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Development of STEM-Based E-Modules on Freshwater Fisheries to Facilitate 21st Century Skills

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Abstract: The urgency of this research lies in the pressing need for universities to align with Learning Process Standards, which mandate the development of teaching materials grounded in research findings. Such materials are crucial for nurturing highly skilled and competent graduates in various fields. Specifically, the creation of STEM-based E-Modules in freshwater fisheries courses is vital for equipping biology students with 21st-century skills. These skills are essential for applying scientific knowledge to real-life scenarios and for generating societal benefits through innovative products. The research method used is Research and Development design, using the PPE model, namely Planning, Production, and Evaluation. Data collection using expert team validation sheets and questionnaire sheets. Data analysis uses Miles and Hubermann analysis to analyze expert validation data. The results of validation by validators in the STEM-based freshwater fisheries E-Module include assessment results from media experts showing assessment results of 83% (very feasible) and assessment results from STEM content experts of 81% (very feasible). The results of the questionnaire by lecturers showed an average score of 83% (practical) and the results of questionnaires by students show an average score of 80% (practical). Based on the results of the study, it can be concluded that the developed STEM-Based E-Modules on Freshwater Fisheries can facilitate students to practice 21st century skills.

Keywords: Freshwater fisheries; STEM; 21st century skills.

Introduction

Education should prepare learners for the challenges of employment in an ever-changing technology-driven society by helping them develop higher-order thinking skills (Liu & Zhang, 2022). Recent years have grown a focus on the need to prepare learners for higher education and equip them with the skills and knowledge they need to become successful innovators in the world of work in the 21st century (Gamage et al., 2022; Mallillin & Mallillin, 2019; Zubaidah, 2019). One form of learning that can improve the skills of learners is STEM, STEM learning aims to develop student creativity or as a means to improve real-world problem-solving skills (Perignat & Katz-Buonincontro, 2019; Ulya et al., 2023). Proven STEM learning can be applied to all teaching materials and train students to think scientifically, use technology to obtain various information, and train learners to integrate various components of learning various kinds of knowledge or interdisciplinary (Milaturrahmah et al., 2017). The learning needed in the 21st century is learning that can prepare students to achieve superior, creative, innovative, and competitive achievements in the future in the fields of science, technology, engineering, and mathematics (STEM), The development of STEM-based modules can make it easier for teachers to implement learning in accordance with the demands of the 21st century (Diana & Turmudi, 2021; Mukaromah et al., 2022).

The development of technology-based teaching materials that are more innovative, creative, effective, efficient and contextual in accordance with the conditions, needs, characteristics of the material and students is a demand in learning. One element of lecturer competence is being able to develop and utilize

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media and learning resources (Syahmani et al., 2021). Lecturers are required to be able to develop media and teaching materials by utilizing technological advances (Malik et al., 2021; Rahmawati et al., 2022). The development of STEM-based teaching materials can facilitate students in learning related to the real world through activities to identify problems, collect data to solve problems, think of solutions, and consider the results in a multidisciplinary manner (Mufidati et al., 2023)(Wahono et al., 2018). STEM-based teaching materials are innovative learning resources in accordance with the demands of the curriculum and the characteristics of 21st Century learning (maharani Zan et al., 2023; Rasmi et al., 2023). Global STEM is essential to training 21st Century skills in addressing the challenges of 21st Century economic and technological progress (Tijani et al., 2021)(Kelley et al., 2021).

Technology-based modules have the potential to be effective in improving 21st Century skills, namely critical thinking, creative, collaboration and student communication (Nesri & Kristanto, 2020). The research conducted is in line with the leading research topics developed by the University in the field of Education, namely the development of learning, media, and evaluation of technology-based learning to improve the competence of lecturers and improve the quality of learning. The purpose of this development research is to create STEM-based digital modules that are made to be applied to the Freshwater Fisheries course, on each material topic into STEM activities that are integrated with the achievement of 21st Century skills. Integrating STEM in freshwater fisheries learning can facilitate students to grow 21st Century skills because STEM learning is learning with an integration pattern between science, technology, engineering and mathematics using real life contexts that can train students in higher-order thinking, exploring creativity, innovation, manipulative and affective and applying knowledge as a form of related problem-solving environment by utilizing technology (Cahyaningsih & Roektiningroem, 2018).

In the freshwater fisheries course, students' expected abilities are not only memorizing concepts about freshwater fisheries, but also students must be able to compile their own knowledge and be able to use knowledge to solve contextual problems. With STEM-based digital modules, where in its application the module facilitates students to be able to integrate four knowledge in the form of Science, Technology, Engineering and Mathematics, so that students can build their own knowledge (Diana & Turmudi, 2021; W et al., 2022). The aim of this research is to develop STEM-based digital modules focusing on freshwater fisheries and to foster the development of 21st-century skills such as problem-solving, collaboration, critical thinking, and creativity through the utilization of these modules. The e-modules provides an interactive and easily accessible learning resource to facilitate technology-oriented freshwater fisheries education.

Method

The research method used is Research and Development (R and D) design. The model used in this study is the PPE model, namely Planning, Production, and Evaluation (Richey & Klein, 2014). The stages of the PPE model are described as follows; planning, production, and evaluation. *Planning* means the activity of making plans for STEM-based digital biology modules integrated with 21st century skills. This planning begins with an analysis of the application needs of the STEM-based digital biology modules for prospective biology teacher students based on the results of previous research / literature studies. *Production* is the activity of making STEM-based digital biology modules products integrated with 21st century skills that will be used in the biology learning process. *Evaluation* is an activity to test how high the product of this research has met the feasibility and criteria as a digital-modules. Validation of this teaching product is carried out through *expert judgment* to find out whether this application is feasible or not suitable for use. Digital modules that have been validated can be known for their shortcomings which will then be corrected according to input from validators. There are 2 validators who validate or conduct *expert judgments*, namely media experts and content experts.

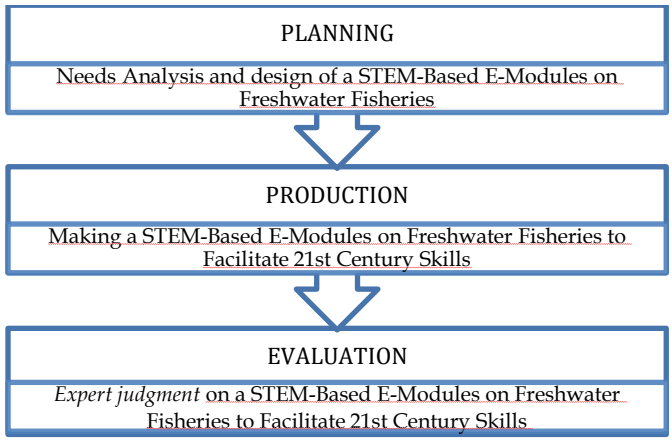

Figure 1. PPE Model Research Design

Research instruments used in the research "Development of Digital Modules of integrated STEM-based biology 21st Century Skills" include: Questionnaire sheet containing questions that researchers will ask biology students and lecturers at FKIP UNIKU to obtain information about the integrated

STEM-based biology Digital Module 21st Century Skills. The questionnaire used in this study is a type of closed questionnaire, because respondents only need to give answers to one of the alternative answers provided on a scale of 1-4, as for the criteria of Score 1 = Strongly Disagree (STS), 2 = Disagree (TS), 3 = Agree (S), 4 = Strongly Agree (SS).

The expert judgment *validation sheet* is used to determine the feasibility of the 21st Century Proficiency integrated STEM-based biology Digital Module. The statement submitted relates to the design of the application using answer choices, namely 5 (very good), 4 (Good), 3 (Enough), 2 (Less), 1 (Very Less) by marking a checklist (√) on the available alternative choices.

Data Analysis in this study uses qualitative data analysis techniques according to Miles & Huberman (1992) which consists of four stages, namely: data collection, data reduction, data presentation, conclusion drawing / verification (Dull & Reinhardt, 2014). Data collection was carried out based on research instruments using questionnaire sheets and expert team validation sheets. Data reduction was carried out to summarize the data from validation results and the questionnaire to provide a clearer picture and focus on the needs of developing integrated STEM-based e-modules for 21st Century Skills. Data processing of validation sheet results is carried out by calculating the percentage of answers from media and material experts. The validation sheet answers use a Likert scale consisting of alternative answers 1-5. The conclusion of the feasibility assessment is obtained after calculating the percentage of data. The formula used to calculate the percentage of data is as follows (Formula 1).

$$P = \frac{\sum x}{\sum xi} \times 100\% \quad (1)$$

(Arikunto & Jabar, 2018)

Information:

P = Percentage score

∑x = Number of scores obtained

∑xi = Number of ideal scores

100% = Absolute number

The interpretation of the calculation data in this study refers to the following assessment criteria:

Tabel 1. E-module Validity Criteria

Percentage (%)	Category
81-100	Very Valid
61-80	Valid
41-60	Valid Enough
21-40	Invalid
0-20	Invalid

In addition to the validity result data, questionnaire data was also obtained to determine the responses of teachers and students regarding the practicality of the products developed. questionnaires filled out by teachers and students who have carried out learning using STEM based e-modules. To determine the practical value of STEM based e-modules, it is determined using modified criteria from (Lestari et al., 2021) which can be seen in Table 2.

Table 2. E-module Practicality Criteria

Practicality Value (%)	Category
81-100	Very Practical
61-80	Practical
41-60	Practical Enough
21-40	Less Practical
0-20	Impractical

The presentation of data is carried out by gathering information organized to enable drawing conclusions and taking action. The findings are then described to make them more systematic and easy to understand. At this stage, data validation is conducted where validators will provide input on the shortcomings of this integrated STEM-based biology digital module for 21st-century skills to then be refined/revised. Conclusion Drawing is an activity of a complete configuration based on the results of data presentation and data processing results. These conclusions were also verified during the study.

Result and Discussion

The results of this study are in the form of a STEM-Based E-Modules on Freshwater Fisheries which was developed using the PPE research model, namely Planning, Production, and Evaluation (Richey & Klein, 2014). At the Planning stage, the research team made a product plan for a STEM-Based E-Modules on Freshwater Fisheries. At this stage, the research team determined the five module components, including; course learning outcomes (CPMK), learning activities (implementation, concept, application and reflective). At the application stage integrated with 21st century skills including; critical, creative, collaboration, communication. In addition, the team conducted a needs analysis in the field that most students in the Biology Education Study Program used Android smartphones more often than reading books in printed form. It becomes the basis for the team to develop E-modules that can be easily accessed on student smartphones. Students can use and read e-modul anywhere. This STEM-based freshwater fisheries e-module facilitates students to be able to integrate four knowledge in the form of Science related to freshwater fisheries, Technology in the field of freshwater fisheries, Engineering in the field of freshwater fisheries and Mathematics about calculating various kinds of data

related to freshwater fisheries, so that students can build and apply their own knowledge about freshwater fisheries in everyday life (Diana & Turmudi, 2021; Dotimineli & Mawardi, 2021; Rungkat et al., 2023).

The second stage of the PPE model is production, at this stage the e-modules that have been designed are started to be developed. The e-modules is developed with canva application. It is expected that canva application can be used using an Android smartphone or computer with the aim of taking advantage of students' habits in using their smartphones. The layout example of the modules design is shown in Figure 2.

Figure 2. Designing E-modules Using Canva

The last stage is Evaluation, before being used in research, the module has been tested for feasibility by two media validators and two content validators and an assessment of the level of practicality using user questionnaires (lecturers and students). The average validator score is used to check the validation score of the e-module, which is then converted into a validation criteria interval. The assessment of STEM-based e-modules is assessed based on aspects of content quality, language, appearance, and learning aspects. The correction results from validators were then revised, before this STEM-based e-module was implemented in a limited trial class (Ulya et al., 2023). The evaluation results from validators and users are as follows (Figure 3).

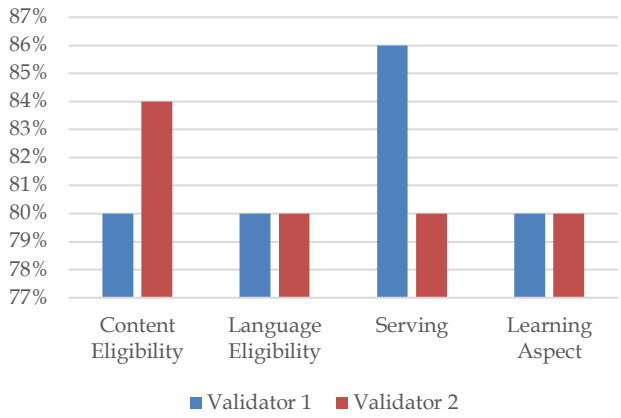

Figure 3. Validation Result from Content Expert

Based on figure 3, it explains that the validation results from material experts obtained an average score from 2 validators on the aspect of presenting STEM material, which is 83%, on the aspect of content feasibility which is 82%, then the average score on language and learning aspects is 80%. In general, the validation results are in the valid category.

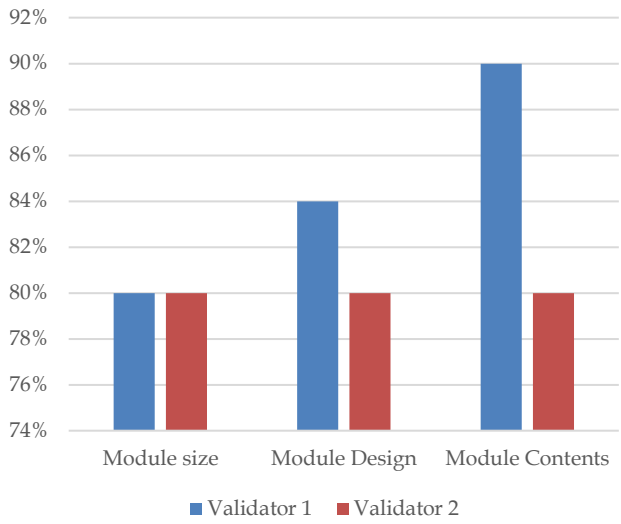

Figure 4. Validation Result from Media Expert

Based on Figure 4, it explains that the validation results from media experts are obtained from the average score of 2 validators on the module size, which is 80%, on the module design aspect which is 82%, then the average score on the module content aspect is 85%. In general, the validation results are in the valid category.

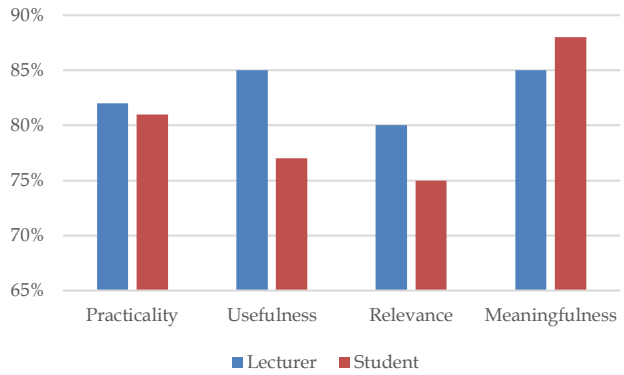

Figure 5. Questionnaire Result

Based on Figure 5, it explains that the results of questionnaires from teachers and students. The average score of the teacher questionnaire is 83% while the average score in students is 80%. In the practicality aspect, an average score of 82% was obtained, the usability aspect was 81%, the relevance aspect was 78%, and the meaningful aspect was 87%. In general, the results of evaluation by users are in the practical category. The advantages of using e-modules in the process include; flexible learning time and place, e-module access can be online and offline, interactive features, edutainment value, cost-effective printing, Interactive Assessment using quizziz applications, kahoot, and others (Trilestari & Almunawaroh, 2021).

STEM learning is very relevant to be applied in learning, because it has a positive impact on students' lives. In carrying out STEM learning, lecturers can provide opportunities for students so that they can develop creative ideas and develop them according to their areas of expertise. 21st century skills can be trained through STEM, so students can learn in-depth knowledge and make problem-solving solutions that are closely related to their lives (Khairati et al., 2021; Sukma et al., 2023). Students can benefit from it and apply the knowledge they learn directly in life. Through this STEM students receive a variety of information that can then create ideas and creativity to make a product (Sole, 2021). Based on the analysis of the freshwater fisheries e-module that has been developed, it provides students convenience, practicality in terms of use. E-modules supported by images, videos and colors can help students focus on the learning material so as to affect the level of understanding and attraction of students to the learning material (Irdawati et al., 2023).

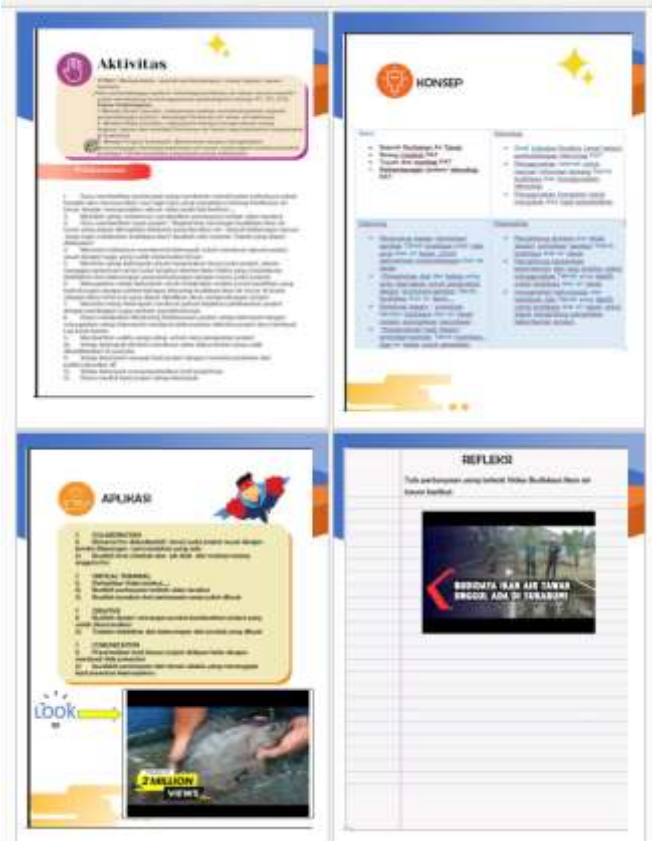

Figure 6. E-module Contents Display

The e-module developed is a complete teaching material that contains material, learning activities, learning videos, assignments and evaluations on freshwater fisheries material that integrates STEM to facilitate students' 21st Century skills. STEM-based teaching materials are innovative learning resources in accordance with curriculum demands and the characteristics of 21st Century learning (Moreland et al., 2006). STEM is very important for practicing 21st Century skills in overcoming the challenges of 21st Century economic and technological progress (Kelley et al., 2021). Learning and using teaching materials with a STEM approach can significantly have a positive influence in developing students' thinking skills (Becker & Park, 2011).

Figure 7. STEM Products

Through STEM learning on freshwater fisheries material, students are asked to make a product (figure 6). Products made by students are in the form of fish feed that utilizes organic waste. STEM products made by students can have selling points and train students' entrepreneurial spirit and creativity. So that the development of STEM-based e-modules developed can increase student entrepreneurial innovation (Sasmita et al., 2021). STEM-based e-modules facilitate students to practice 21st century skills such as critical thinking, creative, collaboration and communication abilities. STEM learning aims to carry out meaningful learning for students through systematic integration of knowledge, concepts, and skills so that students can create a product/work (Syukri et al., 2021).

Based on the analysis of the freshwater fisheries e-module that has been developed, it provides students convenience, practicality in terms of use. E-modules supported by images, videos and colors can help students focus on the Through STEM learning, students can increase science and technology literacy through reading activities, writing problem solving results, making observations and doing science so that it can be useful for developing skills to solve problems in everyday life (Utomo et al., 2017). STEM integrated into learning encourages students to work cooperatively to develop problem-solving skills, critical thinking skills and creatively demonstrate understanding of concepts in science learning (Morrison, 2006).

STEM-based E-modules can be used as alternative teaching modules used by students in studying freshwater fisheries courses, so that e-modules can make it easier for students to learn freshwater fisheries material anywhere and anytime because this e-module can be accessed using mobile phones or laptops. E-modules are learning innovations that use technology that helps create many effective learning solutions, increase access and flexibility (Lestari et al., 2021; Mirza et al., 2022). In accordance with the results of the development of a valid STEM integrated freshwater fisheries E-Module. Practical and suitable for use to facilitate students' 21st Century skills, especially in learning Freshwater Fisheries.

Conclusion

The results of validation by validators in the STEM-based freshwater fisheries E-Module include assessment results from media experts showing assessment results of 83% (very feasible) and assessment results from STEM content experts of 81% (very feasible). The results of the questionnaire by lecturers showed an average score of 83% (practical) and the results of questionnaires by students show an average score of 80% (practical). Based on the results of the study, it can be concluded that the developed STEM-Based E-Modules on Freshwater Fisheries can facilitate students to practice 21st century skills. Through STEM, students can make a STEM product using freshwater fishery materials in the form of fish food that utilizes organic waste. STEM also encourages creativity and an entrepreneurial spirit in students.

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Author Contributions

I.S, R.W, A.F.H and E.J devised the STEM-based E-Modules on freshwater fisheries courses , I.S and A.F.H methodology. ; R.W and E.J create validity instruments and analysis.; I.S ; writing original draft article about development of STEM-Based E-Modules on Freshwater Fisheries to Facilitate 21st Century Skills, A.F.H, R.W and E.J; review and editing, I.S.; administration & funding acquisition

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Conflicts of Interest

The research team stated that no conflict of internal and LPPM Universitas Kuningan had no role in the designing the study; in the data collection, analysis, or interpretation of data; make of scriptwriting; or in making decisions to publish research results in this Journal.

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