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Development of E-Supplement Biomordant from Several Species of Ferns (*Pteridophyta*) as A Teaching Material for Green Chemistry Course

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Abstract

The purpose of this study was to determine the feasibility of Green Chemistry E-Supplement with material Biomordant from Several Species of Ferns (*Pteridophyta*). The method used in this research is Research and Development (R&D). The e-supplement teaching material development model used is ADDIE. The subject of this research is Green Chemistry E-Supplement with material Biomordant from Several Species of Ferns (*Pteridophyta*). The data collection techniques used were direct communication and measurement techniques. The research instrument used was a feasibility assessment sheet and data analysis using a Likert scale. The feasibility of e-supplement was assessed by two validators. The final results of the feasibility assessment in the aspects of material, media, and language obtained a percentage of 98%. So, it can be concluded that the Green Chemistry E-Supplement with material Biomordant from Several Species of Ferns (*Pteridophyta*) is very feasible.

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INTRODUCTION

Learning refers to a series of programs arranged by educators with the aim of teaching individuals or groups through various efforts, strategies, methods, and approaches to achieve planned goals (Akrom & Istiq'faroh, 2021). The learning process is divided into two main activities, namely learning activities and teaching activities. In learning activities, there is a lot of emphasis on students as active individuals in an effort to gain insight and knowledge in learning activities. Meanwhile, teaching activities emphasize a lot on educators as people who try to convey insights and knowledge in learning activities. In learning activities, educators and students need facilities or tools such as teaching material (Arif & Rukmi, 2020).

Teaching material are one of the main tools in learning activities. The teaching material contain learning materials that are designed in such a way as to have interesting and systematic elements to achieve several expected competencies. As one of the main tools in learning activities, teaching material can be used as a measuring tool for the success of a learning activity. In a learning activity, teaching material can be said to be the main aspect in the learning process in the classroom. The use of teaching material can help educators and students in learning activities. One type of teaching material that can be utilized in learning activities is supplementary books (Arif & Rukmi, 2020). According to Sothayapetch et al., (2013) books play an important role in the learning process.

Minister of National Education Number 2 of 2008 article 6 (2) states that in addition to textbooks, educators can use educators' guidebooks, enrichment books, and reference books in the learning process. According to Abdillah et al., (2020) companion books or student supplement books are learning resources that can be used as a complement that can increase students' understanding of the subject matter. Supplement books are books that can enrich and improve mastery of science and technology, skills, and shape the personalities of students, educators, education managers, and other communities. This type of book is not solely intended for students but can also be used by other parties or society in general. Supplement books are needed to increase learners' creativity and knowledge. In learning, many sources are needed so that learners' knowledge develops, not only the cognitive aspects but also the application and application (Rizki et al., 2016).

Ferns (*Pteridophyta*) are plants that are easily found in West Kalimantan. Some ferns can be used as natural dyes (Andries et al., 2022). According to Lestariningsih et al., (2021) ferns or ferns have leaf dyes that can be used as natural dyes for textile products through the ecoprint technique. Based on previous research, some of the fern species contain secondary metabolites including tannins, this was explained by Swandi & Salmi, (2023) that the methanol extract of resam fern leaves *(Gleichenia linearis*) contains tannin compounds. Furthermore, in the research of Shah et al., (2014) the extract of uban fern leaves *(Nephrolepis biserrata*) in methanol solvent found tannin compounds, besides that in the leaves of dayak ferns (*Blechnum orientale*) also found tannin compounds (Lai et al., 2010).

Lestari et al., (2020) explained that tannin compounds can have potential as a mordant material in natural coloring. In addition, tannins can also be used as textile dyes in fabrics (Hong, 2018). Tannin that act as mordant have a tendency to color, so they can strengthen the overall color of the fabric. The use of natural mordant (biomordant) is done to prevent the impact caused by metal mordants where the metal is ecologically dangerous considering the residue is discharged directly into the environment (Adu et al., 2022). According to (Permatasari & Lestari, 2023) synthetic waste (chemicals) from textile dyeing is one of the problems still faced by society and the fashion industry today. The increased use of synthetic dyes produces hazardous chemical waste, the waste is difficult to decompose in final disposal which has an impact on environmental damage and public health.

One of the elective courses in the Chemistry Education Study Program, Faculty of Teacher Training and Education, Tanjungpura University is Green Chemistry. Green Chemistry is defined as a model in the process of making products by reducing or eliminating the use of chemicals (Ratnawati & Praptomo, 2023). In the higher education curriculum, Green Chemistry is important in preparing for a more sustainable future, encouraging social responsibility, and encouraging innovation in chemistry and technology. In addition, the inclusion of Green Chemistry into the higher education curriculum is in line with global efforts to protect the environment (Azzajjad et al., 2024).

The Green Chemistry course focuses on thinking about chemistry to save the environment and the health of living things from the use of hazardous chemicals. In the Green Chemistry course, it is based on 12 principles which are important steps towards environmental conservation and sustainable development. Based on the results of interviews with lecturers teaching Green Chemistry courses, currently students do not have Green Chemistry course e-supplement books, the lack of teaching materials is currently a limitation for students in mastering the concepts and skills taught. In addition, in learning Green Chemistry students do not know the substance of Green Chemistry and the lack of knowledge about the use of natural materials around. So that the Green Chemistry E-Supplement with material Biomordant from Several Species of Ferns (*Pteridophyta*) is needed in learning, the purpose of developing this e-supplement is able to overcome students' difficulties in understanding the context of sustainable

Green Chemistry, increase students' insight and knowledge in preventing the negative impact of hazardous chemicals and can foster student interest and motivation in learning. With the e-supplement, it is hoped that the learning objectives of Green Chemistry will be achieved.

METHOD

The method used in this research is Research and Development (R&D). The e-supplement teaching material development model used uses ADDIE. The ADDIE model development research type is the steps or process to develop and produce a new product. In addition, the ADDIE model development research aims to improve existing products (Arif & Rukmi, 2020). The reason for using the ADDIE development model is because it is simple and easy to learn and its structure is systematic (Muliani et al., 2019). The ADDIE development model has five stages including Analysis, Design, Development, Implementation, and Evaluation (Cahyadi, 2019). However, in this study, the implementation stage was not carried out because the development in this study was only to determine the feasibility level of the e-supplement. The flow of the ADDIE model stages according to Branch, (2009), can be seen in Figure 1.

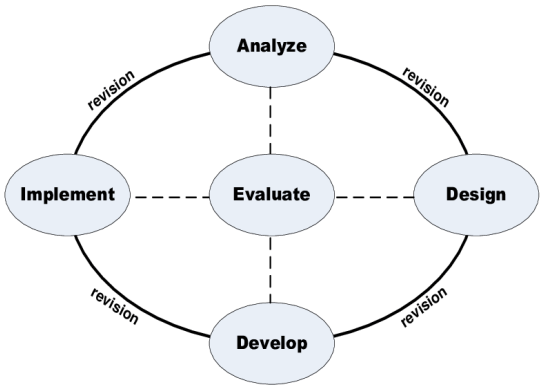


Figure 1. Steps of the ADDIE Model

The first stage is the analysis stage. The analysis stage carried out is problem analysis and needs analysis. At this stage, direct interviews were conducted with lecturers teaching Green Chemistry courses regarding teaching material used in Green Chemistry courses. The second stage is the design stage. The design stage is carried out by making a media design in the form of a storyboard, determining the format of the e-supplement that will be made both the writing format and the content/material format, then compiling a feasibility assessment sheet (Ersando et al., 2022). The third stage is the development stage. The development stage is carried out to realize the product that has been designed and assess the feasibility of the product (Kurnia et al., 2022).

The product that will be produced from this research is additional teaching material in the form of Green Chemistry E-Supplement with material Biomordant from Several Species of Ferns (*Pteridophyta*). The product that has been produced is then validated by testing its feasibility based on material, media, and language aspects. The feasibility of the product was assessed by two validators. The last stage carried out is evaluation. The evaluation stage is carried out at each stage of analysis, design, to development. The evaluation carried out at this stage is formative evaluation. In this evaluation, improvements (revisions) are made at each stage including analysis, design, and development (Nukila et al., 2022).

Data collection techniques in this study used direct communication techniques and measurement techniques. Direct communication techniques by conducting direct interviews with lecturers teaching Green Chemistry courses. The measurement technique was carried out by two validators by filling in the feasibility assessment sheet of the e-supplement that had been designed. The research instrument used was a feasibility assessment sheet. Instruments

are used to collect data needed to assess products (Puspasari & Suryaningsih, 2019). The data analysis used is a Likert scale (1-4). After obtaining the assessment data, the data was then interpreted with certain criteria (Table 1).

Table 1. Criteria for interpretation of feasibility assessment scores

Assessment Score	Criteria
76%< X ≤ 100%	Very feasible
51% < X ≤ 75%	Feasible
26% < X ≤ 50%	Not feasible
0%< X ≤ 25%	Very unfeasible

(Nurdiana et al., 2023)

The formula used to calculate the percentage of product feasibility is as follows.

$$P=\frac{f}{N}\times 100\%$$

Description:
P : percentage of feasibility
f : score obtained from the validator
N : maximum score
(Hidayat et al., 2022)

RESULTS AND DISCUSSION

Product development is carried out using the ADDIE model. In this study, the ADDIE model used was evaluating the analysis, design, and development sections. The implementation stage has not been applied in this study. The stages carried out in the ADDIE model include the following.

Analysis Stage

The analysis stage carried out is problem analysis and needs analysis. At this stage, direct interviews were conducted with lecturers teaching Green Chemistry courses regarding teaching material used in Green Chemistry courses. The results of the analysis show that students do not have complementary books (e-supplement) in Green Chemistry courses, complementary teaching material are needed to increase student creativity and knowledge. So that learning does not only focus on certain teaching material sources, it is necessary to have varied learning resources such as e-supplement that can deepen student understanding.

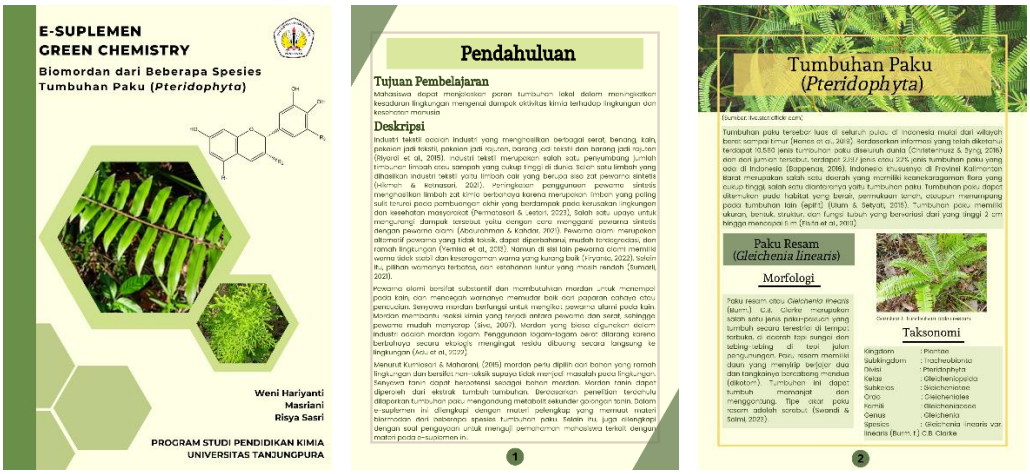
Design Stage

The design stage is carried out by making media designs in the form of storyboards, determining the format of e-supplement, namely the writing format and content/material format, and compiling feasibility assessment sheets. The preparation of the feasibility assessment sheet was carried out by compiling aspects and assessment indicators that would be given to the validator lecturer to determine the feasibility of the developed e-supplement.

Development Stage

The development stage in this study includes the development of e-supplement products and product feasibility test assessments. At this stage the validator provides criticism and suggestions which are then used as input and further revisions are made (Saski & Sudarwanto, 2021). The software used in making this e-supplement is *Canva*. Making e-supplement is tailored to the learning objectives. The selection of images, colors, words and sentences is also adjusted to the characteristics of the material, so that students can easily understand the content

of the e-supplement teaching material information. Green Chemistry E-Supplement Product with material Biomordant from Several Species of Ferns (*Pteridophyta*) can be seen in Figure 2.



(a) (b) (c)

Figure 2. Display of Green Chemistry e-supplement. a) display of the e-supplement cover; b) display of the e-supplement introduction section; c) display of the e-supplement material content

After making the product, the next stage is feasibility assessment and improvement. Feasibility assessment is carried out based on material, media and language aspects. The purpose of the feasibility assessment is to determine or measure the level of feasibility of the media that has been developed based on percentage criteria. The feasibility assessment of material, media, and language aspects was carried out by 2 validators. The results of the feasibility assessment of the three aspects obtained very feasible results with a percentage of 98% with very feasible criteria. Data on the results of the feasibility assessment of material, media, and language from the two validators can be seen in Table 2 below.

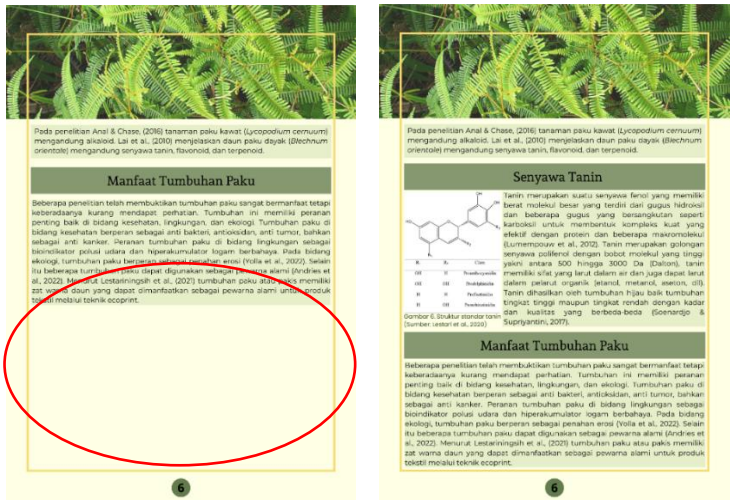
Table 2. Data from the assessment of the feasibility of material, media, and language from the two validators

Aspects	Number Statements	Assessment Score Validator 1	Assessment Score Validator 2
Material	1	4	4
	2	4	4
	3	4	4
	4	4	4
	5	4	4
Media	6	4	4
	7	4	3
	8	4	4
	9	4	3
	10	4	4
Language	11	4	4
	12	4	4
	13	4	4
Total score		52	50
Presentase		100%	96%
Average Percentage		98% (Very feasible)	

Based on the evaluation from the validator, there are several indicators in the e-supplement that need to be improved in all three aspects, namely:

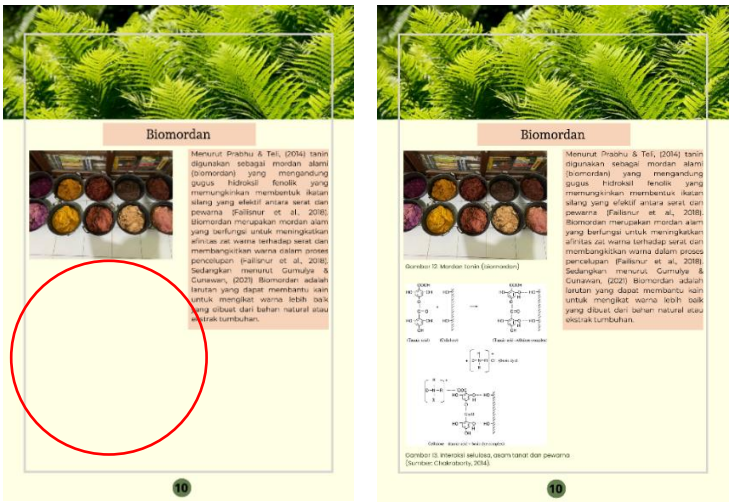
Material Aspect

In the material aspect, the material presentation indicator in the e-supplement needs to be improved by adding some sub-material content, namely about tannin compounds and biomordant reactions in binding with cellulose fibers and dyes. The addition of the content of the sub-material is done to help and clarify concepts that are difficult to understand in e-supplement. By providing a more detailed explanation, students will more easily understand the content of the learning material. According to Rahdiyanta, (2015), the presentation of the material must be complete and in accordance with the learning outcomes. Some of the revised e-supplement results on the material aspect can be seen in Figure 3 below.



Before revision After revision

(a)



Before revision After revision

(b)

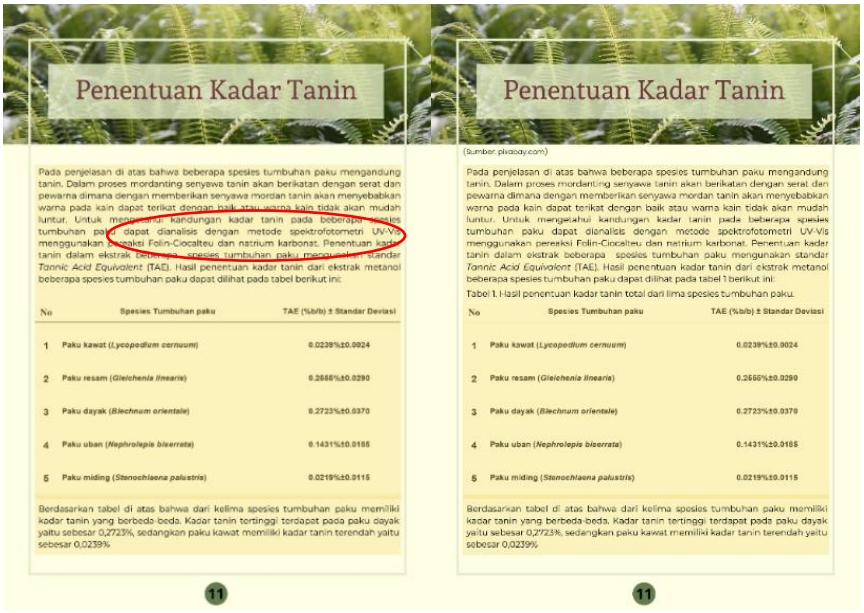
Figure 3. Revision of e-supplement on material aspect. a) revision of material on tannin compounds; b) revision of material on biomordant reaction

Media Aspect

In the media aspect, the visual display indicator of teaching material in e-supplement needs to be added to each picture and table. On images (which are not personal documentation) it is necessary to include the source to provide legality and disclosure of information about the images used in the e-supplement. In addition, the layout of the writing on the types of mordants needs to be improved by making the sentence into one sentence. Some of the revised e-supplement results on the media aspect can be seen in Figure 4 below.

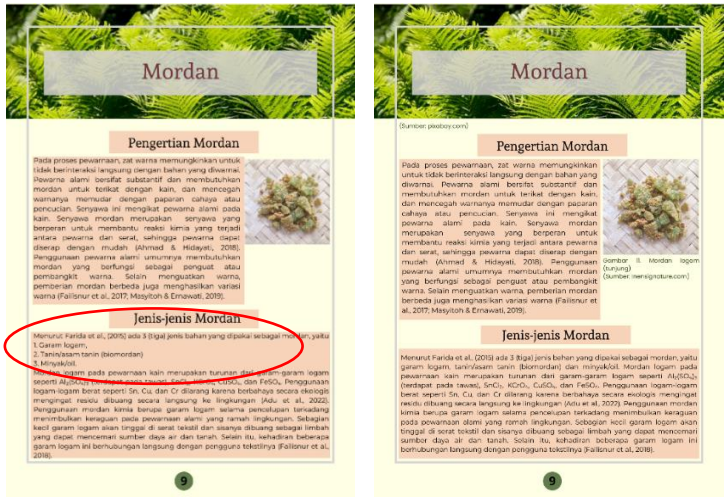
Before revision After revision

(a)



Before revision After revision

(b)



Before revision After revision

(c)

Figure 4. Revision of e-supplement on media aspect. a) revision of captions and sources on each picture; b) revision of table captions; c) revision of text layout

Language Aspect

In the language aspect, the straightforward indicator in the e-supplement needs to be improved on sentences that are less effective. According to Dina, (2015), effective sentences are correct and clear sentences that can be understood by others correctly. Some of the revised e-supplement on the language aspect can be seen in Figure 5 below.

Before revision After revision

Figure 5. Revised e-supplement on the language aspect of the effective sentence section

Based on the aspects that have been described, the Green Chemistry E-Supplement with material Biomordant from Several Species of Ferns (*Pteridophyta*) obtained a percentage of 98% with a very feasible category. This is in line with the research of Reski et al., (2016) regarding the development of local wisdom-based textbook supplement that get an assessment score of 84.58% which is included in the decent category with a good predicate. Then in the research of Sofia et al., (2022) the development of biology supplement books received an assessment score from experts with a percentage of 91.25% with a very feasible category. The

acquisition of the assessment of product development indicates that the product developed is feasible to use in learning as a media supplement.

This Green Chemistry e-supplement has advantages and disadvantages, the advantages given to this e-supplement are that it is more practical to use because it can be accessed easily via smartphone devices and computers. In addition, it is also equipped with questions so that it can train students' level of understanding. The weakness in this e-supplement is that it is only a simple text that contains sentences and images, not complete with audio visuals or others.

CONCLUSION

Green Chemistry e-supplement are declared feasible to use as complementary/supportive teaching material from the point of view of expert validators. The average percentage obtained from the two validators was 98% with very feasible criteria so that the e-supplement could be used in learning.

RECOMMENDATIONS

Updates are needed for the development of this Green Chemistry e-supplement such as the addition of information delivery in the form of audio, graphics, animation, or video. In addition, further research is needed to find out how effective the use of this e-supplement is in learning Green Chemistry courses.

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