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Development of Research-Based Teaching Materials to Improve Critical Thinking Skills in the Use of Extremely Low Frequency Electromagnetic Waves to Increase Food Security

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ABSTRACT
Critical thinking skills are needed in the 21st century, so efforts are being made to improve them, one of which is by developing research-based teaching materials, and research into the use of Extremely Low Frequency Electromagnetic waves to increase food security is currently being carried out very intensively. This research aims to describe the development of research-based teaching materials to improve critical thinking skills in the use of Extremely Low Frequency Electromagnetic waves to increase food security. This development research uses the Borg and Gall method, which consists of 10 steps. The subjects of this research were 90 students at the University of Jember. Undergraduate Physics Education students in classes A, B, and C in environmental physics courses and on material on the use of Extremely Low Frequency electromagnetic waves to increase food security. This research uses quantitative analysis. The results of this research state that research-based teaching materials are effective in improving students' critical thinking skills in the material on the use of Extremely Low Frequency Electromagnetic waves to increase food security with a score of 82.33 based on critical thinking indicators.

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1. INTRODUCTION

The 21st century is the era of globalization, in this era, the development of science, technology, and information is taking place very quickly and there is also competition between nations in this world, to anticipate and even win this competition Indonesia must prepare itself by growing and developing the next generation. have many skills to support this, one of the skills needed is critical thinking skills (Suardana, *et al*., 2018). The 21st century is a century in which there are massive changes in society, from an aggressive society to an industrial society, and one must be knowledgeable (Afandi, *et al.*, 2016). In this century, society is required to have breakthroughs in thinking, drafting concepts, and further actions so society needs skills that support these demands, one of the skills needed is critical thinking skills (Cahyono, 2017). Critical thinking skills are a tool that can be used to survive in this century (Chukwuywnum, 2013). However, the critical thinking skills of students in Indonesia are still relatively low and need to be improved (Purnamasari, *et al.*, 2017).

Critical thinking is a skill that creates, applies, and uses concepts logically in solving problems (Atabaki, *et al.*, 2015). Critical thinking skills are included in high-level thinking skills because high-level thinking skills are abilities consisting of critical and creative thinking, analysis, problem-solving, and visualization (Ramos, J. L, *el al.*, 2013). There are three reasons for the need for critical thinking skills for students, namely the demands of the times require individuals to be able to search, select, and use information in their lives, each individual is required to be able to think critically in looking at the various problems they face, critical thinking can help individuals compete healthily. and fair and able to create good cooperation with other individuals (Maulana, 2017). Critical thinking skills can be formed in every person through the world of education because education has an important role in forming attitudes, knowledge, and skills (Maskhur, *et al.*, 2019).

Critical thinking skills in Indonesia are still low and evidence needs to be improved regarding the low level of critical thinking skills such as research at high schools in Buleleng Regency, Bali which shows that the average score is 43 out of 100 (Suardana, *et al*., 2018), research on education students Tadulako University Physics: 90%

of subjects are classified as less critical (Maguna *et al.*, 2016), and the results of the analysis of critical thinking need that have been carried out by researchers still often get scores below 50 out of 100, (Suarniati, *et al.*, 2018). This can happen because of inappropriate learning strategies, such as teacher-centered learning (Teacher Center Learning) (Utomo *et al*., 2020). As a result of teacher-centered learning, students do not have opportunities and are not involved in the learning process so students cannot process learning analytically, synthetically, and argumentatively, which are part of critical thinking skills (Sahyar, et al., 2017).

Critical thinking skills can be developed through student-centered contextual learning (Student Center Learning) and constructive learning strategies (Qarareh, 2016). One alternative to improving critical thinking skills is by using research-based learning. Research-based learning requires students to be able to discover, explore (develop knowledge) to solve the problems they face and test the truth of this knowledge (Wardoyo, 2013). Currently, research related to the use of extremely low frequency electromagnetic waves to increase food security is being intensively carried out (Qumairoh, *et al*., 2021).

Electromagnetic waves are waves consisting of a magnetic field and an electric field that does not require an intermediary medium for their propagation, where the electric field is perpendicular to the magnetic field and the magnetic field is perpendicular to the propagation (Sudarti, 2016). A magnetic field will emerge from equipment related to electronics when there is an electric current circulating it. This is by Oersted's research in 1819, describing that a magnetic field can occur because there is a flow of electric current (Finn, 1994). The extremely low frequency magnetic field has a frequency ranging from 0 to 300 Hz (Qumairoh, 2021). Exposure to a magnetic field can damage proteins in pathogenic bacterial cells so that it can inhibit the growth and development of pathogenic bacteria (Kinestri, 2015). The use of Extremely Low-Frequency magnetic fields in the food sector shows positive impacts based on previous research.

An example of Extremely Low-Frequency research in the food sector is on gado-gado seasoning which shows that intensity of 646.7 $\boldsymbol{\mu}$T with an exposure time of 30 minutes is a dose that has been proven to be effective on the prevalence of Salmonella Typhimurium in gado-gado seasoning (Sudarti, 2016), in the intensity of 730.56 $\boldsymbol{\mu}$T for 60 minutes can inhibit the increase in pH in milkfish (Nurhasanah, *et al*., 2018), the intensity of 700 $\boldsymbol{\mu}$T and 900 $\boldsymbol{\mu}$T for 30 minutes and 60 minutes can affect the pH and density of chicken meat due to the formation of pathogenic bacteria the acid has been damaged (Lutfiana, *et al.*, 2018), then at an intensity of 300$\boldsymbol{\mu}$T for 90 minutes it can inhibit the increase in pH of vaname shrimp because the growth of pathogenic bacteria is inhibited (Qumairoh, *et al*., 2021).

Based on the following statements, it can be seen that there is a need to develop teaching materials based on research on the use of extremely low frequency electromagnetic waves for food security to improve students' critical thinking skills. The objectives of this research are 1) Describe the stages of developing research-based teaching materials on the use of extremely low frequency electromagnetic waves on food security, 2) Test the effectiveness of research-based teaching materials on the use of extremely low frequency electromagnetic waves on food security in improving thinking skills critical of students

2. RESEARCH METHOD

This research is development research carried out in the S1 building of the Physics Education Study Program, Faculty of Teacher Training and Education at the University of Jember. This research used test subjects, namely students in classes A, B, and C in environmental physics courses. The small group test was carried out on class A students, the large group test was carried out on class B students, and the distribution stage was carried out on class C students. Determining subjects used random sampling techniques. The research was carried out in the odd semester of September-October of the 2023/2024 Academic Year. The development research design refers to Borg and Gall's development research procedures consisting of research and informant collecting, planning, developing a preliminary form of product, preliminary field testing, main product revision, main field testing, operational product revision, operational field testing, final product revision, dissemination and implementation (Borg, W.R. & Gall, 1983).

In this research, data analysis was carried out using a quantitative approach. Analysis of critical thinking skills is calculated based on each indicator of critical thinking skills from Ennis. The measurement of critical thinking abilities is obtained from the analysis of students' pretest and posttest answers which have been adjusted to Ennis' critical thinking indicators, namely elementary clarification, basic support, interference, advanced clarification, strategies, and tactics (Ennis, 2013). The student's final score is calculated by adding up all the scores for each indicator, using the formula:

$$\boldsymbol{Cs = \frac{JS}{N} x10}$$

Information:
Cs : Asses student's critical thinking skills
JS : The number of scores obtained by the student
N : score sum

Table 1. Criteria for Student Critical Thinking Ability

Percentage (%)	Criteria
76 – 100	High
51 - 75,99	Enough
26 - 50,99	Low
0 - 25,99	Very low

(Source: Sugiyanto et al., 2018)

3. RESULT AND DISCUSSION

Based on the 10 stages of Borg and Gall development (research and informant collecting, planning, developing a preliminary form of product, preliminary field testing, main product revision, main field testing, operational product revision, operational field testing, final product revision, dissemination, and implementation) it was obtained the following results:

1. Research and informant collecting

This stage is carried out by conducting a needs survey of teachers using interview techniques that contain information about the level of students' critical thinking skills, efforts that have been made to improve critical thinking skills, obstacles faced by students in improving critical thinking skills, and a needs analysis test on students were given ten essay questions that had been adjusted to critical thinking indicators and then scoring was carried out, the result of which was that physics education students had critical thinking skills that were still relatively low and needed to be improved.

2. Planning

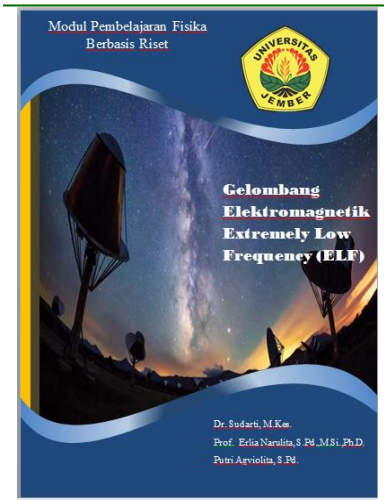
After analyzing needs and identifying problems with students' critical thinking skills, a learning plan is prepared to improve critical thinking skills, such as preparing research-based teaching materials that are appropriate to the material and are currently being intensively used, namely the use of extremely low frequency electromagnetic waves to increase food security and preparing a critical thinking test so that it can measure students' level of critical thinking before and after learning using the teaching materials

3. Develop a preliminary form of the product

The product development step taken is to prepare a draft of research-based teaching materials that can train and improve students' critical thinking skills through the material. The design of teaching materials is divided into three parts, namely: introduction, content, and conclusion. Research can be seen in Table 2.

Table 2. Research-based Teaching Materials

No	Component Based Teaching Materials	Design Research-Based Teaching Materials
1	Introduction	a. Cover b. Foreword c. List of contens d. Glossary e. Concept maps f. Introduction g. Core competencies and basic competencies h. Study guide
2	Content	a. Leraning objectives b. Learning material: understanding, characteristics and use of extremely low frequency electromagnetic waves for food security from research articles related to this material c. Supporting Material: practice reviewing articles on the use of extremely low frequency electromagnetic waves for food security and practice critical thinking questions
3	Closing	a. Bibliography



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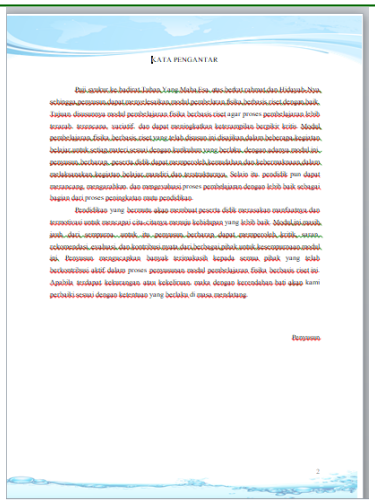

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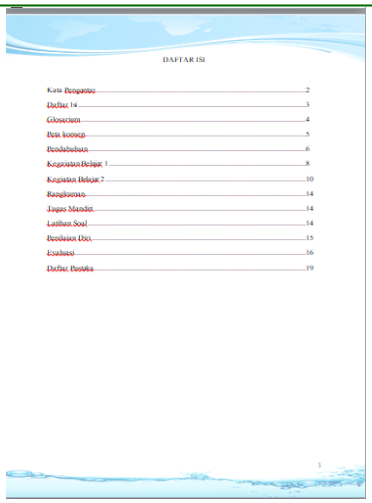

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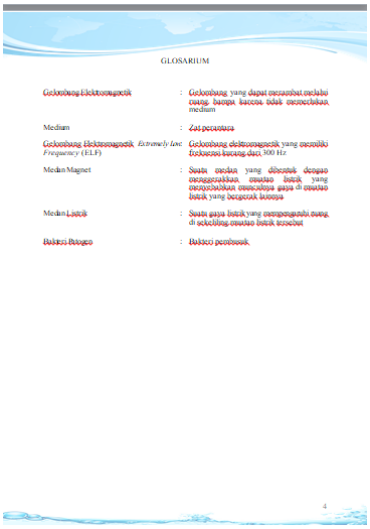
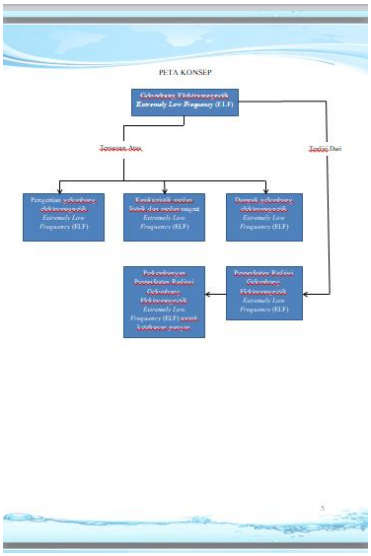
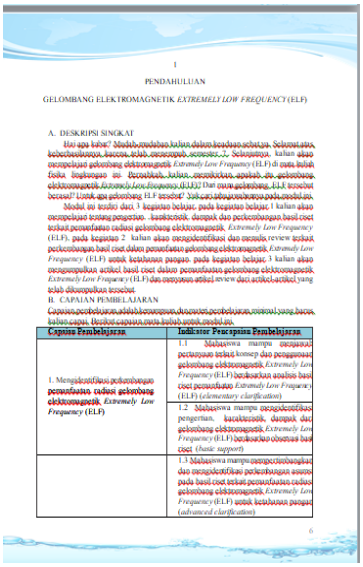


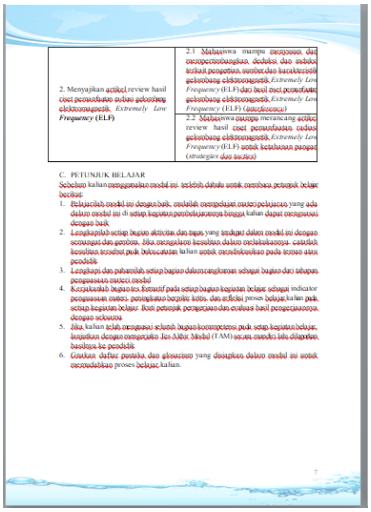
Glossary



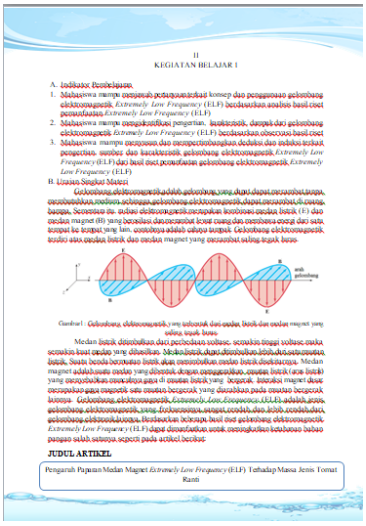
Concept Maps



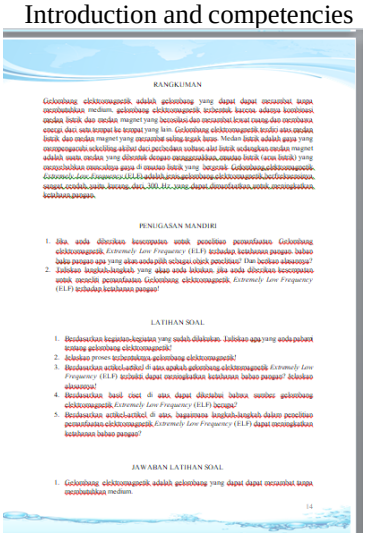
Introduction and competencies



Study Guide



Electromagnetic Wave Concepts and Articles



Practice reviewing articles and working on critical thinking questions

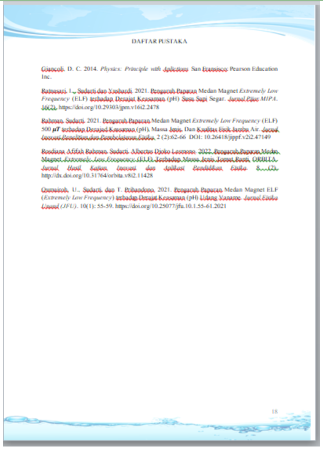


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Figure 1. Design of Research-Based Teaching Materials to Improve Critical Thinking Skills in the Use of extremely low frequency Electromagnetic Waves to Increase Food Security

The next activity is expert validation, validation is carried out by 3 experts, the validation process consists of validation of the teaching materials developed, validation of learning tools (syllabus, lesson plans, pretest-posttest questions on critical thinking skills, and LKPD)

4. Preliminary field testing
Conduct initial field trials involving the subjects of some students in class A of the environmental physics course at the unej physics education study program. Data collection and analysis can be done by observation and questionnaires. In the initial trial of the product, students were checked for interest in the teaching materials, suitability of the teaching materials for the material being taught, sharpening critical thinking skills, and making it easier for students through questionnaires, with the result that 83% of class A students stated that they were interested in the teaching materials. teaching materials are appropriate to the material, teaching materials can hone critical thinking skills, and teaching materials can make it easier for students to learn the material

5. Play product revision
Improvements to the initial product are produced based on the results of initial trials. Product revisions based on recommendations and suggestions by a team of experts

6. Main field testing
The trial stage of the revised teaching materials was for all class A students in the environmental physics course at the Bachelor of Physics Education, Jember University, then analyzed the learning steps by the allocation of time and learning tools through observations from 3 observers, with results of 80 % is appropriate but needs to be improved

7. Operational product revision
Improvements/refinements to wider teaching materials and learning tools, so that the product developed is an operational design that is ready to be tested again

8. Operational field testing
Operational test steps that have been produced for class C subjects in the environmental physics course in the physics education study program. effectiveness test through analysis of data obtained through pretest and posttest to increase students' critical thinking, which refers to critical thinking indicators from Ennis (2013). These indicators are presented in Table 2.

Table 2. Ennis Critical Thinking Indicators (Ennis, 2013)

Number	Indicators	Activity
1	*elementary clarification*	Focusing questions, analyzing arguments, asking and answering questions that require explanation or challenge
2	*basic support*	Consider the credibility of the source and make considered observations
3	*interference*	Formulate and consider deductions and induction, formulate decisions and consider the results

Number	Indicators	Activity
4	*advanced clarification*	Identify terms and consider definitions, identify assumptions
5	*strategies and tactics*	Determine an action and interaction with other people

Next, the effectiveness test of critical thinking skills was obtained from the average score of the pretest and posttest critical thinking skills carried out in class C in the environmental physics course in the physics education study program. The pretest and posttest consist of 10 essay questions. The average scores of the pretest and posttest can be seen in Table 3.

Table 3. Result of Critical Thinking Skills in Class C

	Mean Score of Critical Thinking Pretest	Mean Score of Critical Thinking postest
	49,13	80
Category	Low	High

Table 3. shows the increase in students' critical thinking skills in the learning process. This increase is shown by the average critical thinking score which increased from 49.13 in the low-category test to 80 in the high-category posttest. The average calculation results for each indicator are shown in Figure 3.1

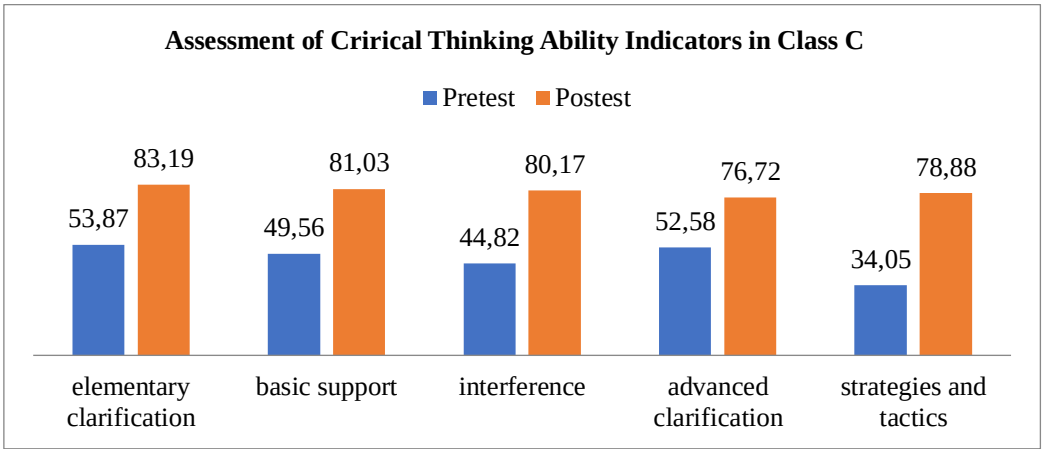

Figure 2. Assessment of Critical Thinking Ability Indicators in Class C

Figure 2. shows the increase in students' critical thinking abilities observed from each indicator after learning using research-based teaching materials. In the basic clarification indicator, which contains activities focusing on questions, analyzing arguments, and asking and answering questions that require explanation or challenge, the increase in the pretest and posttest scores obtained was 29.32. For the basic support indicator which contains the activities that consider the credibility of the source and make considered observations, the increase in the pretest and posttest scores obtained was 31.47. For the interference indicator which contains the activities formulate and consider deductions and induction, formulate decisions, and consider the result, the increase in the pretest and posttest scores obtained was 35.35. In the advanced clarification indicators, which contain activities that identify terms and consider definitions, identify assumptions, the increase in the pretest and posttest scores obtained was 24.14. In the strategy and tactics indicators which contain activities of determining an action and interacting with other people, the increase in the pretest and posttest scores obtained was 44.83. This shows that research-based teaching materials are effective in improving students' critical thinking skills.

9. Final product revision
Final improvements to the product being developed to produce a final or final product that is more ready to be disseminated

10. Dissemination and implementation
Disseminate the product developed and apply it to class B subjects in environmental physics courses in physics education study programs. Next, carry out a test of the effectiveness of critical thinking skills obtained from the average score of the pretest and posttest critical thinking skills. The pretest and posttest consist of 10 essay questions. The average scores of the pretest and posttest can be seen in Table 3.4.

Table 4. Result of Critical Thinking Skills in Class B

	Mean Score of Critical Thinking Pretest	Mean Score of Critical Thinking postest
	48,22	82,33
Category	Low	High

Table 4. shows the increase in students' critical thinking skills in the learning process. This increase is shown by the average critical thinking score which increased from 48.22 in the low-category test to 82.33 in the high-category posttest. The average calculation results for each indicator are shown in Figure 3.

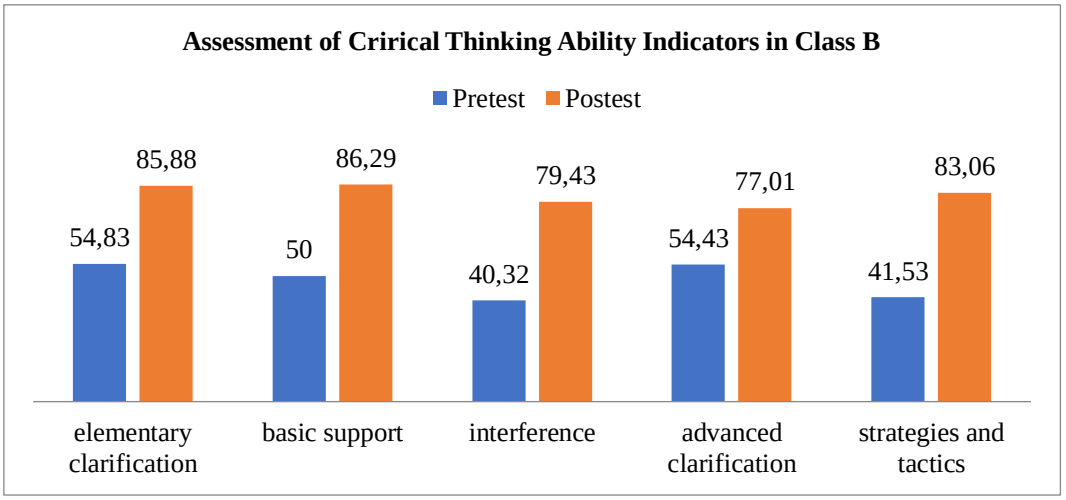

Figure 3. Assessment of Critical Thinking Ability Indicators in Class B

Figure 3. shows the increase in students' critical thinking abilities observed from each indicator after learning using research-based teaching materials. In the basic clarification indicator, which contains activities focusing on questions, analyzing arguments, and asking and answering questions that require explanation or challenge, the increase in the pretest and posttest scores obtained was 31,05. For the basic support indicator which contains the activities that consider the credibility of the source and make considered observations, the increase in the pretest and posttest scores obtained was 36,29. For the interference indicator which contains the activities formulate and consider deductions and induction, formulate decisions, and consider the result, the increase in the pretest and posttest scores obtained was 35.35. In the advanced clarification indicators which contain activities that identify terms and consider definitions, identify assumptions, the increase in the pretest and posttest scores obtained was 22,58. In the strategy and tactics indicators which contain activities of determining an action and interacting with other people, the increase in the pretest and posttest scores obtained was 41,53. This shows that research-based teaching materials are effective in improving students' critical thinking skills and the results of the final revision of research-based teaching materials show a better increase in critical thinking skills.

4. CONCLUSION

Critical thinking skills are needed in the 21st century, there are massive changes in society, from an aggressive society to an industrial society and one must know to survive. Improving critical thinking skills can be done early in the education sector by making efforts such as innovating in creating research-based teaching materials. Based on the research data analysis that has been carried out, it can be concluded that research-based teaching materials improve critical thinking skills in the use of Extremely low frequency electromagnetic waves to increase food security. These results were obtained from an average critical thinking ability score of 82.33 which was measured by indicators of critical thinking skills such as basic clarification, basic support, interference, further clarification, strategy, and tactics. The results of this research can be continued in the development of teaching materials to improve critical thinking skills or skills needed in the 21st century.

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