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Development of a STEAM-Based Homeostatic Module to Improve Students' Cognitive Abilities

Zico Fakhrur Rozi[1*], Aceng Ruyani[2], Badeni[2]

[1] Universitas PGRI Silampari, Indonesia.
[2] Universitas Bengkulu, Indonesia.

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Corresponding Author:
Zico Fakhrur Rozi
zico.fakhrurrozi@gmail.com

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Abstract: This research aims to develop a STEAM-based homeostatic module to improve students' cognitive abilities. The subjects of this research were students of the Biology Education Study Program at PGRI Silampari University. In the learning process, students are given an assignment in the form of a project to test honje fruit extract (*Etlingera hemisphaerica*) as antihyperglycemia, antihypercholesterolemia and antihyperuricemia. Module development uses a 4D development model, with define, design, develop and disseminate stages. The instruments in the research are validation questionnaires for material experts, media experts, language experts, response questionnaires and evaluation test sheets. The research results showed that the module developed contained steam elements and was assessed as appropriate by material expert validators with a v-aiken value of 0.91, media experts 0.91 and language experts 0.88. Student responses to the module were 48.44 in the positive category. Students' cognitive abilities have increased with an N-gain value of 0.64 in the moderate increase category. Based on these results, it can be concluded that the STEAM-based homeostatic module is effective in improving students' cognitive abilities. The results of the analysis using the anova test showed that there were differences in the average learning outcomes between the experimental class and the control class.

Keywords: Animal physiology; Cognitive abilities; Module; STEAM

Introduction

Education according to Law no. 20 of 2003 is a conscious and planned effort to create a learning atmosphere and learning process so that students actively develop their potential to have religious spiritual strength, self-control, personality, intelligence, noble morals, and the skills needed by themselves, society, nation and state (Rosli et al., 2022). Education can shape a person's personality. 21st century education aims to build students' intelligence abilities so they are able to solve existing problems. Basically, each individual's cognitive abilities must be different from one another, students' abilities in capturing material vary (Rosa et al., 2020). Science education is a process of teaching students to understand the nature of science: products, processes and developing scientific attitudes and being aware of the values that exist in society, developing attitudes and actions in the form of positive science applications.

Cognitive abilities are brain-based skills needed to perform simple to the most complex level tasks (Hasanah et al., 2022; Kano et al., 2022; Quiñones et al., 2020). The dimension of knowledge in the development of cognitive psychology consists of four types of knowledge, including Factual, Conceptual, Procedural, and Metacognition. In the factual dimension, students are required to have knowledge that is used to solve problems. In the conceptual dimension, students are provided with knowledge about classifications and categories, principles and generalizations, as well as models and structures. In the procedural dimension,

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students are guided to carry out an investigation using appropriate methods and in the metacognition dimension, it concerns cognition in general as well as awareness and knowledge about one's own cognition.

The initial analysis of the Biology Education Study Program at PGRI Silamapri University was carried out by looking at the lecturers' class semester learning plans (Buono et al., 2022). The results of the analysis in terms of curriculum, learning strategy and learning evaluation aspects show that the existing RPS is not in accordance with the higher education curriculum. In RPS there are elements of science but there are still less elements of technology, engineering, art, and there are no elements of mathematics as a tool to help solve problems. Furthermore, the results of the RPS analysis stated that there were no assignment plans, assessment instruments and teaching materials. The positive impact of the analysis results is that the learning process uses teaching materials such as modules, however the modules used only contain science elements without any technology, engineering, art and mathematics elements. Modules that only contain science elements cause students to lack technological mastery. Based on the questionnaire given to students, 90% of students need teaching materials that are practical and contain STEAM elements so they can be accessed anywhere at any time (Haddar et al., 2023). Apart from that, in animal physiology courses, students have never received project-based assignments. This condition causes a lack of students' cognitive abilities. Therefore, it would be very good to develop STEAM-based modules to improve students' cognitive abilities, especially in the factual, conceptual, procedural and metacognitive dimensions (W. Utomo et al., 2023).

The module developed is thought to be able to improve students' cognitive abilities because it contains elements of science, technology, engineering, art and mathematics with project activities related to solving problems in everyday life. STEAM-based science modules equipped with biotechnology games, tests and validation sheets can improve students' cognitive learning outcomes (Sofia et al., 2020). E-book-based modules using the Kvisoft Flipbook Maker application are suitable for increasing students' interest in learning and cognitive learning outcomes (Rusli et al., 2019) and the use of E-Modules has a significant effect on students' cognitive learning outcomes (Mutmainnah et al., 2021).

Based on the background above, it is very important to carry out research on the development of STEAM-based homeostatic modules to improve students' cognitive abilities. This research is important because facing the 4.0 era, there is a need for teaching materials that are practical and can be accessed at any time without being hampered by time and space (Tasse et al., 2018). In the teaching materials there will be student project activities to design experimental activities regarding the use of natural materials as anti-diabetes drugs as an effort to integrate Science, Technology, Engineering, Art and Mathematics which guides students in improving cognitive abilities in the factual, procedural, conceptual and metacognitive dimensions (Taylor, 2018).

The development of a STEAM-based homeostatic module to improve students' cognitive abilities in the factual, conceptual, procedural and metacognitive dimensions is a novelty or new finding that has never been developed before. There have been several previous STEAM-based module developments but they did not specifically measure students' abilities in the 4 cognitive dimensions. Modules with STEAM elements make it easier for students to adapt in constructing new knowledge based on technological developments, as well as understanding the importance of maintaining a healthy lifestyle to maintain body homeostasis. In the module there is also a project to test E. hemisphaerica fruit extract as a drug for hyperglycemia, hypercholesterolemia and hyperuricemia. The STEAM element in the e-module is one of the innovations carried out in preparing industrial technology 4.0 where learning uses digitalization. The application used is also not difficult to use in developing e-modules and is able to include images, videos, practice questions which can help the learning process independently.

Method

This research uses a quantitative approach with the Research and Development (R&D) type of research which refers to the Thiagarajan development model (Lawhon, 1976), which consists of the define, design, develop, and disseminate stages. This research was carried out during August-December 2024. The research was carried out at the Biology Education Study Program at PGRI Silampari University. The test subjects in this research were students from the Biology Education Study Program who took animal physiology courses.

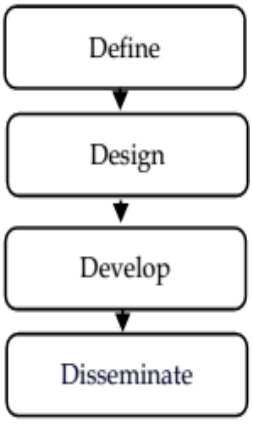

Figure 1. Model research design

In the first stage, namely define, at this stage student analysis is carried out. Student analysis is carried out to examine student characteristics which include abilities, background knowledge and the level of student cognitive development as an illustration for developing. The beginning-to-end analysis is carried out to find out the basic problems faced in the learning process, namely solving problems. In solving the problems faced, new learning materials will not be developed, but existing materials based on the curriculum developed using modules. Task analysis is carried out to formulate learning objectives which are developed using the STEAM approach which is oriented towards students' cognitive understanding, formulating learning objectives based on the general objectives of the course. The second stage is Design, which consists of 4 steps that must be passed, namely constructing criterion-referenced test (preparation of test standards), media selection (media selection), format selection (format selection), and initial design (initial design). The third stage in developing 4D model learning tools is development. The development stage is the stage for producing a development product. This stage consists of two steps, namely expert appraisal (expert assessment) accompanied by revision and delopmental testing (development trial). In this research, expert assessments were carried out by material, media and language experts.

The final stage in developing 4D model learning tools is the dissemination stage (dissemination). The dissemination stage is carried out to promote the product developed so that it is accepted by users by individuals, groups or systems. Material packaging must be selective to produce the right shape. There are three main stages in the disseminate stage, namely validation testing, packaging, and diffusion and adoption (Lawhon, 1976). In the validation testing stage, the product that has been revised at the development stage is implemented on the actual target or targets. At this stage, goal achievement is also measured which aims to determine the effectiveness of the product being developed. Furthermore, after implementation, researchers/developers need to observe the results of achieving the goals. Solutions that have not been achieved must be explained so that they do not repeat themselves once the product is disseminated. Data analysis techniques can be seen in table 1.

Table 1. Data Analysis Techniques

Data	Data Analysis Techniques
Needs Analysis	Descriptive
Product Validation	V Aiken
Practicality	Descriptive
Cognitive Ability	t-test

Table 2. V Aiken Assessment Criteria

V value	Category
$0.68 < V \leq 1.00$	Tall
$0.34 < V \leq 0.68$	Currently
$0 < V \leq 0.34$	Low

Data analysis technique to determine the effectiveness of using a STEAM-based homeostatic module by looking at the score gain value. The increase in students' cognitive abilities that occurs before and after lectures is calculated using the *N-gain formula* which is determined based on the average normalized gain score, namely the comparison of the gain scores. The *N-gain* calculation developed by Hake (Guntara, 2021) is as follows:

$$N_{-gain} = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}} \quad (1)$$

N-gain score obtained is used to see the increase in cognitive abilities and concept mastery between before treatment and after treatment. N_{-gain} scores are grouped into high, medium and low categories as can be seen in table 3.

Table 3. Classification of N-gain

N-gain category	Information
$0.70 > N_{-gain}$	Tall
$0.30 \leq N_{-gain} \leq 0.70$	Currently
$N_{-gain} < 0.30$	Low

Result and Discussion

This research was carried out at PGRI Silampari University with the research subjects being Biology Education Study Program students who took animal physiology courses in the 5th semester of the 2022/2023 academic year. The teaching materials developed are STEAM-based homeostatic modules to improve students' cognitive abilities using the 4D development model. At the *define stage*, the researcher collected information and carried out a preliminary study to examine information about student learning needs, interviewed lecturers and carried out an analysis of the RPS for the animal physiology course. Analysis of student needs is carried out by distributing or giving learning needs questionnaires to students.

The results of the student needs questionnaire for the Biology Education Study Program at PGRI Silampari University were divided into several indicators and the results of student responses to the need for teaching materials. The teaching materials that students expect are teaching materials that are easily accessible, practical and easy to carry anywhere (A. P. Utomo et al., 2020). Lecturer activities in learning are really needed by

students to produce learning that is interesting and not boring. The solution offered is STEAM-based (digital) teaching materials that facilitate students' cognitive abilities in the factual, conceptual, procedural and metacognitive dimensions. The application of interactive digital teaching materials with the *discovery learning model* can improve student learning achievement (Khamidah et al., 2019). Digital teaching materials are able to increase students' learning independence, increase learning motivation and can improve students' cognitive development (Alperi, 2020; Sari, 2021).

The results of interviews with lecturers who teach animal physiology courses show that lecturers already have RPS, in preparing RPS lecturers only pay attention to students' cognitive aspects. The assessments carried out have not addressed the four cognitive dimensions of students consisting of factual, conceptual, procedural and metacognition. The interview results show that in the learning process lecturers often use discussion methods by utilizing learning resources such as animal physiology reference books, student discussion sheets, and the internet. The learning resources used can only help students understand some material. This is because the lecture material is quite dense in animal physiology, especially homeostasis material. The interview results also showed that lecturers had never created and used teaching materials such as modules or modules, lecturers still used *PowerPoint* and utilized several applications in learning such as *e-learning and WhatsApp Group (WAG)*. In fact, the availability of facilities and infrastructure on campus is quite supportive in implementing digital-based learning by utilizing information and communication technology. The learning activities that have been carried out also do not fully direct students to cognitive abilities in the factual, conceptual, procedural and metacognitive dimensions (Hasibuan et al., 2022).

RPS analysis is also carried out with the aim of mapping Course Learning Outcomes related to the material that will be taken during the research. This data will later be used as a basis for preparing sub-CPMK, indicators and learning objectives. The most important essence that must be developed is that RPS must adapt to the development of the industrial era 4.0 so that teaching materials need to be developed that can be used without being limited by space and time. Good learning is not only carried out face to face in class but can be carried out online with the help of mobile devices such as smartphones, laptops, computers and tablets, which can be used to access information anywhere and at any time (Delcker et al., 2018; Gikas et al., 2013). Online learning patterns are indeed needed for learning in the era of industrial revolution 4.0 (Andrianto, 2022). The development of this module is to improve students' cognitive abilities in the factual, conceptual, procedural and metacognitive dimensions.

Based on the results of the material expert feasibility test analysis using V Aiken, the results obtained were that teaching materials in the form of STEAM-based homeostatic modules were very suitable for use with an average V value of 0.91 with a very high valid interpretation. These results are an indicator that the teaching materials can be used for the next stage. The results of the analysis using Aiken's V show that the V value for media experts is 0.91 with a very high valid interpretation. However, there are several points that need to be improved. The conclusion from media experts states that the module can be used with slight revisions and can be continued at the next stage. The results of the analysis using Aiken's V show that the V value for linguists is 0.88 with a very high valid interpretation. However, there are several points that need to be improved. The conclusion from the linguist stated that the module could be used with minor revisions and could be continued at the next stage. The results of the expert validation V-Aiken analysis can be seen in table 4.

Table 4. Results of Expert Analysis with V Aiken

Validation	Aiken's V Value	Criteria
Materials	0.91	Very high
Media	0.91	Very high
Linguist	0.88	Very high

Based on the results of validation analysis from validation of material experts, media experts and language experts using V-Aiken. The results of the analysis show that each material expert obtained 0.91 with very high valid criteria, media experts 0.91 with very high valid criteria, and language experts 0.88 with very high valid criteria. These results indicate that the module developed is very suitable for use in animal physiology courses. Input from expert validators becomes part of the product revisions produced to obtain a good module product that can be published widely (Özer et al., 2023). The final product of this teaching material is implemented to improve students' cognitive abilities in the factual, conceptual, procedural and metacognitive dimensions. The practicality of the module can be determined by using a questionnaire in the form of responses to the results of the module development (Acar, 2013).

In this research, to obtain a practical module, it is necessary to carry out small group trials. This small group trial consisted of 9 students. When the learning process took place using this STEAM-based homeostatic module, it was seen that student activity had begun to emerge (Bati et al., 2018). However, even though the homeostatic module has been validated by experts,

when carrying out small group trials, several small errors were still visible. For example, typos or typing errors were still found in the writing (Tran et al., 2021). Therefore, with this small group trial, researchers can also see the shortcomings of thorough teaching materials as a material for improvement. At the end of this small group trial lecture, students were asked to fill out a student response questionnaire (Acar, 2013). Where this questionnaire contains positive and negative statements. From the results of the recapitulation of the small group trial student response questionnaire, it was found that five students gave very positive responses while four students gave positive responses. Apart from that, an average score of 48.44 was also obtained which was in the positive category. This means that the homeostatic module developed is practical and can be used by students during field trials (actual classes). During the lecture process, lecturers are required to prepare good learning tools so that the objectives of the lecture material can be achieved (Hutabarat, 2019). According to him, lecturers who do not plan and prepare all the necessary equipment properly will mean that the implementation of the learning process will not be effective. Such situations can influence students towards the learning process, which ultimately results in not achieving learning outcomes. Therefore, planning the learning process is an important part that must be developed before implementing learning. A good lesson plan is the key to implementing learning activities step by step to achieve learning outcomes (Aziira et al., 2023). Good learning activities carried out by lecturers and students should be reflected in the learning plan (Chen et al., 2023).

The results of the development of the homeostatic module that have been developed can be used as teaching materials with the following advantages: teaching materials are very practical and can be used anywhere because they can be opened both offline and online using a smartphone or computer device, the application created has a small capacity and can Downloaded by all types of Android as long as you have quota and memory on your smartphone (Tasse et al., 2018). The small capacity of this application will not interfere with its operation on a smartphone. In the module there are STEAM elements which can facilitate students' cognitive abilities in the factual, conceptual, procedural and metacognition dimensions (Chen et al., 2023). There are evaluation questions that can be used as indicators of student understanding. The display presented is attractive, there are pictures and videos that support the learning material and can foster student learning independence (Aftiani et al., 2021). Apart from the advantages, there are also disadvantages to this teaching material, namely limited features in the application (Hasibuan et al., 2022). Students cannot write essay answers on the professional flip pdf based module application (Prameswari, 2020). The material presented only consists of 3 materials and does not facilitate the material in one semester. The module that was developed was then implemented in large classes with the average student learning outcomes obtained can be seen in the picture below (Bati et al., 2018).

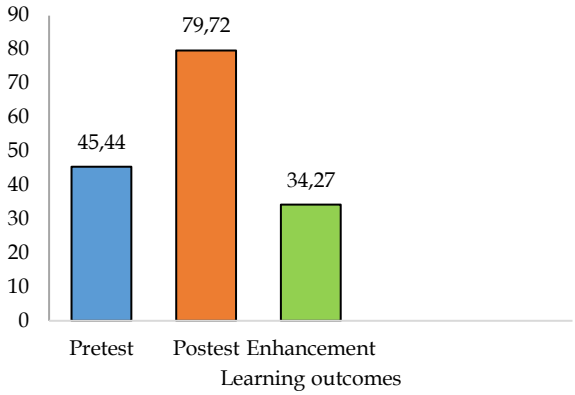

Figure 2. Student cognitive ability learning results

The research results show that the STEAM-based homeostatic module can improve students' cognitive abilities. In the experimental class there was an increase in learning outcomes. The difference in learning outcomes from the pretest and posttest results of the experimental class was 34.27 and if analyzed using N-gain the value obtained was 0.64 with a moderate increase category. Meanwhile, in the experimental class the difference in learning outcomes was 11.44 with an N-gain value of 0.219 in the low gain category. The implementation of STEAM in learning is the process of applying ideas, concepts and concepts contained in meta-disciplinary knowledge in learning that can improve students' cognitive abilities in facing technological advances (Kartono, 2021). STEM contributes collaboratively to enriching students' abilities (Ammar et al., 2024).

Next, to find out the differences in learning outcomes in the control and experimental classes, an analysis was carried out using ANOVA using the SPSS 24 application. Before the analysis was carried out using the anova test, the learning outcome data was carried out for a normality test using the Kolmogorov-Smirnova test, it was known that the sig value in the experimental class was 0.20 and the control is 0.12. This result is greater than 0.05, which indicates that the posttest data from the experimental and control classes is normally distributed. Next, a homogeneity test was carried out using the Levene Statistics test and the result was that the sig. 0.23 > 0.05 then the data is declared homogeneous. Once the data is normally distributed and homogeneous, the conditions for carrying out the anova test have been fulfilled. The results of the ANOVA

test analysis using SPSS 24 are a sig value of 0.000 < 0.005 so it can be concluded that there is a difference in average cognitive abilities in the experimental class and the control class. These learning results show differences in students' cognitive abilities in factual, conceptual, procedural and metacognition dimensions in the experimental class and the control class. The average score for learning outcomes in the experimental class was 79.72 while the control class was 60. These results show that the homeostatic module is effective in improving students' cognitive abilities. STEAM-based learning that offers meta-disciplinary education in developing cognitive abilities to solve problems. Integration into STEAM will be able to provide new opportunities for students to carry out the learning process directly and have good problem solving in order to face the era of increasingly globalization (Katz-Buonincontro, 2018). The module developed is a homeostatic module with STEAM elements in it. Students carried out experimental activities by testing natural ingredients in the form of honje fruit extract on mice's blood sugar levels, mice's cholesterol levels and mice's uric acid levels (Fauziah, 2022; Ndeot et al., 2022; Wahyuningsih et al., 2020). The STEAM elements in the module can improve students' cognitive abilities in the factual, conceptual, procedural and metacognitive dimensions. Apart from that, STEM can guide students in practicing 21st century skills (Setiawati et al., 2024).

The presence of STEAM elements in learning has a great influence on students' cognitive abilities. The implementation of STEAM in learning is the process of applying ideas, notions and concepts contained in meta-disciplines in learning which is expected to improve abilities in both cognitive aspects (Mu'minah et al., 2020; Puspitasari et al., 2020). Furthermore, project-based learning in modules involves five disciplines and fosters a good learning environment where all students involved contribute (Zubaidah, 2020) and can prepare future generations to face the challenges of the times (Hadinugrahaningsih et al., 2017). STEAM emerged as a popular pedagogical approach to enhance students' creativity, problem-solving skills, and interest in STEM fields, the definition and goals of STEAM education remain ubiquitous (Perignat et al., 2019). Project-based modules also greatly influence student learning outcomes (Dwi et al., 2024)

In the project carried out by students, it was discovered that there was an effect of giving honje fruit extract on blood sugar levels, cholesterol levels and uric acid levels. In honje fruit extract there are secondary metabolite compounds which have potential as medicine. The results of chemical analysis of honje flowers stated that this part of the plant contains alkaloids, flavonoids, foliphenols, steroids, saponins and essential oils (Dasi et al., 2023). The antioxidant content of kecombrang plant leaves is higher when compared to flowers and rhizomes (Chan et al., 2011). Therefore, having active compounds such as polyphenols and flavonoids makes kecombrang nutritious. Another combrang extract, *Etlingera elatior*, caused a decrease in lipid hydroperoxide and protein-carbonyl content, as well as a significant increase in total antioxidants and antioxidant enzymes in mice (Jackie et al., 2011). Furthermore, it is known that honje leaf extract has an effect on *Mus musculus* blood glucose levels (Putri, 2021; Ruyani et al., 2014).

Conclusion

The homeostatic module is suitable for use based on validation from material, media and language experts with very high valid criteria. Based on the N-gain experimental class, there was an increase in student learning outcomes after using the homeostatic module.

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Author Contributions
Each author contributed in some way to the completion of this research activity. The main author provided research ideas. The second and third authors helped design research methods, collect and present research data.

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Conflicts of Interest
Regarding this study, the author declares that there is no conflict of interest.

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