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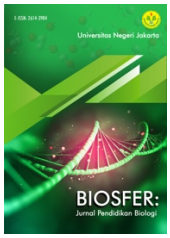

Development e-module on genetic materials to enhance student's critical thinking skills

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ABSTRACT

Genetic material is classified as material that is difficult for students to understand because the material is abstract, there are many foreign terms, and there are many complex molecular reactions, so students have difficulty developing critical thinking skills. Therefore, developing a good, suitable, effective, and attractive media is necessary. . This study aims to develop an e-module on the topic of genetic substance, to test the feasibility of the e-module, and to determine the differences in critical thinking skills before and after the implementation of the e-module. This type of research is research and development research with a 4D Thiagarajan model consisting of define, design, development,and disseminate. This research was conducted without the dissemination stage. The results of the validation of media experts are 81.7% (fair enough) and material experts are 85.5% (very feasible). The results of the trial were limited to 10 students, namely 92.1% (very decent) and 80.4% biology teachers (quite decent). The results of field trials are 90.2% (very feasible). The results of the t-test indicate that there are differences in critical thinking skills before and after the implementation of the e-module. This study implicate that e-modules on the topic of genetic substances are feasible to use and to empower students's critical thinking skills.

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INTRODUCTION

The era of the 21st century is considered the era of technology, where technology plays a very important role in human life and the rapid development of science. Education in the 21st century requires not only scientific knowledge from teachers and students but also skills in dealing with information technology and media(Mawaddah et al., 2018). One of the uses of technology in education is realized through learning media, where the media refers to the use of real objects and visual images that can be used in the learning process and communicated to students. According to Jalinus & Ambiyar (2016), the media can provide incentives to students so that learning becomes more effective, supports the achievement of educational goals, and motivates students to understand the learning material (Gaol & Sitepu, 2020).

One of the learning media that can be used to support learning activities is e-modules (electronic modules), where this media has the advantage that it can be accessed anywhere, more interactive than print modules with a variety of displays. E-modules that are practical and can be used at any time and anywhere have the following characteristics, namely interactive, easy navigation, have a variety of features such as images, videos, motion components (Aprilia & Suryadarma, 2020) E-modules can also be accessed through various devices, such as smartphones, tablets, and laptops (Pratiwi et al., 2021). Learning to use e-modules is more flexible because it can be accessed anywhere and this advantage helps students become more active and independent (El-senousy & Alquda, 2017). Based on pre-research data at SMA Batik 2 Surakarta, it shows that 89.9% of respondents need learning media that facilitates interaction with media or teachers and the preferred learning media is e-module.

There are some weakness in genetics material current teaching materials including less interactive, less illustrative, do not emphasize important concepts that must be mastered by students, and do not empower critical thinking skills much. A teaching material should be designed and written as a whole and systematically so that it can be used by educators to help and support the learning process (Ardiansyah et al., 2016). Therefore, it is necessary to develop e-modules as learning media which interesting, interactive and efficient when used in learning. E-module development can be made with various applications or software, one of which is the Adobe Illustrator application. According to Pasha and Saputro (2018), the advantage of using Adobe Illustrator is that it is equipped with additional new effects such as 3D and is compatible with Adobe Portable Document Format (PDF). The disadvantage of Adobe Illustrator software is that in its operation it requires a computer with a high capacity, the layout work is complicated, and takes a long time to make a project (Setyawati, 2019).

Critical thinking is one of the strengthening of character education that must be taught in schools so that students can compete in the 21st century (Fridanianti et al., 2018). Critical thinking is also a cognitive ability that must be owned and developed by students (Khasanah & Ayu, 2017). Critical thinking skills are abilities that can be used in problem-solving and considering a correct decision Purwati et al., (2016). According to Facione (2020), critical thinking skills consist of interpretation, analysis, conclusion, evaluation, explanation, and self-regulation

Critical thinking skills can be learned through student-centered learning. Student are trained to practice their reasoning skills in dealing with various daily problem in groups or individually (Kurniati et al., 2021). In training students' critical thinking skills, it should be supported by the use of appropriate teaching materials and learning media. An appropriate learning media can support the achievment of learning objective, motivating and enganging for students. The use of electronic module as learning media can present authentic problem in the form of object that are not directly observed. Moreover there were additional feature like video, animation, games, quiz, and navigation integrated systematically in e-module, so that students can conceptualize, analyze, and evaluate information through learning activities contained in the e-module (Seruni et al., 2020).

The quality of learning will be optimal if the learning carried out is student-centered learning and not teacher-centered. Teacher-centered learning leads to inactive students in the classroom (Jayawardana, 2017). The learning habits of students who tend to feel comfortable with the teacher's explanation (teacher center) without asking for more details during learning result in low students' critical thinking skills (Priyadi et al., 2018). Research by Bustami et al., (2018), proves that teachers who use expository learning and play a role as the main information source during learning make students passive during class. Research by Bustami et al., (2018), supported by Hairida (2016), prove that teacher-centered learning cannot improve students' critical thinking skills. Low critical thinking skills are supported by Agnafia (2019), states that students' critical thinking skills are still low because the

learning implemented in schools does not empower critical thinking skills. Critical thinking skills are important to support life full of challenges in a globalized world of the 21st century (Muhlisin et al., 2016). (Fahim & Pezeshki, 2012) state that critical thinking skills is active reasoning and deliberation to be used to decide or evaluate something of the issues facing the complexities of modern life.

Genetic substance material is one of the biology subjects that is studied at level XII of the odd semester of Senior High School (SMA). Genetic substance material discusses chromosomes, DNA and RNA structure, DNA replication, and protein synthesis. According to Aina (2017), students do not understand in detail the genetic material because the material is difficult materials to learn in class XII SMA in odd semesters. Wijayanti & Trimulyono (2019), stated that genetic material is considered difficult because the presentation of the material is not able to direct students' mindset and understanding. One of the topics contained in the genetic substance chapter is protein synthesis, where the material is abstract, and in most cases, this material is only presented in the form of concepts and theories, so it is quite complicated for students to understand (Hamidah et al., 2020).

The development of learning media in genetics substance material which is able to train students' critical thinking skills was rarely implemented in learning. The development of learning media on genetic material carried out by (Deli, 2022) was 2D video, but this research still has limitations in making videos which require using more sophisticated computer specs, besides that the use of video also limits interaction between students. In this research, an E-module of genetic material was developed which contains various components such as videos, presentation of contextual material, quizzes, discussion forums, and games. With these various features it is hoped that it can empower students' critical thinking skills, on the other hand the use of E-modules can also increase student interest in learning and increase student interaction with teachers.

METHODS

ResearchDesign

This study was research and development (RnD) with 4D models (Thiagarajan, 1976). The 4D is modified into 3 stages, namely define, design, develop, and disseminate (Salfia, 2021).

Population and Samples

The sampling technique was purposive sampling. The criteria used in this study were 12th grade high school students and science majors who have studied genetic substance material and who have devices with Android and Windows operating systems. The population of this study were students from SMA N 1 Dayeuhluhur, Cilacap class XII IPA . The limited trial sample was carried out on 10 students and 1 biology teacher to assess the product of media development (Nurhadi et al., 2020). Field trial samples were taken from a total population of 40 students based on calculations using the Slovin formula.

Instrument

The instruments used in the definition stage are interview sheets to capture teacher needs analysis, questionnaires to find out student needs analysis. The research instruments used at the develop stage were media expert validation sheets, material expert validation, learning expert validation, and E-module user response questionnaires distributed to teachers and students. Meanwhile, at the disseminate stage, pre-test and post-test questions were used to determine differences in students' critical thinking skills before and after using the E-module in learning. Critical thinking ability indicators that are measured consist of interpretation, explanation and self-regulation (Facione, 2011).

Procedure

The e-module was developed by referring to the 4D procedure (Thiagarajan, 1976) which includes the Define, Design, Develop, and Disseminate stages. This research begins with the define stage which consists of front-end analysis to find out the fundamental problems in learning (Setiabudi et al., 2019). Student analyses were conducted to determine the characteristics of learning media that will be developed based on students' need (Mulyasari & Sholikhah, 2021). The stages of front-end analysis and student analysis in this study were carried out by collecting data through an analysis of student and teacher needs questionnaires.

Task analysis was conducted to compile assignments based on basic competencies and learning

indicators (Kurniawan & Dewi, 2017). The stages of task analysis were carried out by making lesson plans that were adjusted to the KD (Basic Competence) and GPA (Indicator of Achievement of Competence) genetic substance material. Followed by concept analysis to identify the important and material content that will be included in the learning media (Rizki & Linuhung, 2016). The stages of concept analysis in this study were carried out by compiling genetic substance material that would be included in the learning media. Learning objectives were formulated to describe the indicators of learning achievement based on the concept and task analysis (Setiabudi et al., 2019). This stages were carried out by elaborating on indicators of competency achievement that are adjusted to the RPP for genetic substance material.

The design stage is to design learning media products that will be developed which consists of 3 step, namely media selection, format selection, and initial design (Kurniawan & Dewi, 2017). Media selection identify learning media that are relevant to the characteristics of the material and optimize the use of teaching materials in the learning process(Mi'rojiyah, 2016). This stages was conducted based on the results of the research from the define stage.

The format selection is to design the learning content and resources (Kurniawan & Dewi, 2017). The stages of selecting the format in this study are adjusted to the needs of the results at the define stage. The initial design stage aims to design learning tools to be developed based on the analysis carried out at the define stage(Santi & Santosa, 2016). The initial design stage in this research was carried out by making flowcharts and storyboards of e-modules that would be developed so that the initial product (draft 1) was produced.

The development is to produce learning media products that have been reviewed and validated from experts (Kristanti & Julia, 2017). Learning instruments were validated by learning experts and e-module media are validated by media experts and material experts. The next stage was product testing which consists of two stages, namely limited product trials and field trials conducted on students and teachers who implement the developed e-module in learning.

The disseminate stage include the evaluation of E-module to asses the students' critical thinking skills. The data gained from pre-test and post-test of assay of six indicator of critical thinking (Facione at al. 2011). Pretest and posttest scores then processed and to find out the differences in critical thinking skills before and after After the implementation of the e-module, a paired sample test was carried out t-test).

Data Analysis Techniques

The data analysis technique used in this research was qualitative and quantitative analysis. Qualitative data were obtained from the results of teacher interviews, suggestions from validators, and media user respondents. Quantitative data were obtained from the results of distributing needs analysis questionnaires, and media feasibility assessments from validators, teachers, and students. Qualitative data were analyzed descriptively by describing the data obtained thoroughly and this analysis began with data collection and then interpreted descriptively (Samsu, 2017). Quantitative data in this study used a Likert scale of 1 to 4 (Antika & Suprianto, 2016). The Likert scale can be seen in Table 1.

Table 1.
Likert scale

No	Answer	Score
1	Strongly agree	4
2	Agree	3
3	Don't agree	2
4	Strongly disagree	1

The total score calculated by the formula:

$$\text{Result} = \frac{total\ score\ obtained}{Maximum\ score} \text{ x } 100\%.$$

The percentage results obtained are based on the above calculations, then interpret according to criteria and categories according to Rohman et al., (2021) which can be seen in Table 2.

Table 2.
List of score percentage criteria and categories

Percentage Score(%)	Criteria	Category
85.01- 100.00	Very feasible	Worth using, without revision
70.01-85.00	Quite feasible	Worth using with minor revision
50.01-70.00	Not feasible	Recommendations for large-scale revision
01.00-50.00	Invalid	Not worth using

To determine the differences in students' critical thinking abilities before and after implementing the e-module, genetic substance material was analyzed using a paired sample T-test in the form of pretest and posttest data (Jumhur et al., 2021). The prerequisite test for the paired sample t-test is a normality test. and homogeneity test at the 5% level (Mishra et al., 2019).

RESULTS AND DISCUSSION

Define Stage

The curriculum used in learning biology at SMA N 1 Dayeuhluhur, namely the 2013 curriculum with the learning model used that is varied and not only using one learning model. However, in practice the learning model is often used namely the Discovery Learning learning model with the learning method discussion and question and answer as well as the dominant learning media used namely power point.

The learning resources used in biology learning are books print and modules as a companion to student learning. Related material on class 12 biology lesson, respondents stated that there were several material that is considered difficult for students to understand, namely inheritance, then the genetic substance material regarding protein synthesis (transcription and translation) as well as coding of nitrogenous bases that need to be repeated so that students can understand the material.

In the process of learning material that is abstract (eg genetics substance), respondents stated that they did not use special learning media in communicating the material and learning media that often used in the form of power point. Furthermore, in learning biology relates to the problems of everyday life day and train students' critical thinking skills. One of training/empowerment of critical thinking skills in biology learning genetic substance material by providing HOTs practice questions. Respondents stated that mastery of genetic material is important for students because the material has a close relationship with everyday life and stated that there is a need for empowerment critical thinking skills in learning biology, especially in the material genetic substance through HOTs questions that are poured or contained in the media learning that is easily accessed independently by students.

Design Stages

The learning media product designed in this research was an e-module on the topic of genetic substance DNA, RNA, DNA replication, and protein synthesis. The developed media can also be used independently and empower students' critical thinking skills. The development of media that can be used independently by students refers to Darmayasa et al., (2018), which proves that the e-module is one of the independent learning resources that can be used by students.

The learning media developed by the researcher is in the HTML.5 format to facilitate operation through various devices such as laptops, and mobile phones (android or IOS), facilitating student interaction with materials and teachers through discussion rooms (tlk.io and Google Classroom) , interactive game charting and nitrogen base coding. Related to the characteristics of the e-module above, supported by research Zakiyah & Dwiningsih (2021), revealed that e-modules have the advantage of being interactive which makes them easy to navigate, displaying animated images, audio, and video so that there is an automatic reciprocal effect.

The e-module developed also contains critical thinking questions in the form of essay questions. This was also supported by Mahyudi & Kurniawan (2022), which proves that in the 21st century one of the skills that can be used to develop students' critical thinking skills. The display of the e-module specifically developed by researchers to empower students' critical thinking skills is as follows (Figure 1):

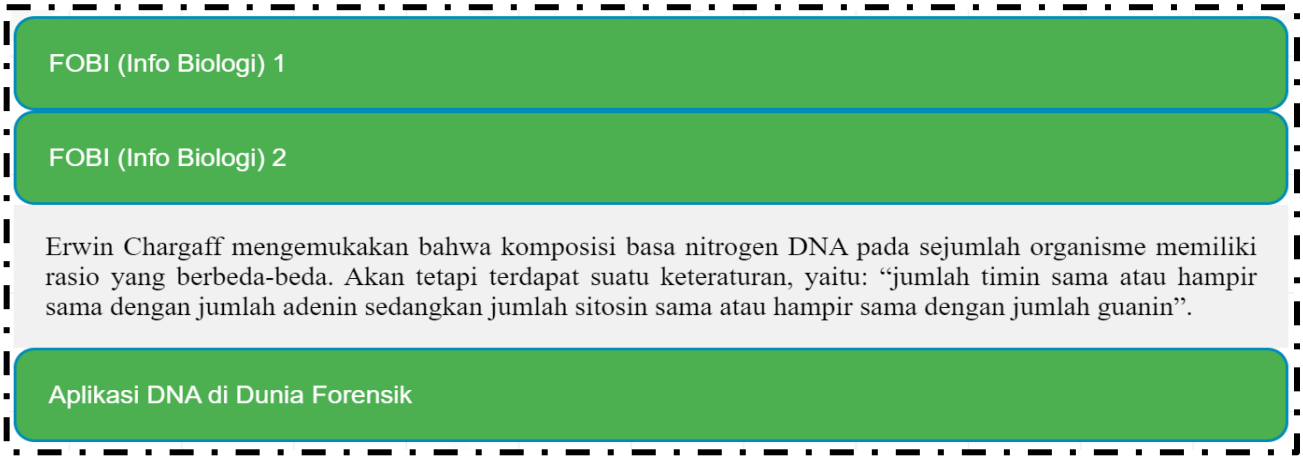


Figure 1. Menu phobia 2 DNA material about the nitrogenous base composition of DNA.

In this section, there was information regarding the rules for calculating the nitrogenous base composition of DNA in organisms. Through this section, students are directed to be able to interpret and evaluate the calculation of the nitrogen base of an organism through pretest-posttest questions. An understanding of the composition of nitrogenous bases really needs to be emphasized to students, considering that there are often misconceptions about this concept. The results of the research by (Syamsiar & Raharjo, 2021) revealed that the level of misconception in the DNA structure material was 38.1% where most students had difficulty distinguishing the nitrogen base arrangement in DNA and RNA and knowing the proportion of the ratio of the number of nitrogen bases in the genome of living things.

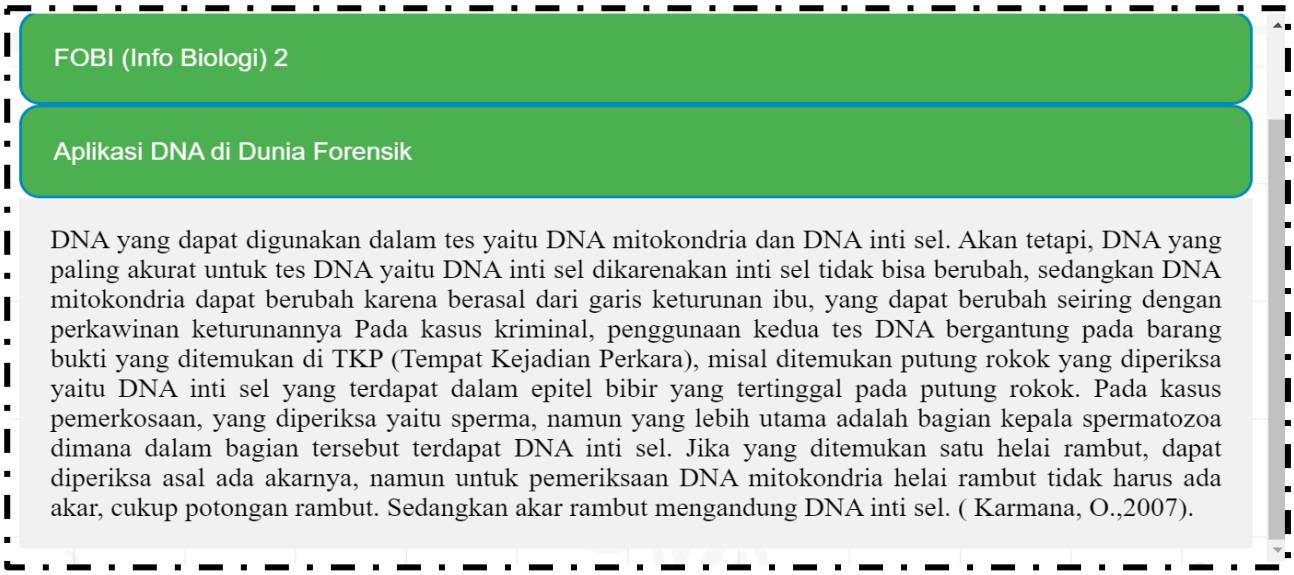


Figure 2. DNA application menu in the forensic world

In this section, there was information related to DNA application in forensics, which includes mitochondrial DNA and nuclear DNA tests (Figure 2). Empowerment of critical thinking skills in this section, namely the presentation of problems in everyday life, and students are directed to be able to interpret what actions/tests are appropriate and self-regulation in solving these problems. This is in line with the results of research by (Wongsila & Yuenyong, 2019) which revealed that learning on genetic material and DNA technology units with the Science Technology Society (STS) approach can empower students' critical thinking and problem solving abilities.

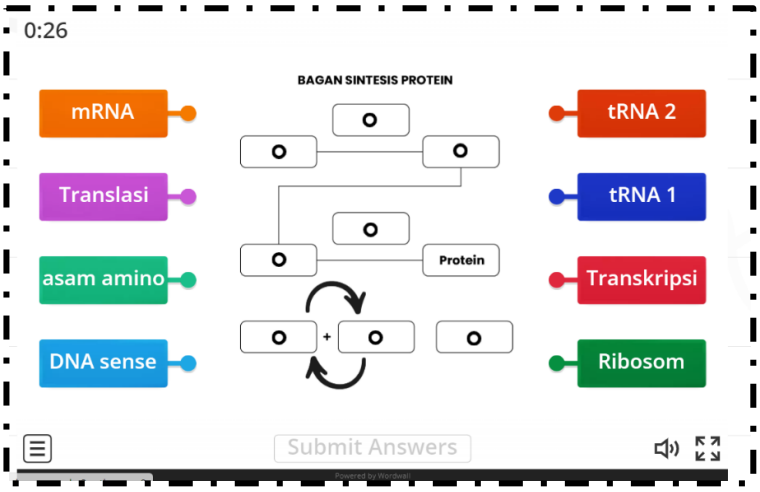


Figure 3. Game chart of the protein synthesis process

In this section, an interesting packaged protein synthesis chart game is used to train students in explaining and concluding the processes that occur in protein synthesis (Figure 3).

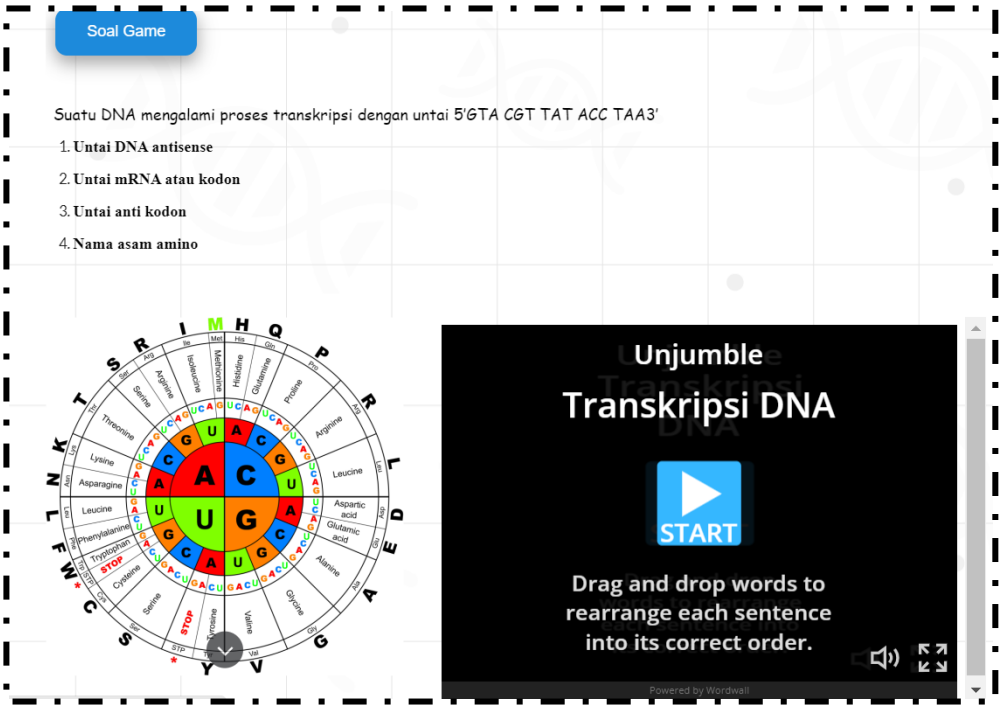


Figure 4. Nitrogen base translation game

The nitrogen base translation game was packaged in an interesting way to guide students in evaluating, explaining, and analyzing the coding of nitrogenous bases from DNA sense to form the amino acids that makeup polypeptides (Figure 4). The addition of game features to the e-module media serves to enrich the learning experience of students with various learning styles (Connolly & Stansfield, 2007). The use of game-based learning that is integrated in this e-module can also combine the achievement of learning objectives with the entertainment of students' learning experiences when playing the game (Gachkova & Somova, 2020), in addition, the addition of game applications can improve students' ability to remember and apply theoretical knowledge in real life (Kapp, 2012). There are two simulative games in this e-module, namely pairing the stages and components of the protein synthesis process (Figure 3) and pairing three selected nitrogenous bases with the appropriate amino acids (Figure 4). Simulative games are used for the acquisition or training of different skills, teaching effective behavior in the context of simulated conditions or situations (Gachkova & Somova, 2020). In this study, the addition of game features was also intended to empower students' critical thinking skills. In accordance with the

results of (Cicchino, 2015) research which states that the integration of game-based learning in learning is effective in promoting higher levels of critical thinking, including the development of independent beliefs prior to engaging in collaborative discourse and providing opportunities for guided reflection.

Develop Stage E-modules on the topic of genetic substances to empower students' critical thinking skills were validated by media experts and material experts and tested on a limited basis and in the field (Figure 5).

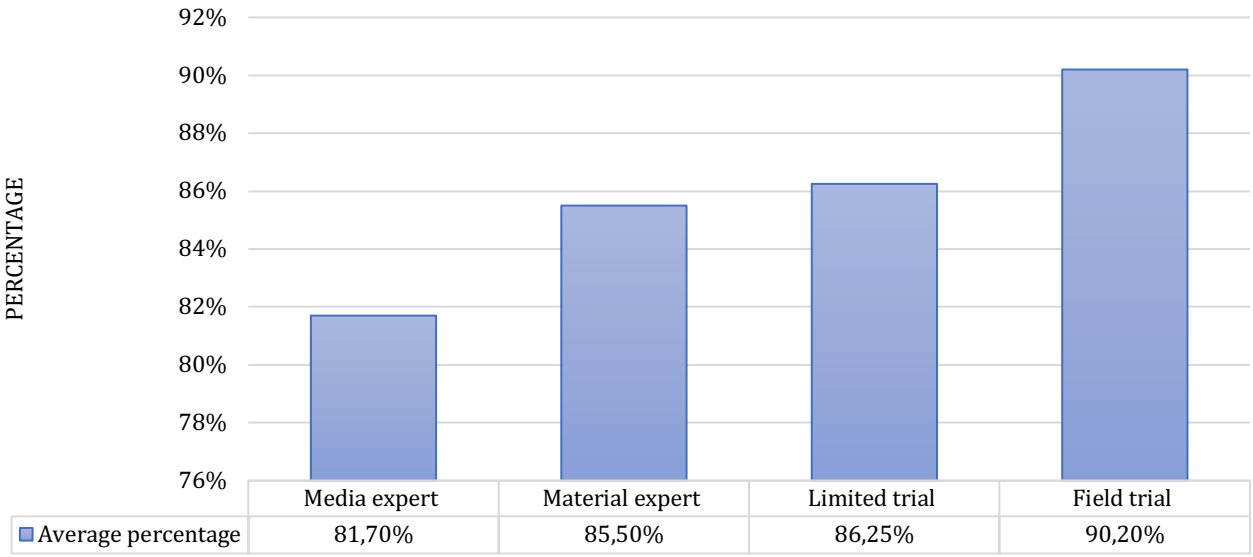
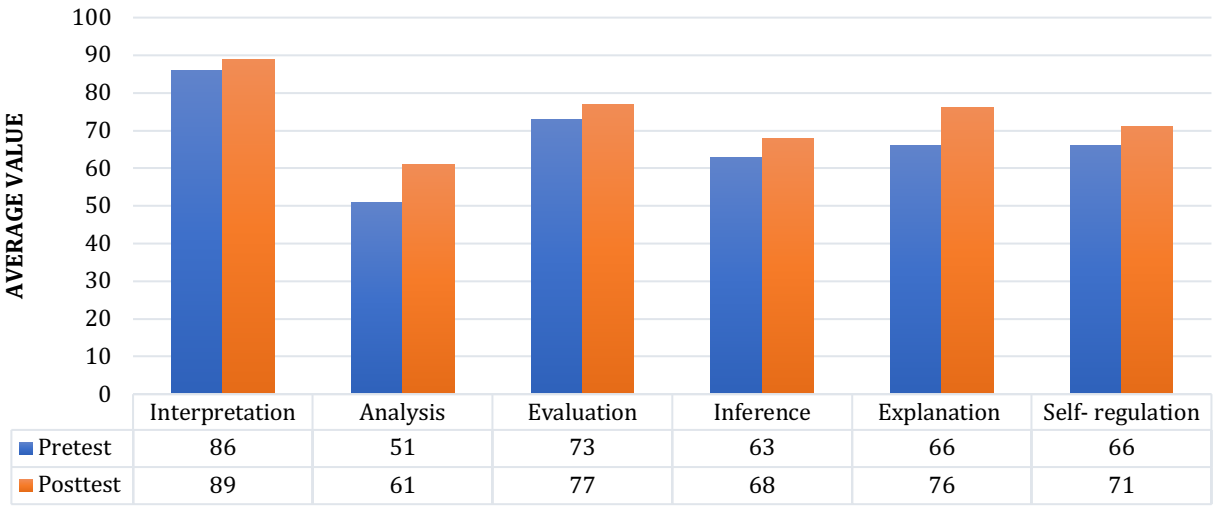


Figure 5. E-module feasibility assessment

The average percentage of eligibility from media experts was 81.7% (fairly valid) and material experts were 85.5% (very valid). According to (Rohman et al., 2021) the value range is 70.01%-85.00% for quite valid criteria and the value range is 85.01%-100% for very valid criteria.

The feasibility of the product was also assessed based on limited trials and field trials. The results of the feasibility of the product trial limited to 10 students obtained an average percentage of 92.1% and the test on teachers obtained an average percentage of 80.4%. According to (Rohman et al., 2021) the results of the percentage of students' limited trials with a value of 92.1% are included in the range of values of 85.01%-100% and the criteria are very valid and are categorized as suitable for use without revision. While data from teachers' limited trials with a value of 80.4% were included in the range of values of 70.01%-85.00% and the criteria were sufficiently valid and categorized as suitable for use with minor revisions. The results of the feasibility of the product in a field trial with respondents of 40 students obtained an average percentage of 90.2% and the value included in the range of values (85.01%-100%) with very valid criteria with categories suitable for use without revision.

Disseminate To find out the differences in critical thinking skills, namely by giving pretest questions before using the e-module and posttest after using the e-module on the topic of genetic substances which includes questions related to aspects of ability. critical thinking, namely interpretation, analysis, evaluation, conclusion, explanation, and self-regulation. The results of research related to empowering students' critical thinking skills before and after using e-modules showed significant differences. This was supported by the results of the paired t-test using SPSS 25 significance value (2-tailed) pretest and posttest of 0.000 (< from 0.05). The e-module on the topic of genetic substance developed was equipped with HOTs questions related to the material discussed to empower students' critical thinking skills. The average value of aspects of critical thinking skills on the questions contained in the e-module of genetic substances can be seen in Figure 6.



	Interpretation	Analysis	Evaluation	Inference	Explanation	Self- regulation
Pretest	86	51	73	63	66	66
Posttest	89	61	77	68	76	71

Figure 6. The average student's Critical Thinking Score

Based on Figure 6., the highest score for critical thinking skills aspects was the interpretation aspect with a pretest score was 86 and a post-test value was 89. Interpretation at this stage, the interpretation carried out by students is to recognize and understand comprehensive information regarding the structure and role of DNA, which is a collection of nucleotides, each of which consists of three components, namely nitrogen bases, phosphate groups and ribose sugar. Most of the students already know that DNA is the constituent of genes that encode a trait. In learning using the E-module, several topics regarding DNA structure and its role in inheritance are also presented. These findings are supported by the results of research (Agnafia, 2019) which proves that the interpretation aspect is classified as good because this aspect is related to the training of students in interpreting and re-expressing the data presented. . On the other hand, the lowest score for critical thinking skills aspects was the analysis aspect with a pretest value was 51 and a post-test value was 61. The analysis aspect was classified as low because students have not been able to identify the concept linkages of the questions/statements. In the analysis stage, students still experience difficulties in analyzing the composition of nitrogen bases in living things based on Chargaff's law and students can communicate the ratio of the number of purine nitrogen bases (Adenine and Guanine) to the number of pyrimidines (Cytosine and Thymine). However, in the E-module this material has been presented in games feature so that it can help students' understanding in determining the composition of the number of nitrogen bases in several types of living species. The use of e-modules on genetic material were equipped with information on the latest biotechnology applications, a skill-enhancing room menu containing critical thinking questions, study room menus, discussion menus, game features, and animated videos about DNA replication and protein synthesis which are expected to train students' critical thinking. The highest increase was in the analysis and explanation aspects, which were 10 points respectively. Several topics on genetic material that studied by developing critical thinking skills include explaining the structure of DNA, interpreting the role of genes as carriers of traits, analyzing the process of DNA replication and the process of protein synthesis, determining the ratio of nitrogenous base composition, and assessing the results of translating DNA into protein. All the material were teached in Problem-based model served on this E-module. This is supported by the research results of (Anesa & Ahda, 2021) which state that the use of PBL-based e-modules on genetic material is effective in improving students' critical thinking skills.

CONCLUSION

The e-module developed uses Adobe Illustrator software with characteristics including having HTML.5 format with the aim of making it easier to access (via Android and IOS smartphones and laptops), loading material on the topic of genetic substances (the subject consists of DNA, RNA, DNA replication, and protein synthesis), the menus presented in the e-module are 7 (guide menus, KI, KD, GPA and learning objectives menu, skill 1 learning room menu, study room menu, discussion room menu, training room menu ability 2, and reference menu), also accompanied by interactive games and

essay questions to empower students' critical thinking skills.

The assessment of the feasibility of the learning media developed by the researcher is feasible to use with an average assessment from media experts (81.7%), material experts (85.5%), learning experts 94.2% (RPP), and 94.3% (questions), limited trial (86.25) and field trials (90.2%). The difference in students' critical thinking skills before and after using the e-module showed a significant difference and this was evidenced by the significance value (2-tailed) in the paired sample t-test of 0.000 (<0.05), so it was concluded that decision-making from this value, there are differences in critical thinking skills before and after the use of genetic substance e-modules.

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