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Green Synthesis of Silver Nanoparticle using Anthurium andraeanum Leaves Extract for High School Practicum Module

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ABSTRACT

Nanotechnology is a new subject in the Merdeka Curriculum that presents challenges in the chemistry learning process. Teachers need help delivering nanotechnology material due to a lack of understanding of the material and teaching materials. Therefore, a practicum module for synthesizing silver nanoparticles based on green chemistry was developed. The objectives of this study were (1) to know the quality of the practicum module in terms of feasibility and (2) to know the teacher's response to the developed module. The results of this study indicate that (1) Anthurium andraeanum leaves have the potential as a bioreductor for the synthesis of silver nanoparticles based on the color change of the silver nanoparticles solution and based on the absorption of UV-Vis spectrophotometer light at a wavelength of 438 nm which shows the characteristics of silver nanoparticles. (2) The developed practicum module has met the criteria of being highly valid, with a percentage of 93% in terms of media and 88% in terms of material. (3) The teacher's response to the developed product is very good, with a percentage of 98%. The developed practicum module is suitable for use in learning nanotechnology.

INTRODUCTION

The government and the Ministry of Education, Culture, Research, and Technology of Indonesia proposed the Merdeka Curriculum to upgrade the 2013 curriculum (Angga et al., 2022). The Merdeka Curriculum contains various intracurricular learning, with better learning materials (Bahriah et al., 2022). Moreover, the material in the Merdeka Curriculum is more interesting due to the integration of experiences in everyday life (Rahmadhani et al., 2022). The Merdeka Curriculum has three characteristics: project-based learning, learning with essential material, and a more flexible curriculum structure (Bahriah et al., 2022). In order to perfect the previous curriculum, the material discussed in the Merdeka Curriculum also adapts to the needs and developments of the times. Nanotechnology material is material that is part of the subject of atomic structure. This material discusses atomic theory, the particles that compose atoms, Bohr's theory of electron configuration, and the advantages and benefits of nanotechnology (Sari & Suryelita, 2022).

The preliminary analysis, conducted through interviews with the high school teacher, showed that implementing the Merdeka curriculum improved the students' innovation and critical thinking. In this new curriculum, students were guided to learn independently; hence, they experienced science by learning new materials such as green chemistry and nanotechnology. Moreover, students can learn global perspectives through new chemistry learning materials. Students need help learning this new material due to the lack of resources that match the high school level. Teachers have hardship in delivering the new materials due to a lack of understanding. Based on Sari & Suryelita (2022), 68.3% of students need help understanding this material. One alternative to overcome this problem is to carry out practicums assisted by practicum modules, which contain practicum materials and steps. Practical modules are teaching materials arranged systematically based on measurable learning objectives to achieve learning objectives (Sa'idah & Yulistianti, 2018)(Marfu'ah & Meristin, 2022)

This research aims to develop a practicum module of silver nanoparticle synthesis based on a green chemistry approach using *Anthurium andraeanum* leaves extract as a reducing agent. This module consists of the nanoparticle synthesis mechanism and the characterization. Anthurium andraeanum leaves contain high levels of flavonoid compounds (Osorio-Guarín *et al*., 2021), which can help donate electrons to Ag^+ ions to produce Ag^0 (Bere *et al*., 2019)**.** A green synthesis-based synthesis method aims to reduce solvent waste using a safe distilled water solvent and green chemistry. Apart from that, the practicum also provides empirical experience for students and teachers regarding the synthesis of silver nanoparticles. By providing an empirical experience with the objectives of implementing the Independent Curriculum, it is hoped that students and teachers' understanding of nanotechnology material can be deeper.

METHOD

Research Design

This research and development were conducted to determine the best path for silver nanoparticle synthesis using *Anthurium andraeanum* leaf extract. After finding the best synthesis path, the data was used to produce a practicum module. This research focused on developing silver nanoparticle synthesis using a green chemistry approach and a practicum module.

Research Target

The targets of this research were (1) the best synthesis path for the silver nanoparticle using *Anthurium andraeanum* leaves extract and (2) two high school teachers as respondents for practicum module development through the purposive sampling method.

Research Data

The target data was the optimum condition for silver nanoparticle synthesis, such as (1) incubation time and (2) volume of *Anthurium andraeanum* leaves extract, as well as the validation data for the developed practicum module. The data was collected through laboratory experiments, product feasibility tests, and a questionnaire for the respondents.

Research Instrument

The instruments were classified into two groups. The first group consisted of laboratory instruments for collecting data for silver nanoparticle synthesis, such as glassware, FTIR Shimadzu IR-Spirit, SEM Jeol JSM-7100F, and spectrophotometer UV-Vis Shimadzu 1800. The second group was for practicum module development and feasibility test, which consisted of an interview sheet, validation sheet, and respondents' questionnaire.

Data Analysis

The data analyzed in this research can be categorized into two groups. Group one consisted of silver nanoparticle synthesis and characterization. Group two included the interview results, product validation, validation of question items, validation of respondent questionnaires, and teacher response questionnaires.

a) Silver nanoparticle synthesis

Add 1 mL of *Anthurium andraeanum* leaves extract onto 5 mL 0.0002 M $AgNO_3$, then shake it until perfectly mixed. The solution then left for 1 hour. Characterization was done with spectrophotometer UV-Vis (Shimadzu UV-1800), *Fourier transform infrared spectroscopy*

(FTIR) (Shimadzu IR-Spirit), and SEM (JSM-7100F, Jeol) to analyze the result. The FT-IR data are listed in Table 1.

b) The Interview Data

The interviews' data were analyzed descriptively to obtain the information needed to solve the problem under study. The steps were data collection, presentation, and conclusion.

Table 1. Functional groups and wavelength

No	Functional group	Wavelength (cm^{-1})
1	3500-3000	-OH
2	3150-3050	-CH (aromatic)
3	2950-2800	-CH (aliphatic)
4	1850-1730	-C=O
5	1650-1400	-C=C
6	1300-1000	-C-O
7	840-800	-CH (aromatic)

Silverstein et al. (2005)

c) Practicum Modules' validation

The product validation data of modules and materials are analyzed to determine the percentage of module products that are suitable for product presentation and materials. The analysis is carried out by calculating validation results using a formula. The validity is achieved if the achievement level is above 60%.

$$p = \frac{\Sigma \text{ score}}{\Sigma \text{ maximum score}} \times 100\%$$

Table 2. Level of Achievement and Feasibility of Module and Module's Materials

Percentage %	Criteria
81,00-100,00	High validity
61,00-80,00	Moderate validity
41,01-60,00	Low validity
21,00-40,00	Invalid
00,00>20,00	Very invalid

Sumber: Akbar (2013)

d) Respondents' Questionnaire

Respondents filled out the questionnaire to find out responses and respondents' assessments regarding the practicum module that is being developed. Analysis of teacher respondent questionnaire results is calculated using a formula (Arini & Lovisia, 2019).

$$\rho = \frac{f_i}{n} \times 100\%$$

Where:
ρ = percentage
f_i = score
n = maximum score

Table 3. Level of Achievement and Feasibility of Module and Module's Materials by Respondents' Questionnaire

Percentage (%)	Criteria
82≤P≤100	Very good
62,5≤P≤80	Good
42,5≤P≤60	Fair
22≤P≤40	Poor

The good criteria are achieved if the achievement level is above 62,5 % (Table 3).

RESULTS AND DISCUSSION

This research was not just about finding a synthesis path for silver nanoparticles but about finding the best one. We used *Anthurium andraeanum* leaf extract as a reducing agent, a unique approach that yielded promising results. The data from this synthesis path is now being used to develop a nanotechnology practicum module. This tool will revolutionize the way we teach and learn about atomic structure and nanotechnology in the Merdeka Curriculum.

The first stage of this research was an interview with a high school teacher. Based on that interview, it was known that the teacher needed help delivering teaching material that matched the Merdeka Curriculum and had a low understanding of the new nanotechnology teaching materials due to the lack of material suitable for high school students. Hence, students need help understanding the topic of nanotechnology.

Merdeka Curriculum has special characteristics, such as focusing on project-based learning, which contains essential material and more flexible learning implementation (Bahriah et al., 2022). Thus, new teaching materials are needed to provide empirical experience to students to develop their ability to learn independently, think critically and creatively, and have a global perspective. Based on this background, in this research, teaching materials were developed as a chemistry practical module, "Green Synthesis of Silver Nanoparticle using Anthurium andraeanum Leaves Extract."

Experimental Data

The development of practicum modules is carried out based on experiments. The experiments carried out by the researchers were then developed into part of the practical module component. Laboratory experiments to develop practicum module products are as follows:

1. *Anthurium andraeanum* leaves preparation

   The preparation involved drying the *Anthurium andraeanum* leaves in an oven at 60 ^oC for 48 hours, as shown in Figure 1. The *Anthurium andraeanum* leaf powder was then continued with the extraction procedure. Infundation extraction was the chosen method for this step. In this extraction step, water was used as a solvent to extract the chemical compound of the natural product, such as leaf (Supomo et al., 2021). The extraction procedure started with adding 5 g of Anthurium andraeanum leaves powder into 50 mL of DI water, set at 80 ^oC for 20 minutes. After the heating step, the extract was filtered and diluted in DI water up to 100 mL. Then, it cooled down to 4 ^oC to preserve the chemical compound; thus, it was not destroyed (Gunawan & Mulyani, 2004). Figure 2 shows the extraction result.

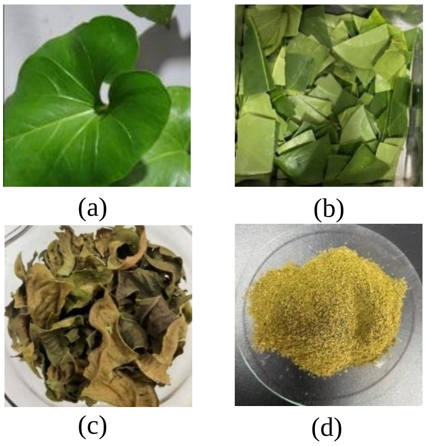


Figure 1. *Anthurium andraeanum* leaves (a) original form, (b) after cutting (c) after drying, and (d) the powder

The extract is yellowish green and solved in DI water because of the phenolic compound in *Anthurium andraeanum* leaves. The presence of phenolic compounds is also confirmed by FT-IR data, shown in Figure 3b. Several peaks confirm the phenolic compound based on FT-IR data. There are bands at 3302,33231 cm^{-1} for the -OH group, 1839,70762 cm^{-1} for the -C=O group, 1645,45278 cm^{-1} for the -C=C group, and 1291,22336 cm^{-1} for -C-O group. Phenolic compounds, flavonoids, have an important role in nanoparticle synthesis as reducing agents that can cause reduction reactions (Fabiani et al., 2019).

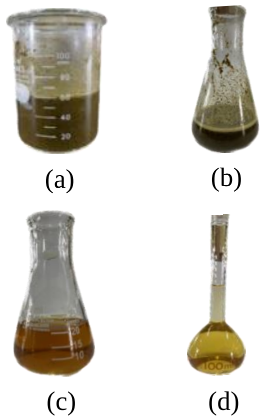


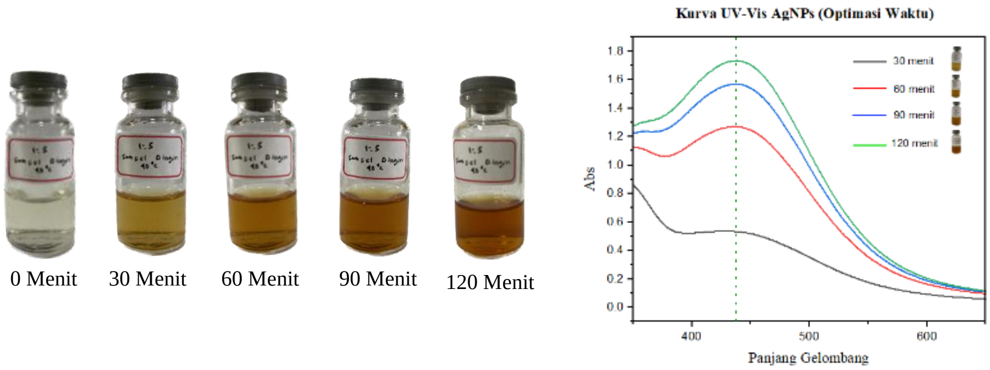
Figure 2. Extraction results (a) extract before heating; (b) extract after heating; (c) extract after filtering; (d) extract after dilution

2. Silver Nanoparticle Synthesis using *Anthurium andraeanum* leaves extract.

The green synthesis approach is a safe nanoparticle synthesis mechanism. Plant extract and microorganisms are used as reducing agents in this synthesis (Purnomo *et al.*, 2017). The material was prepared by adding 0.00085 g $AgNO_3$ to 25 mL DI water; this solution was known as a precursor. Leaves extract was prepared using the method mentioned earlier. *Anthurium andraeanum* leaf extract has abundant phenolic compounds, such as flavonoid, which was useful as a reducing agent in silver nanoparticle synthesis. A phenolic compound as a reducing agent is able to conduct a reducing reaction, changing Ag^{+} into Ag,which indicates the formation of silver nanoparticles (Karimah *et al.*, 2020). The formation of silver nanoparticles was then observed by changing the color of the solution from clear without color to yellow, red brick, or dark brown (Rahim *et al.*, 2020).

In order to get the best result, the optimum condition should be determined. First is the incubation time for the silver nanoparticle formation reaction. The incubation times were varied every 30 minutes, from 30 minutes to 120 minutes, with the volume of precursor and the leaves extract at 5 and 1 mL, respectively. Figure 3 shows the result of the optimum condition determination for incubation time. The color change of the solution is shown in Figure 3a, and Figure 3b shows the UV-Vis spectrophotometry analysis of the silver nanoparticle solution.

Based on the color change, it is known that the reaction took place after 30 minutes; the color changed from crystal clear to yellowish brown. The color continued to become darker as the incubation time increased. The optimum condition is 120 minutes, based on the color changing and UV-Vis spectrophotometry spectra. UV-Vis spectrophotometry's spectra in Figure 3b show that the maximum wavelength of silver nanoparticles is 438 nm. 400-450 nm is the maximum wavelength of silver nanoparticles (Prasetyaningtyas *et al.*, 2020). Moreover, the spectra of 120 minutes are sharp and narrow, indicating the uniform shape of silver nanoparticles.

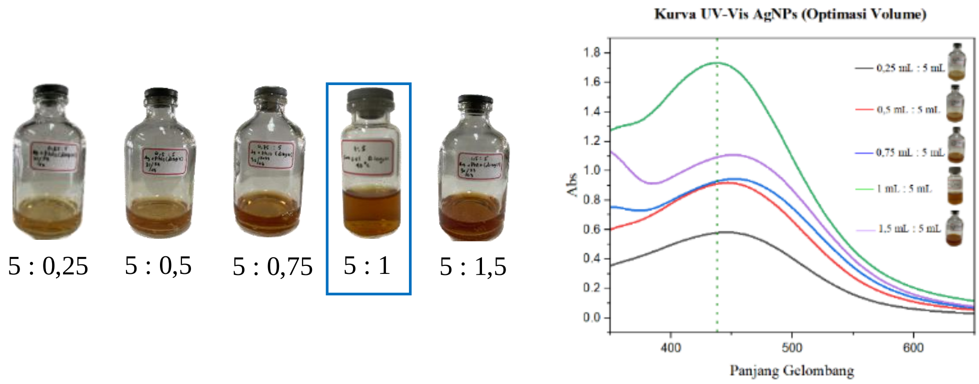


(a) (b)

Figure 3. Optimum condition of incubation time, based on: (a) changes in color of synthesized silver nanoparticle and (b) UV-Vis spectrophotometer's spectra.

Another aspect that impacts the synthesized silver nanoparticle formation is the Anthurium andraeanum leaf extract volume. The number of reducing agents affects the synthesis result; if the number of reducing agents is high, the synthesized silver nanoparticles' size will be smaller (Amriani & Tuahatu, 2021). The extracts' leaves varied in volume from 0.25, 0.5, 0.75, 1, and 1.5 mL, and the best incubation time (120 minutes) was chosen for the synthesis. The optimization result for leaf extract is shown in Figure 4.

The best-synthesized silver nanoparticle was carried out with 5 ml AgNO3 0.0002 M and 1 mL leaves extract based on Figure 4. In the beginning, with 0.25 mL leaves extract, the color was yellowish brown and slightly darker when the extract volume increased (Figure 4a). However, based on the UV-Vis spectrophotometer's spectra, after adding 1 mL of leaf extract and the volume increased to 1.5 mL, the absorbance decreased, and the spectra became wider compared with the previous volume (Figure 4b).

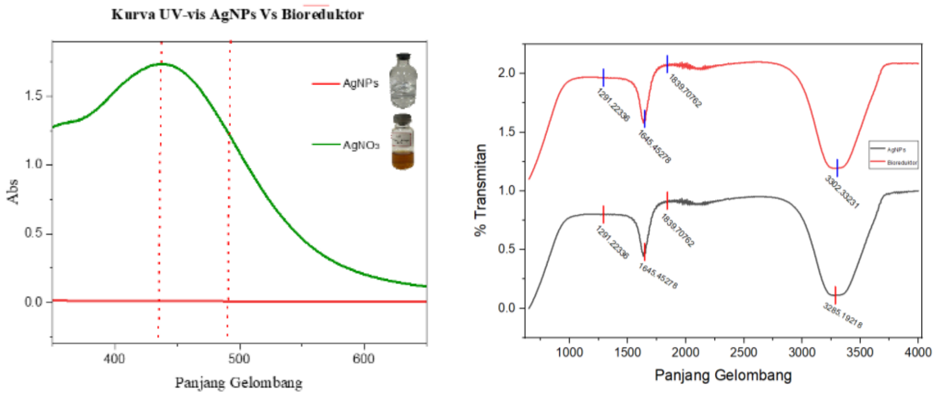


(a) (b)

Figure 4. Determination of the optimum leaves extract volume based on (a) changes in color of synthesized silver nanoparticles and (b) UV-Vis spectrophotometer's spectra.

Based on the UV-Vis spectrophotometer's spectra, each variation of reducing agent volume in the synthesis of silver nanoparticles succeeded in producing silver nanoparticles. Amriani & Tuahatu (2021) stated that the greater the amount of reducing agent, the smaller the particle size will be; therefore, in this study, the results of the synthesis of silver nanoparticles with a larger volume of reducing agent produced a smaller maximum wavelength, a high and sharp spectrum because the smaller maximum wavelength means, the smaller the particles produced, and the narrower the spectrum, the more uniform the variations in size and shape of the silver nanoparticles produced.

Based on the optimum conditions, silver nanoparticles were then synthesized and analyzed using a UV-Vis spectrophotometer, FTIR spectroscopy, and SEM electron microscope (Figure 5). This analysis aims to determine whether silver nanoparticles are formed through an analysis process based on maximum wavelength, the functional groups present, and the shape and size of the silver nanoparticles formed.



(a) (b)

Figure 5. (a) The analysis result of silver nanoparticles compared with $AgNO_3$ using a UV-Vis spectrophotometer and (b) FTIR spectroscopic analysis of silver nanoparticles and *Anthurium andraeanum* leaf extract.

The analysis results of the silver nanoparticle solution, compared with the $AgNO_3$ solution using a UV-Vis spectrophotometer, showed that $AgNO_3$ did not exhibit a maximum wavelength. However, the characterization results for the synthesized silver nanoparticles produced an absorbance of 1.734 with a maximum wavelength of 438 nm. Based on these results, it can be concluded that silver nanoparticles have formed (Prasetyaningtyas *et al*., 2020).

Table 4. Results of FTIR Spectroscopy Analysis of Silver Nanoparticles vs Reducing Agent

Wavelength (cm^{-1}) (Reducing agent)	**Wavelength (cm^{-1}) (Silver nanoparticle)**	**Functional group**
3302,33231	3285,19216	-OH
1839,70762	1839,70762	-C=O
1645,45278	1645,45278	-C=C
1291,22336	1291,22336	-C-O

The reducing agent, *Anthurium andraeanum* leaves extract, and the silver nanoparticle solution were characterized using FTIR spectroscopy. Based on research conducted by Silverstein *et al*. (2005), Table 1 shows the analysis of functional groups and wavelengths using FTIR. Characterizing the reducing agents and silver nanoparticles aims to compare the functional groups in the two solutions. Table 5 shows the silver nanoparticles and reducing agent solutions analysis using FTIR spectroscopy.

The flavonoid compounds, which we characterized based on FTIR spectroscopy analysis, exhibit a unique array of functional groups. These include -OH, -C-O, -H, -C=C, and -C=O (Wayan *et al*., 2017). Each group has its distinct band shape and wavelength, adding to the complexity and richness of the compounds. For instance, the -OH group shows a curved band shape at a wavelength of 3302.33231 cm^{-1}, the -C=O group shows a sharp band shape at a wavelength of 1839.70762 cm^{-1}, the -C=C group shows a sharp band shape at a wavelength of 1645.45278 cm^{-1}, and the -C-O alcohol group shows a broadened band at a wavelength of 1291.22336 cm^{-1}.

The characterization results of the silver nanoparticles reveal the presence of -OH groups with a curved band shape at 3285.19216 cm-1, similar to the reducing agent. However, a significant finding is the peak shift in the -OH group in the characterization results of silver nanoparticles and reducing agent from *Anthurium andraeanum* leaves extract using FTIR spectroscopy. This shift could indicate a change in the chemical environment, potentially affecting the reactivity of the nanoparticles.

An SEM electron microscope can determine the size and shape of the resulting silver nanoparticles. The results of this analysis are shown in Figure 6. Morphological analysis of silver nanoparticles using an SEM electron microscope at a magnification of x100,000 shows that the particles are spherical and their sizes are not uniform. The sizes of the resulting nanoparticles are 35.6 nm, 39.2 nm, and 45.9 nm. Based on the SEM electron microscope morphology results of the silver nanoparticle synthesis, it was concluded that silver nanoparticles were formed because their sizes corresponded to the size range of silver nanoparticles, which is between 1-100 nm.

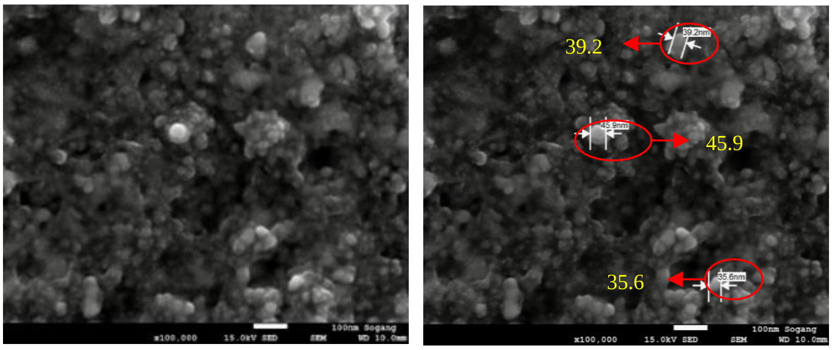


Figure 6. Morphology Analysis of Silver Nanoparticles Using SEM Electron Microscope

Practicum Module Development

Based on the real conditions in the interview, the problem of implementing the Merdeka Curriculum, especially on the nanotechnology topic, was identified, and a practicum module was developed to overcome the problem. The practicum module, "Green Synthesis of Silver Nanoparticle using *Anthurium andraeanu* Leaves Extract," was developed based on laboratory experimental data and several validation steps.

The first step was creating a module design using the Canva application. The chemistry practicum module, entitled "Green Synthesis of Silver Nanoparticle using *Anthurium andraeanum* Leaves Extract," consists of a front cover page, foreword, table of contents, materials, and instructions for each of the four experiments, glossary, bibliography, and back cover (Figure 7).

Figure 7. The Design of the Practicum Module.

After composing the chemistry practicum module entitled "Green Synthesis of Silver Nanoparticle using *Anthurium andraeanum* Leaves Extract," the next step is the development stage. In this stage, the teaching material products, in the form of practicum modules and instruments such as question items and teacher respondent questionnaire sheets, were validated by validators. Two high school chemistry teachers then tested the validated practicum module to determine the quality and suitability of the module as a support for nanotechnology teaching and learning.

In the development step, validators assessteaching material products to determine the quality of the practical chemistry teaching material products and the quality of the practical chemistry module. The module was evaluated in various aspects, including content, presentation, graphics, composition, discussion, and writing.

Table 5. The Validation Result of the Nanotechnology Practicum Module

No	Aspect	Percentage	Criteria
1	Content	100%	High Validity
2	Presentation	96%	High Validity
3	Language	88%	High Validity
4	Graphic	88%	High Validity
	Average	**93%**	**High Validity**

The validator's assessment (Table 5) in terms of media, based on the content assessment aspect, obtained a percentage of 100%. The presentation assessment aspect obtained a percentage of 96%, the language assessment aspect obtained a percentage of 88%, and the graphic assessment aspect obtained a percentage of 88%. Overall, the four aspects of the assessment achieved a combined percentage of 93%. According to the assessment criteria (Akbar, 2013), an achievement level with a percentage of 81.00% - 100.00% meets the criteria for high validity (Dwi Cahyani & Gusman, 2023)(Jayanti, 2018). Therefore, the assessment results from the validator in the media sector were declared high validity. Thus, the product developed as a chemistry practicum module is worthy of testing provided it aligns with the comments and suggestions from the validator.

Table 6. The Validation Result of the Nanotechnology Material in The Practicum Module

No	Aspect	Percentage	Criteria
1	Content	88%	High Validity
2	Composition	88%	High Validity
3	Writing and language	88%	High Validity
	Average	**88%**	**High Validity**

The assessment from the validator in terms of material, based on the content assessment aspect, obtained a validation result percentage of 88%. This was assessed based on the suitability of the material to the learning objectives achieved, the effectiveness of the material content, and the systematic organization of the material in the practicum module. Based on the composition aspect, a validation percentage of 88% was obtained regarding clarity of material presentation and procedures in the practicum module. Similarly, a validation percentage of 88% was obtained based on the language and writing assessment aspects. The overall percentage result was 88% (Table 6). The validation results from the material field validator included in the criteria high validity, indicating that the material in the practicum module is suitable to be presented and tested, with the comments and suggestions from the validator.

The teacher respondent questionnaire (Table 7) was validated based on instructions, respondent coverage, and grammar. Regarding the assessment aspects of the instructions, which were evaluated based on clarity in presentation and clarity of the assessment scale, a validation percentage of 100% was obtained. All aspects assessed received a percentage of 100%, which was declared included in high validity. The validation sheet meets the very valid criteria so that the respondent questionnaire sheet can be given to teacher respondents (Hutabarat et al., 2021).

Table 7. The result of Respondent Questionnaire Validation

No	Aspect	Percentage	Criteria
1	Instruction	100%	High Validity
2	Respondent Coverage	100%	High Validity
3	Grammar	100%	High Validity
	Average	**100%**	**High Validity**

The teacher respondent questionnaire assessment of the nanotechnology practicum module product determines its quality after it has been tested. The teacher respondent questionnaire sheet assesses several aspects, including the module's appearance, content, and language (Table 8).

Table 8. The Result of Analysis of Teacher Respondent Questionnaire Sheets on the Nanotechnology Practicum Module

No	Aspect	Percentage	Criteria
1	Appearance	100%	Very Good
2	Content	94%	Very Good
3	Language	100%	Very Good
	Average	**98%**	**Very Good**

Based on the appearance assessment aspect, which includes the layout of the module, color suitability, and product attractiveness, a percentage of 100% was obtained. For the content aspect, which is based on the material's suitability to the experiment's objectives, clarity of objectives for each experiment, and suitability of post-practice questions, a percentage of 94% was obtained. According to the data in Table 9, the language aspect obtained a percentage of 100%, resulting in an overall assessment percentage of 98%. Based on the assessment criteria from Arini & Lovisia (2019), a percentage of 82% $\leq$ P $\leq$ 100% meets the criteria for being very good. It was concluded that the respondents' assessment of the nanotechnology practicum module products met the very good criteria. Based on the assessment results from respondents 1 and 2, it was concluded that the nanotechnology practicum module is feasible and very good to implement, taking into account the suggestions and comments provided by the respondents. The nanotechnology practicum module is stated to help students practice inference skills in nanotechnology learning.

CONCLUSION AND RECOMMENDATIONS

The results of this study indicate that (1) *Anthurium andraeanum* leaves have the potential as a bioreductor for the synthesis of silver nanoparticles based on the color change of the silver nanoparticles solution and based on the absorption of UV-Vis spectrophotometer light at a wavelength of 438 nm which shows the characteristics of silver nanoparticles. (2) The developed practicum module has met the criteria of being highly valid, with a percentage of 93% in terms of media and 88% in terms of material (3) The teacher's response to the developed product is very good, with a percentage of 98%. The developed practicum module is suitable for use in learning nanotechnology.

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