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Original Research Article

Development of e-module based on *Premna serratifolia* research to identify functional group of secondary metabolites

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ABSTRACT

The absence of self-learning resources tailored to the characteristics of students to study the identification of secondary metabolite functional groups based on research on medicinal plants in West Kalimantan necessitates the development of an e-module. This research aimed to develop an e-module based on *Premna serratifolia* research to identify functional groups in the Natural Products Chemistry course, ensuring its validity and practicality. The ADDIE model was followed, which included analysis, design, development, implementation, and evaluation stages, to develop this e-module. Data were collected using an indirect communication technique by distributing questionnaires. The research sample comprised 30 participants from Universitas Muhammadiyah Pontianak, Universitas Tanjungpura University, and Akademi Farmasi Yarsi Pontianak. The e-module was validated by nine validators, including subject matter experts, media experts, and language experts, with a validity score of 89.3%, indicating it is highly valid. The module was also found to be highly practical through individual, small-group, and large-group testing, with scores of 95.6%, 94.3%, and 98.3%, respectively. This research-based e-module is considered highly suitable and practical as a learning resource for identifying functional groups.

Introduction

In the era of Society 5.0, science and technology are advancing rapidly, especially in the realm of education. As such, it is crucial to improve learning methods by providing valuable educational materials. One promising solution is e-modules, which are digital versions of printed modules that offer support to students on their academic journey, both individually and collaboratively. These modules are highly effective tools for learning chemistry, and by integrating them into their curriculum, educators can enhance the teaching and learning process, making it more engaging and efficient for students (Kuncahyono, 2019; Azkiyati et al., 2022).

The lack of learning resources supporting education is perceived by students taking the Natural Products Chemistry course at three universities located in Pontianak. This information was obtained from a survey conducted on September 8-10, 2023, involving both students and lecturers. Commonly used learning resources include books, scientific articles, and PowerPoint presentations. Students encounter difficulties in using scientific articles as learning resources due to the time required to find suitable references and translate them into Indonesian, as well as the challenge of understanding detailed interpretations of chromatograms and spectra. The utilization of learning resources in the learning process is also considered an effort to improve the quality of student learning outcomes (Ramadhan and Khairunnisa, 2021). Therefore, the development of research-based learning resources is needed to facilitate the learning process of students in the Natural Products Chemistry course. One of the topics taught in this course is Functional Group Identification. Research on functional group identification in Buas-buas or *Premna serratifolia* (*P. serratifollia*), known as a medicinal plant by the community, could be one initiative for the development of such learning resources.

P. serratifolia leaves have been traditionally utilized for various medicinal purposes such as treating stomachaches, headaches, hypertension, diabetes, respiratory difficulties, malaria, and enhancing breastfeeding (Hasanah et al., 2015; Dianita and Jantan, 2017; Hadiarti, 2022). Additionally, it has been found to possess antifungal (Wahyuni et al., 2014), larvicidal (Lestari et al., 2014), analgesic effects (Hasanah et al., 2015), analgesic (Hasanah et al., 2015), antioxidant (Isnindar et al., 2016), and hepatoprotective properties (Asri and Kalsum, 2021). The functional group identification of *P. serratifolia* extract using FTIR has revealed various functional groups such as OH, alkane CH, aldehyde HC=O, carbonyl C=O, aldehyde C=O, sp2 CH, sp3 CH, and alkane C=C C alkana (Tonius et al., 2016; Hadiarti et al., 2015; Shalihin et al., 2022). Therefore, *P.*

serratifolia has become an important characteristic plant of West Kalimantan, which can be utilized as an effective teaching material for Natural Product Chemistry.

The development of a research-based e-module by (Ersando et al., 2022) on the Separation of Phenolic Compounds from Water Extract Fractionation using Preparative Thin Layer Chromatography (TLC) as a Learning Resource for Natural Product Chemistry has been carried out with criteria feasibility in terms of material, media, and language reaching 100%. The validity of other research-based e-modules has also been assessed by media and material experts, achieving 95% and 98%, respectively, and also having a readability level of 88% on the Antimicrobial Test material in Microbiology courses (Ummah et al., 2020). Other research modules have also been evaluated to have high validity in terms of media aspects at 93.90% and material aspects at 97.48% (Manampiring et al., 2020). The use of e-modules has advantages in learning, such as higher interactivity (Abidin and Walida, 2017), facilitating understanding through images and videos, and enhancing 21st-century skills such as critical thinking (Suarsana and Mahayukti, 2013), and skills in the scientific process (Ditasari et al., 2013; Jumadi et al., 2018). Thus, the use of research-based e-modules has been proven valid and practical as a learning resource.

The research is important to create learning resources that are more suitable for the learners, considering their characteristics and needs. The use of *P. serratifolia*, a plant that the learners are already familiar with, is expected to increase their knowledge and appreciation of the natural resources in West Kalimantan. The learning resources will be created using e-modules, which are expected to make the learning process more convenient for the learners and easier for the instructors to deliver the content.

Methods

This study is categorized as Research and Development (R&D) and utilizes the ADDIE development model, comprising of four stages, namely analysis, design, development, and evaluation, as referenced by Manampiring et al. (2020), Ummah et al. (2020), and Ersando et al. (2022). During the analysis phase, the learning requirements of students are evaluated concerning the learning materials used in the subject, with the participation of 31 students and 7 instructors. The design phase entails the development of the initial design, the creation of validation instruments, and assessment of the practicality of the e-module. In the third stage, the validation of the e-module is conducted by nine experts specializing in content, media, and language. The validity assessment is executed through a Likert scale ranging from 1 to 4. The scores provided by validators are then processed to derive a percentage, as per the formula below:

$$P=\frac{\sum X}{\sum Xi} \times 100\%$$

Explanation: P : Percentage; ∑X : Total score obtained; ∑Xi: Total maximum score

The validation process of the e-module's language, media, and content is determined by the criteria outlined in Table 1. Following validation by experts, the e-module is revised accordingly. During the implementation phase, feedback is obtained from students through a Likert scale questionnaire with a range of 1-4. The student responses are measured three times in individual, small group, and large group trials, which are conducted at Muhammadiyah Pontianak University, Tanjungpura University, and Yarsi Pontianak Pharmacy Academy. The scores are then processed using the same validity formula and compared against the criteria specified in Table 2. In the final stage, the researcher evaluates the e-module's final revisions based on the feedback obtained from the respondent questionnaire results.

Table 1. Validity category (Rohmad et al. 2013)

Average scores	Classification
75% - 100%	Valid
50% - 74.99%	Quite Valid
25% - 49.99%	Not Valid
0% - 24.99%	Invalid

Table 2. User response (Sari and Alarifin, 2016)

Average score	Classification
75% - 100%	Very Good
50% - 74.99%	Good
25% - 49.99%	Low
0% - 24.99%	Not Good

Results and Discussion

Analysis Stage

The primary objective of this stage is to obtain a comprehensive understanding of the learning conditions that students encounter in the Natural Product Chemistry course. Referring to the questionnaire distributed to 31 students from 3 universities in Pontianak, scientific articles, teaching modules, YouTube, Google, and PowerPoint are learning resources used in learning Natural Product Chemistry. There 62% of students have difficulty identifying functional groups because the PowerPoint used only contains photos and writing. Apart from that, students also have difficulty understanding English language articles, coupled with the lack of explanation about the stages of FTIR spectrum interpretation. As many as 65% of the 31 students access the internet for 7-8 hours every day. Apart from using PowerPoint and scientific articles, learning also

uses videos to teach functional group identification material based on questionnaires given to lecturers at 8 universities in Indonesia. Therefore, there is a need for learning resources based on research that provides detailed information from lecturers' explanations in class and makes it easier for students to learn the identification of functional groups.

Design Stage

The development of the e-module design is conducted to provide a general overview of the content/material, graphic design, text size, color, and aesthetics of the e-module itself to capture the attention of learners. The first step in the development phase is to outline the framework of the e-module. The e-module is created using the Word application on A5 paper size. The font type used is Arial with a size of 10 and spacing of 1.15. The content format of the e-module consists of a cover with a picture of *P. serratifolia* illustrating the object to be identified. The second part continues with a preface, table of contents (Fig-1), course learning outcomes, sub-course learning outcomes, learning indicators, content, instructional videos, assignments, summaries, formative assessment, answer key for formative tests, glossary, references, index, about the author, and back cover. Afterward, the e-module will be converted into PDF format, which will then be turned into a flipbook through the Heyzine website. After the research-based e-module is completed, the next step is to consult it with the supervising lecturer. To assess the validity and practicality of the e-module, the assessment instrument prepared is validated by three experts. After revising sentence structures, such as adding the phrase "clearly" to the statement "Audio in the e-module is audible," and replacing "PUEBI" with "EYD," the instrument is deemed highly valid with a score of 96.3 %.

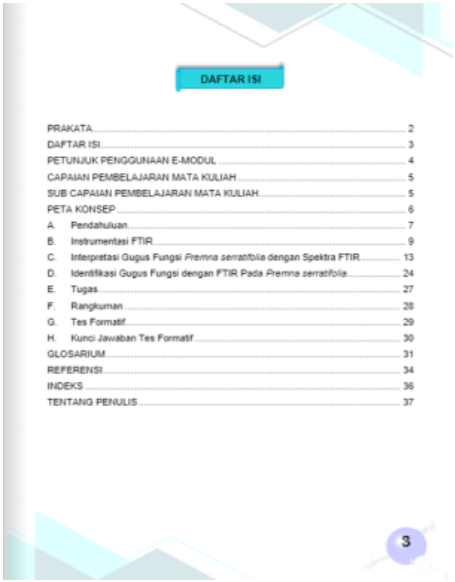


Fig-1. E-Module content

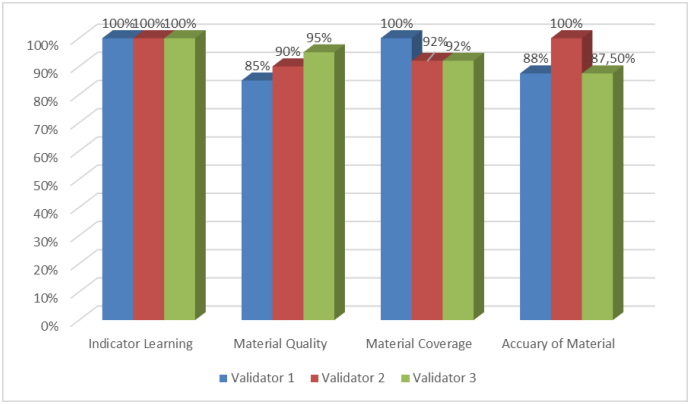


Fig-2. Content feasibility assessment results of the e-module

Development Stage

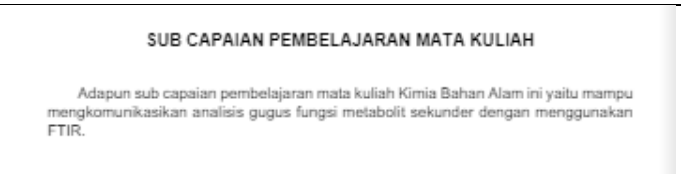
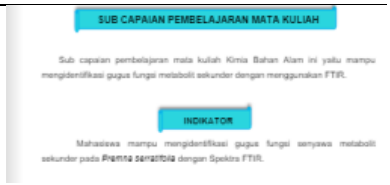
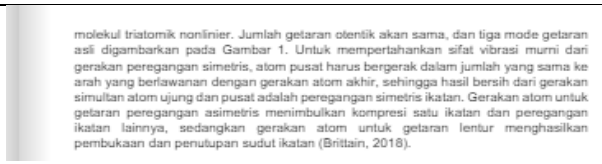
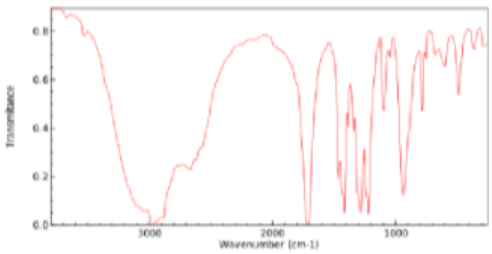
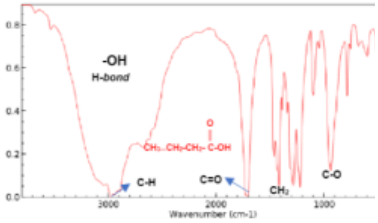
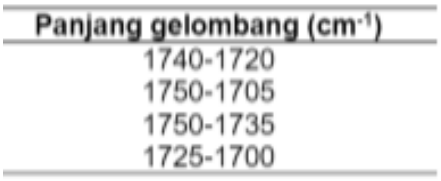
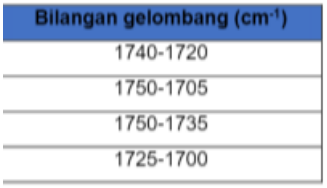
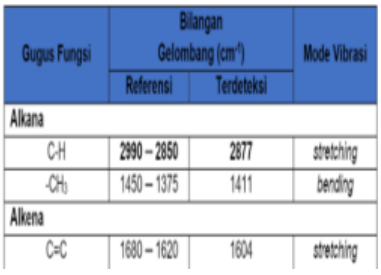
After the e-module is designed, the next step is to conduct a feasibility test of the e-module by 9 validators consisting of subject matter, media, and language experts. Based on the validators' assessments, the e-module is deemed highly valid with a percentage of 89.3%. This validity result is lower than the research conducted by (Ersando et al., 2022), which achieved 100%, as the assessment was done twice, before and after improvements, involving 7 validators.

Content Aspect

Fig-2 lustrates the results of the material feasibility assessment on aspects such as learning indicators, quality, coverage, and accuracy by three organic chemistry experts, particularly in natural material analysis. The learning indicator aspect received

the highest score with an average of 100%, while the material quality obtained the lowest score at 90%. Validators suggested improvements by adding indicators after the sub-course learning outcomes and including types of vibrations such as stretching and bending. Additionally, improvements are needed in replacing the term "wavelength" with "wave number," adding wave number figures to each spectrum image, and enhancing the resolution of FTIR spectrum images to facilitate students' understanding of the data. In the answer key section, the table also needs to be revised to be more systematic and easily understandable (Table 3). The average score of the e-module material feasibility is 94%, falling within the category of highly valid.

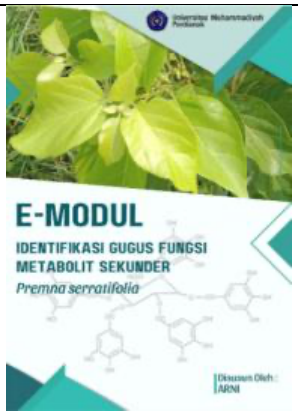
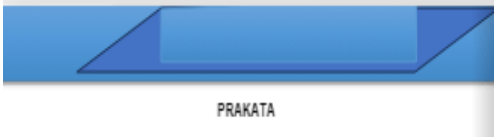
Table 3. Material expert revisions

Suggestions	Before Revision	After Revision
"Added learning indicators after each learning sub-objective."		
"Added more detailed information on types of vibrations such as stretching, bending, and others."	 molekul triatomik nonlinier. Jumlah getaran otentik akan sama, dan tiga mode getaran asli digambarkan pada Gambar 1. Untuk mempertahankan sifat vibrasi murni dari gerakan peregangan simetris, atom pusat harus bergerak dalam jumlah yang sama ke arah yang berlawanan dengan gerakan atom akhir, sehingga hasil bersih dari gerakan simultan atom ujung dan pusat adalah peregangan simetris ikatan. Gerakan atom untuk getaran peregangan asimetris menimbulkan kompresi satu ikatan dan peregangan ikatan lainnya, sedangkan gerakan atom untuk getaran lentur menghasilkan pembukaan dan penutupan sudut ikatan (Brittain, 2018).	
"Include the peak wavenumbers on each spectrum image."		
The term "Wavelength" is changed to "Wavenumber".		
"The table in the formative test answers is revised to be more systematic and understandable."		

Media Aspect

Three media experts gave a score of 89% to the e-module regarding aspects such as cover design (cover layout, typography, cover illustration, and color usage), content design (clarity of content), and multimedia (audio and video), categorized as highly valid, as shown in Fig-3. The highest score, with an average of 91.6%, was given by validators for the content design aspect, while the lowest score of 87.6% was given for multimedia. Validator suggestions include adding molecular images to the cover illustration, exploring different font types, and combining colors to make the e-module more appealing. Improvements to the e-module are presented in Table 4 by adding quercetin molecules to the cover and adjusting the content colors to match the cover, as well as the need for exploring other fonts.

Table 4. Media expert revisions

Suggestion	Before Revisions	Setelah revisi
"Add molecule images to the cover."		
"Revise the content of the e-module and adjust it to match the color of the e-module cover."		

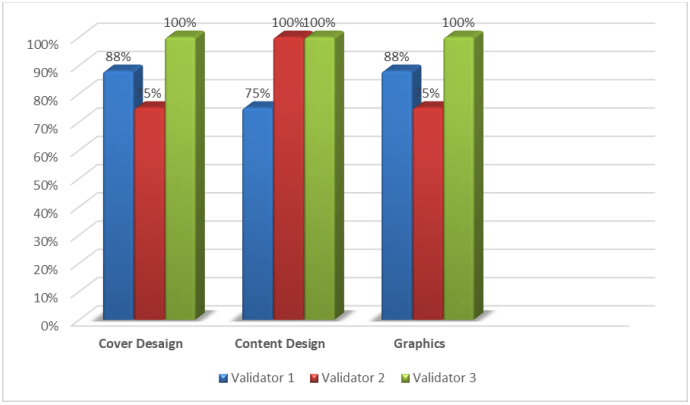


Fig-3. E-module media feasibility assessment results

Language Aspect

The conformity with the norms of the Indonesian language, communicativeness, and clarity obtained a score of 85% with a highly valid category by three language experts. Fig-4 shows that the aspect of conformity with the norms of the Indonesian language received the highest percentage with an average of 87.6%, while the communicative aspect obtained the lowest score with a percentage of 80.6%. The language used should be easy to understand (Rahim, 2021) as well as effective, unambiguous, and clear (Rahim, 2021). Based on suggestions from language experts, attention should be paid to the Revised Spelling (EYD) for writing capital and bold letters in titles and subtitles, punctuation such as commas (,), colons (:), exclamation marks (!), and italicized letters. It is also important to pay attention to the use of the preposition "di" with words indicating location. Each paragraph should ideally consist of a minimum of 3 sentences and a maximum of 8 sentences while avoiding the use of repetitive words. Suggestions and improvements from language experts are displayed in Table 5.

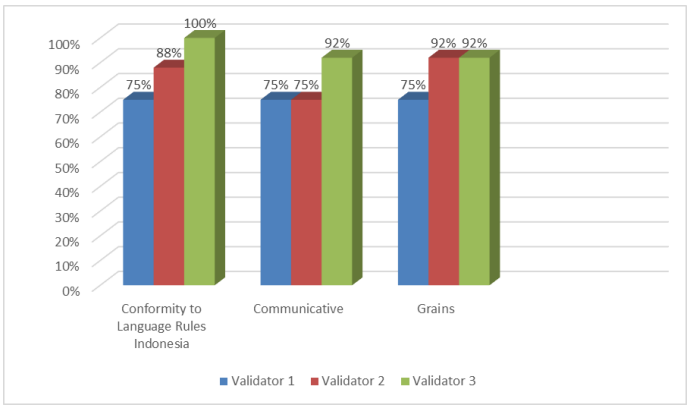
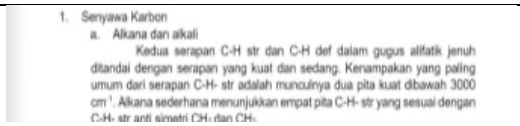
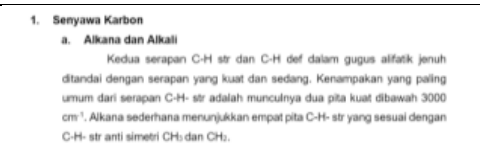
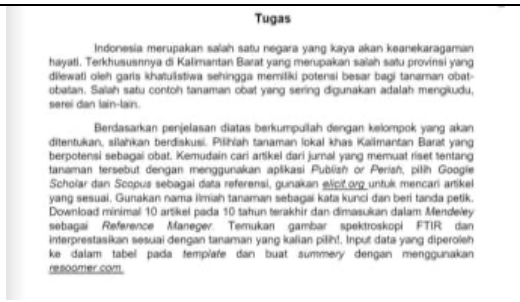
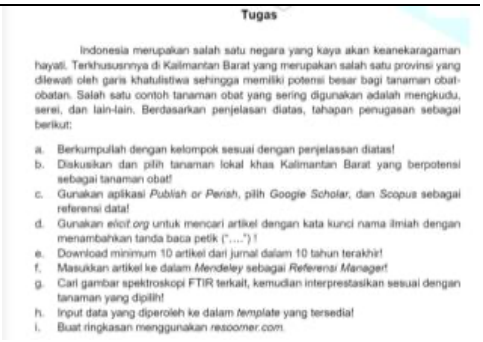
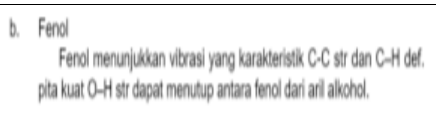
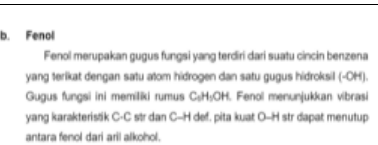


Fig-4. Language feasibility assessment results for e-module

Implementation

The implementation of the research-based e-module on *P. serratifoli*a was carried out by distributing the e-module via WhatsApp to students who had studied the functional group identification material. The e-module was accompanied by an introduction introducing the researcher and requesting students to read the e-module and fill out response questionnaires. A total of 3 students were involved in individual pilot testing, while 9 and 18 students participated in small and large group pilot testing from Muhammadiyah University of Pontianak, Tanjungpura University, and Yarsi Pontianak Pharmacy Academy. Individual pilot testing was conducted on April 23-24, 2024, while small group pilot testing was conducted on April 25-27, 2024, and large group pilot testing was conducted on April 28-30, 2024. The results of the pilot testing provided a score of 96.3% with a highly practical category from the assessment of 30 students. The responses given by students in this study were higher compared to previous research that developed research-based e-modules with practicality scores of 95.61% and 88% (Manampiring et al., 2020; Ummah et al., 2020) with practicality scores of 95.61% and 88%. This is because the number of respondents used in small and large group testing was significantly different, namely 10 and 20 respondents.

Table 5. Language expert revisions

Suggestion	Before Revisions	After Revisions
"Each material point should be in bold."		
"In the Task instructions, it's better to create bullet points for better organization."		
"A paragraph should consist of a minimum of 3 sentences."		

Individual Testing

The results of individual pilot testing showed that the practicality percentage of the e-module reached 96.3% based on the aspects of usefulness, ease of use, and presentation as presented in Table 6. The usefulness aspect obtained the highest percentage score of 97.3%, while the ease of use aspect obtained the lowest score with a percentage of 95.6%. Students suggested improving the quality of the images in the e-module. Quality improvement of the images was carried out on the FTIR spectra to facilitate functional group determination.

Table 6. Results of individual testing

Aspect	Persentase	Category
Usefullness	97.3%	Very Practical
Convenience	95.6%	Very Practical
Appearance	95.8%	Very Practical
Average	96.3%	Very Practical

Small Group Testing

The e-module was deemed highly practical with a percentage of 94.4% by 9 students based on the aspects of usefulness, ease of use, and presentation as outlined in Table 7. The results of the small group testing showed a decrease from the individual pilot testing, with 4 students giving lower scores than in the previous test on the aspects of usefulness and presentation. One aspect of usefulness experienced a decrease from the previous test, while the usability aspect saw an increase. Suggestions and comments received from the small group testing included improvements to writing errors and the appropriate use of capital letters.

Table 7. Results of small group testing

Aspect	Persentase	Category
Usefullness	90%	Very Practical
Convenience	98%	Very Practical
Appearance	95%	Very Practical
Average	94.3%	Very Practical

Large Group Test

Table 8 shows the results of the large group testing with a percentage of 98.3%, categorized as highly practical by 18 students. These results indicate an increase from the small group testing by 4% in the aspects of usefulness and presentation. Three individuals gave lower scores than the previous test, specifically on the convenience aspect in statements numbered 4-7. The usefulness aspect received the highest percentage score of 99%, while the intuitiveness aspect received the lowest percentage score of 97.5%. There were no comments or suggestions for improvement from respondents in the large group testing.

Table 8. Large group test result

Aspect	Persentase	Category
Usefullness	99%	Very Practical
Convenience	97.5%	Very Practical
Appearance	98.6%	Very Practical
Average	98.3%%	Very Practical

Evaluation

During this stage, only minor revisions were incorporated based on the feedback received from each respondent. This is because evaluation has been carried out implicitly at each stage of the process. It implies that evaluation is always conducted before moving on to the next stage, starting from the analysis stage through to implementation. As a result, the evaluation outcomes from the previous stages will function as an input for the subsequent stages.

Conclusion

According to the research, the e-module learning resource on Functional Group Identification in the Natural Product Chemistry course, developed using the ADDIE model, meets the criteria for excellent validity and practicality. The average validity score reached 89.3%, categorized as highly valid, consisting of material validation at 96.3%, media at 94.37%, and language at 98.3%. Based on its practicality score averaging 96.3%, individual testing scored 96.3%, small group testing scored 94.3%, and large group testing scored 98.3%. Therefore, it can be concluded that the developed e-module is an effective learning resource that helps students understand the material on Functional Group Identification in the Natural Product Chemistry course.

Conflict of Interests

The authors declares that there is no conflict of interest in this research and manuscript.

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