it looks more real. Digital teaching material encourage students to explore, expand and explain learning material to develop their critical thinking and skills of creative thinking. The implication of the research results is that teachers must provide learning motivation, guide, and direct students in building student skills through AR-assisted digital teaching material that are integrated with the CTL. The development of electronic teaching materials is limited to teaching materials developed using ICT in learning, limited to high school F phase heat materials, and this research is limited to the use of Unity and Blender software in designing digital teaching materials. The solution to these limitations is that future researchers are expected to be able to create electronic teaching materials for all high school F stage material in the Mardeka curriculum and use more software to design teaching materials.

4. CONCLUSION

Based on the research and discussion results, three conclusions can be put forward. First, the needs analysis obtained results as a guideline for the development of teaching material show that skills of critical

thinking by students, creative thinking, and materials in schools have not been integrated into the CTL model. Second, the validity of electronic heat teaching materials assisted by AR integrated with the CTL model is in the valid category. Third, the practical value of using electronic heat teaching materials assisted by AR integrated with the CTL model is in the very practical category. Thus, AR-assisted electronic heat teaching materials integrated with CTL to improve students' critical and creative thinking skills are valid and very practical to use in the learning process.

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