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# Development of Personalized Learning Student Worksheets to Practice Inquiry Skills

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**Abstract**

**Background:** Personalized learning must be based on exploring students' traits, including learning styles. Knowledge of student learning styles will make it easier to design learning, including practicing inquiry skills. Inquiry skills are abilities that all students need to have. Inquiry skills must be trained through habituation, primarily through practical learning. Many Student Worksheets (LKM) practice inquiry skills but do not accommodate each student's learning style. **Method:** Development of personalized learning LKM to train inquiry skills using the Borg and Gall development research model. **Results:** Initial data was taken through interviews and learning style tests. The results of the learning style test show that 35.72% of students have a visual learning style, 25% auditory, and 39.28% kinesthetic. The next stage is to develop visual, auditory, and kinesthetic LKM products on the characteristics of leaves as quite complex material. The products produced are then evaluated through validation by material and inquiry experts, language experts, and development experts. Product improvements are made based on comments and suggestions from validators. The three LKM products were tested for suitability by students as product users. The feasibility score for the visual type of personalized learning LKM was 89%, the auditory type of personalized learning LKM was 90%, and the kinesthetic type of customized learning LKM was 92%. The results of the effectiveness test of the three products show an increase in students' inquiry skills in the medium category. **Conclusion:** The three LKM personalized learning products fall into the feasible and usable category.

***Keywords:*** Personalized learning; learning style; inquiry skills; leaf characteristics.



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## Introduction

The independent learning policy was launched by Nadiem Makarim, minister of Education and Culture, at the end of 2019. This policy was made for apparent reasons. One is based on the 2018 Program for International Student Assessment (PISA) assessment results, which show that Indonesian students only occupy the sixth position from the bottom (OECD, 2019). Of 79 countries, Indonesia is in the 74th position in literacy and mathematics. Based on this reality, Nadiem initiated an independent learning policy (Faiz & Kurniawaty, 2020; Mustaghfiroh, 2020).

The Ministry of Education and Culture wants to achieve big goals through the freedom of learning policy. This independent learning policy encourages a culture of educational institutions that are autonomous rather than bureaucratic and fosters improvements in the learning system. The concept of independent learning also helps to restructure the national education system. The education system was restructured to celebrate the country's transformation due to developments over time. One way is to return education to its essence as a humanizing process (Sholehuddin, 2018).

Freedom to learn or independent learning is defined in several definitions, including taking responsibility for one's learning; choosing and setting your own goals; deciding what, as well as when and how to study; monitoring one's progress; developing the ability to conduct critical inquiry and evaluation; and evaluating and reflecting on what has been learned (Hockings et al., 2018). In independent learning, students do not use the lecturer as the only source of truth. Students and lecturers must work together to find the truth. Lecturers and students are educational subjects (Vera, 2020; Yamin & Syahrir, 2020). In implementing independent learning, the government wants to apply another trend from modern pedagogy called differentiated learning, also known as personalized learning. Personalized learning stands on the fundamental philosophy of 21st-century pedagogy, namely socio-constructivism, an educational philosophy that serves students. The socio-constructivism philosophy clearly states that knowledge should grow organically in students through fundamental social interactions (Yanuarti, 2017; Irawati et al., 2022; Tarigan et al., 2022). Personalized learning exists in the context of socio-constructivism; therefore, customized learning must refer to the diversity of each student's personality (Afandi & Pranajaya, 2022; Solari et al., 2022; Vladimirovich Kondratiev et al., 2020). The campus is the party responsible for tracing each student's personality traits. So that every student can understand himself well, the student personality data must be processed and grouped according to its distribution. Finally, lecturers use the processed student personality data to personalize scenarios, environments, and learning methods (Ghallabi et al., 2022; Hughey, 2020; Lumbantoruan & Purba, 2020; Zhou et al., 2021). Unfortunately, until now, no valid data has been found regarding how many campuses have conducted personality searches of their students, which is used as a basis for designing the learning process.

The implementation of personalized learning must be based on considering students' traits, such as personality types, learning style, learning speed, and cognitive power (Ghallabi et al., 2022; Hughey, 2020; Makhambetova et al., 2021; Zhou et al., 2021). Learning styles can be explored based on the results of measuring student learning styles. Each student is unique and different, so classroom learning must be able to facilitate diverse abilities. Learning style is a way of learning chosen by someone to be able to understand what they are learning more efficiently. According to De Poter & Hernacki, learning styles are divided into three large groups, namely kinesthetic, visual, and auditory (Cahyani Rahayu & Salamah Zainiyati, 2020; Hidayati et al., 2021; Rido & Wahyudin, 2020; Zuana et al., 2023). Learning styles have several implications for lecturers in terms of classroom teaching. Because all students do not learn in the same way, they cannot be assessed similarly (Wiliam, 2013; Rawlusyk, 2018). Knowing how each student learns will allow lecturers to assess student progress properly.

Various theoretical and practical courses can benefit from personalized learning (Nandigam et al., 2015; Callahan, 2019; Abolafia, 2022). Learning science in higher education provides knowledge about what to study and the experience of learning how to study. Laboratory activities or practical work are essential for science learning (Abrahams & Millar, 2008; Reiss, 2016; Shana & Abulibdeh, 2020). Students can make direct observations and explore and understand biological research subjects. This allows the practicum to combine hands-on activities with thought processes.

The results of interviews with lecturers in the practicum course on plant structure and development show that the practicum instructions used so far are still general and do not consider a personalized learning approach. Apart from that, the practicum presented does not train inquiry skills. Furthermore, because the information and references obtained during lectures regarding leaf shape are very limited, material discussing leaf characteristics must be included with various references. One of the plant organs that is very important for plant life is the leaf or folium. Plants' multiple types of leaves have shown how important they are for their survival, especially in carrying out various tasks such as absorbing nutrients, processing and transporting them, and storing food. The shape of the leaves, which are generally flat, comprehensive, and thin, cannot be separated from their role in absorbing light, and the green color is due to the chlorophyll content in plant leaves, causing the area occupied by the plant to appear green too.

So far, the learning used is still general and does not consider personal learning approaches. To overcome these problems, it is vital to develop learning materials that can meet the needs of each student. One way is to build student worksheets (LKM) on leaves in the practical plant structure and development course. So that personalized learning can be implemented, the LKM developed is based on student learning styles so that each student will get an LKM that suits their learning style.

Personalized learning research related to learning styles in Indonesia has been widely carried out in schools, but it is still scarce at the tertiary level. The results of the literature studies, journal analysis, and personalized learning LKM, which were developed based on learning styles to train inquiry skills in higher education, have not been found. So, research was carried out to create this LKM.

## Method

This research uses the Research and Development method. Several methods are used in R&D, including descriptive, evaluative, and experimental. Initial research used descriptive methods to collect data about existing conditions. Evaluative methods are used to evaluate the product development testing process. And an Experimental method to test the efficacy of the product being made.

Researchers used descriptive evaluative and experimental methods. In this R&D research, researchers are trying to develop student worksheets (LKM) that suit the needs of each student (personalized learning) to practice inquiry skills. The expected product of this research is to obtain an LKM that suits the needs of each student (customized learning) based on emerging learning styles to train inquiry skills in the leaf characteristics practicum contained in the plant structure and development course.

### *Sample or Participant*

The participants in this research were lecturers who taught plant structure and development courses, practicum assistants who assisted lecturers in practical activities, and students who contracted plant structure and development courses.

### *Instruments*

In this research, there were five instruments used: 1) a semi-structured interview questionnaire instrument; 2) a learning style measurement instrument; 3) an expert judgment instrument; 4) a product feasibility response questionnaire instrument with indicators of LKM format, LKM quality, LKM language and writing, LKM benefits; and 5) inquiry skills question instrument as part of the developed LKM effectiveness test,

### *Data collection*

Data collection techniques regarding LKM needs were carried out by interviewing lecturers, assistants, and students using semi-structured interview instruments. Students who contract courses on plant structure and development have their learning styles measured. LKM is developed based on student learning styles. The LKM created is judged by experts online via Google Forms. Product feasibility testing is carried out face-to-face by students with each type of learning style. The product effectiveness test was carried out by giving inquiry skills test questions to students. Product feasibility testing can be carried out effectively with careful preparation from researchers and research subjects.

### *Procedure*

The research and development stage refers to ten steps, according to Borg and Gall. These ten steps are grouped into three stages. The preliminary study stage consists of (1) collecting information. The model development study phase consists of six activities: (2) planning, (3) making prototype product forms, (4) prototype field trials, (5) main product revisions, (6) main product field trials, and (7) revisions of operational products. The model evaluation study phase consists of three activities: (8) operational product field testing, (9) final product revision, and (10) dissemination and implementation. Organizing the research into

three stages is only intended to simplify the process. However, the true meaning of each stage does not diminish.

The preliminary study stage consists of three activities: first, identifying needs. Second, a literature study on learning theories and inquiry skills in the implementation of current practicums, as well as analysis of previous research findings related to learning styles and inquiry skills; and third, field studies to find out the description and obstacles in implementing practical activities on plant structure and development on leaf characteristics. The field study was carried out using semi-structured interviews with lecturers and assistants in the practicum course on plant structure and development. This interview explores information related to the practical learning process of plant structure and development. The results of interviews with lecturers and practical assistants are then described. Data on the learning styles of each student was also obtained from this field study. The findings obtained through needs identification, literature studies, and field studies are used as a basis for the LKM development stage.

The development study stage begins with determining the design of the personalized learning LKM. Next is the product design that will be made. This design includes an LKM design on leaf characteristics for each student's learning style. Then, the components in the LKM, according to the RPS, for the plant structure and development course will be determined. At this stage, a personalized learning LKM product is produced to train inquiry skills for visual, auditory, and kinesthetic students.

The evaluation study stage includes product validation by experts, measuring product suitability by users, and testing product effectiveness. The personalized learning LKM was validated to train inquiry skills by material experts on leaf characteristics, inquiry experts, language experts, and development experts. Revisions were made based on validation results from experts. Next, limited product trials were conducted on students during practical activities on plant structure and the development of leaf characteristics. Data from limited trials and the instrument feasibility response questionnaire results were validated and analyzed. This activity aims to determine the suitability and shortcomings of LKM. The final product of the development is a personalized learning LKM, which is then disseminated and implemented to all students taking courses in plant structure and development. Pretest and posttest were conducted to measure the effectiveness of the developed product.

### *Data analysis*

Percentage analysis is used to analyze quantitative questionnaire data. Analysis is carried out to determine whether the development of the LKM is feasible. This calculation uses the following formula.

$$r = \frac{\sum x}{x \,.\, y \,.\, N} x100\%$$

**Information:**

r = Feasibility Value
∑x = Total Respondent Values
x = Highest Score
y = Number of Questionnaire Points
N = Number of Respondents

Table 1. interprets percentage values into qualitative sentences obtained from calculations.

**Table 1.** Descriptive Percentage Calculation

| Percentage | Category |
|---|---|
| 75,01% < P ≤ 100% | Eligible |
| 55,01% < P ≤ 75,00% | Adequate |
| 40,01% < P ≤ 55,00% | Not Eligible |
| 0,00% ≤ P ≤ 40,00% | Not Eligible |

(Source: Sugiyono, 2009)

A pretest and posttest were conducted on students to measure the effectiveness of the LKM personalized learning product on inquiry skills. The resulting data was analyzed using the Normalized Gain (N-Gain) formula.

$$N\ gain = \frac{Posttest\ scores - Pretest\ score}{Max\ value - Pretest\ Score}$$

Whether or not an increase occurs is based on the N-Gain index, with the following criteria.

**Table 2.** N-Gain Score Categories

| Range | Category |
|---|---|
| G > 0,70 | High |
| 0,31 ≤ g ≤ 0,70 | Medium |
| G < 0,30 | Low |

(Source : Arikunto, 2010)

## Result

Validation is carried out by expert judgment who are experts in their field. The validation results are presented in Table 3.

**Table 3.** Validator Comments and Suggestions

| Validator | Comments and Suggestions |
|---|---|
| **Material and Inquiry** | a. The three LKMs have trained inquiry skills well. Inquiries steps in MFIs have become visible. LKM is not only a recipe but also guides students in making inquiries.<br>b. The level of inquiry presented in the Visual, Auditory, and Kinesthetic LKM is quite good at accommodating each learning style.<br>c. Each LKM found that student competence was assessed according to their learning style. There is a uniqueness to each assessment.<br>d. The specified learning outcomes have accommodated the material on leaves' morphological and anatomical characteristics well. |
| **Development** | a. The three LKMs created have gone through the development stages well. Measuring learning styles at the beginning of preparing the LKM before developing the LKM is appropriate.<br>b. Finding instructions or student practicum LKM that accommodate all learning styles is rare. Moreover, each LKM is explicitly developed for each learning style.<br>c. LKM has shown differentiation for each learning style. |
| **Language and Writing Procedure** | a. Visual LKM:<br>1) The LKM cover design uses white writing on a white background, reducing readability. It's best to change the color of the text or image background.<br>2) Add the words "by:" before writing the name of the LKM author on the cover.<br>b. Auditory LKM:<br>1) The LKM cover design uses black writing on a dark background, reducing readability. It's best to change the color of the text or image background.<br>2) Add the words "by:" before writing the name of the LKM author on the cover.<br>c. Kinesthetic LKM:<br>1) The color of the writing is good, but the background image does not represent the leaves. It is best to replace it with a picture of a whole leaf.<br>2) Add the words "by:" before writing the name of the LKM author on the cover."<br>d. The writing was presented well, no typing errors were found, and there were no ambiguous sentences. Despite this finding, some tables still use 1.5 spaces. It's best to keep it one space apart.<br>e. The appearance/layout is less attractive. It's best to make color pages.<br>f. The language used in the three LKMs is formal and shows the researcher's scientific attitude. |

Researchers make improvements based on comments and suggestions from validators. The results before and after revision are presented in Table 4.

**Table 4.** Revision Decisions from Validators

| Before Revision | After Revision |
|---|---|
| Visual LKM:<br>1) The LKM cover design uses white writing on a white background, reducing readability. It's best to change the color of the text or image background.<br>2) Add the words "by:" before writing the name of the LKM author on the cover.<br>  | Visual LKM:<br>1) The LKM cover design has been improved by changing to a contrasting color.<br>2) The word by has been added on the revised cover before the author's name.<br>  |
| Auditory LKM:<br>1) The LKM cover design uses black writing on a dark background, reducing readability. It's best to change the color of the text or image background.<br>2) Add the words "by:" before writing the name of the LKM author on the cover.<br>  | Auditory LKM:<br>1) The LKM cover design has been improved by changing to a contrasting color. The image displayed on the cover has also been replaced with an image of a leaf bone, which depicts the contents of the LKM.<br>2) The word by has been added on the revised cover before the author's name.<br>  |
| 1) The color of the writing is good, but the background image does not represent the leaves. It is best to replace it with an image of a whole leaf.<br>2) Add the words "by:" before writing the name of the LKM compiler on the cover."<br>  | 1) The LKM cover design has been improved. The image on the cover has also been replaced with a tree, which shows the whole shape of the leaves so that it can depict some of the contents of the LKM.<br>2) The word by has been added on the revised cover before the author's name.<br>  |
| The appearance/layout is less attractive. It's best to make color pages. | The page display has been improved to be more colorful. |

Despite this finding, some tables still use 1.5 spaces. It's best to keep it one space apart.

| Hipotesis: | | |
|---|---|---|
| Bagaimanakah susunan sel jaringan epidermis? Apakah rapat atau renggang? | Bagaimanakah keadaan dinding sel sel epidermis? Apakah dindingnya mengalami penebalan? | Apakah sel epidermis memiliki bentuk bentuk tertentu yang berbeda dengan sel epidermis yang lainnya? |
| | | |

Tables that still use 1.5 spacing have been corrected so that no table lines are left on the next page.

| Hipotesis: | | |
|---|---|---|
| Bagaimanakah susunan sel jaringan epidermis? Apakah rapat atau renggang? | Bagaimanakah keadaan dinding sel sel epidermis? Apakah dindingnya mengalami penebalan? | Apakah sel epidermis memiliki bentuk bentuk tertentu yang berbeda dengan sel epidermis yang lainnya? |
| | | |

The assessment uses a feasibility questionnaire instrument with five leading indicators: LKM Format, LKM Quality, LKM Language and Writing, and Benefits of LKM Development. The results of the LKM feasibility test for the visual learning style of lecturers, practicum assistants, and students are presented in Figure 1 below.

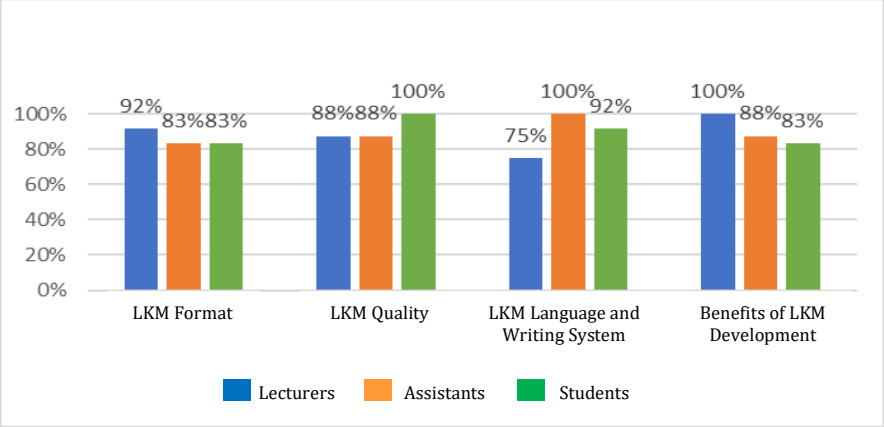


**Figure 1.** LKM Personalized Learning Feasibility Test Results - Visual

The results of the LKM feasibility test for the Auditory learning style from lecturers, practicum assistants, and students are presented in Figure 2 below.

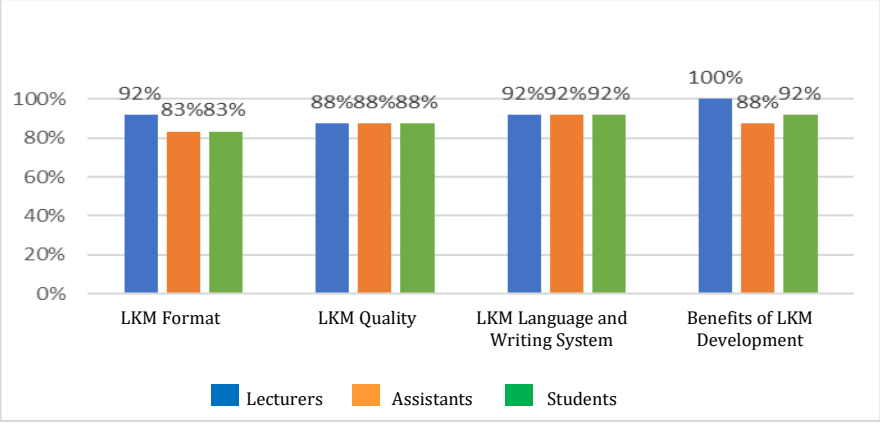


**Figure 2.** Personalized learning LKM Feasibility Test Results - Auditory

The results of the LKM feasibility test for the Kinesthetic learning style from lecturers, practicum assistants, and students are presented in Figure 3 below.

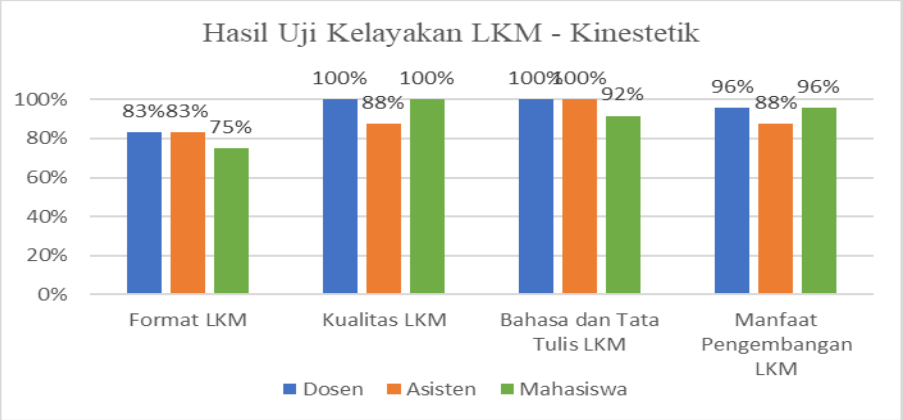


**Figure 3.** LKM Feasibility Test Results Personalized learning - Kinesthetic

The results of calculating the feasibility percentage for visual, auditory, and kinesthetic LKM are 89%, 90%, and 92%, respectively. All three are included in the Eligible category. The eligibility percentage can be seen in Figure 4 below.

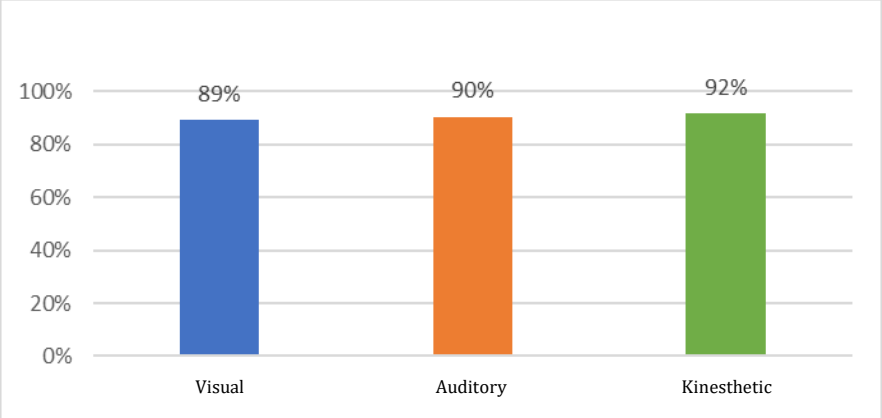


**Figure 4.** Feasibility Result Values for Each Product

Limited product trials were carried out on students during practical activities on plant structure and the development of leaf characteristics. This activity is intended to see the suitability and shortcomings of MFIs. Data from limited trials and the instrument feasibility response questionnaire results were validated and analyzed. The results of the product feasibility test are in Table 5.

**Table 5.** Feasibility Test Results for Each Product Based on Indicators

| Indicators | LKM Visual | LKM Auditory | LKM Kinesthetic |
|---|---|---|---|
| LKM Format | 86% | 86% | 81% |
| LKM Quality | 92% | 88% | 96% |
| LKM Language and Writing System | 89% | 92% | 97% |
| Benefits of LKM Development | 90% | 93% | 93% |

The final product of development is disseminated and implemented to all students taking plant structure and development courses. Pretest and posttest were conducted to measure the effectiveness of the developed product. The results of product effectiveness tests based on indicators measured in students' inquiry abilities are presented in Table 4 below.

**Table 4.** Product Effectiveness Test Results

| Indicator | Initial Score | Final Score | N-Gain | Improvement Category |
|---|---|---|---|---|
| Identifying problems | 64,29 | 75,00 | 0,30 | Low |
| Designing experiments and carrying out experiments | 39,29 | 85,71 | 0,76 | High |
| Analyzing and Interpreting data | 46,43 | 82,14 | 0,67 | Medium |
| Constructing explanations | 53,57 | 75,00 | 0,46 | Medium |
| Generate arguments from many pieces of evidence | 64,29 | 82,14 | 0,50 | Medium |
| Communicating information | 39,29 | 92,86 | 0,88 | High |
| **Average Overall Mean** | 51,19 | 82,14 | 0,60 | Medium |

## Discussions

This research has succeeded in developing learning media through personalized learning Student Worksheets (LKM) to practice inquiry skills on good quality material on leaf characteristics based on expert validation and effectiveness test results. The developed personalized learning LKM for practicing inquiry skills is a new product suitable for use and has never been a similar product before.

Previous research results related to LKM have found the development of LKM in higher education based on guided inquiry to improve students' science process skills (Ni'mah, 2016), the development of LKM to increase the scientific literacy of prospective science teachers (Rosdiana et al., 2018), and the development of LKM basic biology which focuses on inquiry learning to improve students' science process skills (Mursali & Safnowandi, 2016). However, there has been no development of personalized learning LKM based on student learning styles. This customized learning LKM to train students' inquiry skills is new research and has not existed before.

The personalized learning LKM in this research is based on each student's learning style. Franzoni & Assar (2009) state that the personalization-based learning model cannot be separated from student learning styles. This learning style determines each student's most suitable learning method. By knowing their students' learning styles, lecturers can quickly identify their learning characteristics and choose effective learning methods.

In the guidelines published by the Ministry of Education and Culture regarding the importance of understanding learning styles, there are three learning styles for students: visual, auditory, and kinesthetic (Wiedarti, 2018). This personalized learning LKM is designed to accommodate every type of student learning style. So, three kinds of LKM were produced: visual personalized learning LKM, auditory personalized learning LKM, and kinesthetic personalized learning LKM. Apart from personalized LKM based on the type of student's learning style, this LKM is also designed to train students' inquiry skills. The ability to inquire includes several aspects, including asking research questions, planning experiments, carrying out investigations, analyzing and interpreting data, constructing explanations, and producing arguments from many pieces of evidence (NRC, 2011).

LKM is designed to assess student competency according to their learning style. Researchers emphasize that when preparing practicum reports, students are challenged to report practicum activities according to their respective learning styles. Research shows that visual students are more likely to remember information if they see the source directly. The tools used are graphics, posters, diagrams, colored modules, handouts, and others. Auditory students tend to speak well. They learn easily if they talk about certain things with other people. One way to teach auditory students is to allow them to talk in groups and show the results. In the kinesthetic learning style, students tend to remember information through activities they do themselves. Therefore, to implement kinesthetic-based biology learning, media is needed that students directly experience during their learning process. Students become more active in learning because of this.

The prepared personalized learning LKM contains material on leaf characteristics. This LKM is prepared based on the learning outcomes required in the study program curriculum.

Material on leaves' morphological and anatomical characteristics has been well accommodated in this LKM. The LKM explains that the characteristics of leaves are very diverse, both genetically and ecologically, due to adaptation to their environment. To understand the characteristics of leaves, in this LKM, we study 1) leaf blade shape, 2) leaf apex shape, 3) leaf basal shape, 4) leaf veins, 5) leaf margins, and 6) leaf flesh and single leaf types compound. This LKM is prepared in detail and systematically. This aligns with Mursali & Safnowandi (2016), who state that LKM is a systematic study of teaching and practicum materials. LKM is very useful because it can be used as a learning guide, observation sheet, discussion sheet, concept discovery sheet, and a tool for honing critical thinking in teaching and learning activities. In addition, because the LKM is arranged systematically and illustrated, it attracts students' attention and increases their interest in learning.

The validation results of teaching material development experts show that it is still rare to find practical instructions for students or LKM that accommodate all learning styles. Moreover, each LKM is explicitly developed for each learning style. This is the novelty of this development research. Through personalized learning LKM products, differentiated learning for each student can be done well. The customized learning LKM developed has been tested for its suitability by students as users. Four indicators are used to determine suitability: the LKM format, LKM quality, LKM language and writing, and the benefits of LKM development. Each student assesses the visual, auditory, and kinesthetic personalized learning LKM according to their learning style.

Students with a visual learning style provide an assessment of the feasibility of the visual Personalized Learning LKM. The student assessment results of the personalized visual learning LKM are in the appropriate category. However, there is diversity in each assessment indicator. The highest assessment results are in the LKM quality indicator, and the lowest value is in the LKM format. This is in line with the characteristics of a visual learning style, which demands a greater variety of colors, graphs, and diagrams to make it easier for them to understand things. This aligns with the opinion of Bobbi De Porter & Mike Hernacki (2015), who state that visual learning allows students to see sources of information directly, making remembering certain concepts or material easier.

The second product produced is the personalized auditory learning LKM. The student assessment results of the personalized auditory learning LKM are in the appropriate category. The customized learning auditory LKM received the highest feasibility score on the LKM development benefits indicator. Auditory students tend to speak well. They prefer to learn by talking to other people about specific topics. For learning activities based on the auditory learning style, students must be in an atmosphere that allows them to use their hearing abilities fully. One way is to enable people to speak in groups and show what they find. So, students enjoy using LKM, which asks them to work in groups and make practical reports through narrated videos. This follows the learning style of those who do not like taking notes as much as visuals (Wibowo, 2016). So, they feel that this aspect of LKM development will be highly beneficial.

The final product is a kinesthetic personalized learning LKM. The student assessment results of the kinesthetic personalized learning LKM are in the appropriate category. All indicators have a high rating. However, the highest feasibility test results were in the LKM language and writing grammar indicators. This result does not match the character of kinesthetic students who quickly absorb and remember information by moving, making, and touching things. However, all the indicators get high scores if we look at them. So, the practical activities carried out in the laboratory using LKM are very suitable for students with a kinesthetic learning style.

The overall personalized learning LKM effectiveness test results show increased students' inquiry skills in the medium category. Six indicators of inquiry skills are measured before and after learning using this personalized learning LKM. Regarding indicators for identifying problems, the improvement is in a low category. In terms of indicators of analyzing and interpreting data, constructing explanations, and producing arguments from many pieces of evidence, the improvement falls into the medium category. Furthermore, the indicators of

designing and carrying out experiments and communicating information increased in the high category.

Creating research questions that can be researched is one of the sub-indicators for identifying problems with students. Apart from identifying issues, students must have good predictive and reasoning abilities (Lou et al., 2015). Without these two abilities, students will have difficulty creating research questions that can be researched. Rational considerations are required when developing research questions and enabling research to be conducted. In this condition, students are required to think logically and be able to make predictions. In addition, an attitude of curiosity can encourage interest, encouraging students to ask questions (Lou et al., 2015). One of the process skills that requires familiarization is formulating research questions.

Indicators of inquiry skills with moderate improvement were identified in analyzing and interpreting data, making explanations, and making conclusions based on many pieces of evidence. The results of interviews with students show that they do not have a practical learning experience that trains inquiry skills. This means that it is normal for them to have difficulty creating research questions and other indicators of inquiry skills.

Practical learning should ideally give students experience conducting investigations like scientists conducting investigations to answer research questions. One way that can be done to improve students' inquiry skills is to get direct guidance from more experienced lecturers or assistants. Apart from that, there needs to be collaboration between students and lecturers to conduct investigations. This will give students the right experience conducting investigations (Kuter, 2013). The remaining two indicators, designing and carrying out experiments and communicating information, increased in the high category. This shows that the personalized learning LKM that has been prepared is vital in training these two stages. So, this is one of the strengths or advantages of the LKM being developed.

The advantages of personalized learning LKM include the following: First, the developed LKM can facilitate three learning styles: visual, auditory, and kinesthetic. Second, LKM contains clear stages of inquiry so that students have the freedom to explore knowledge.

Apart from having advantages, this LKM has several disadvantages. First, the LKM being developed is still limited to leaf characteristics and does not yet cover more comprehensive material. Second, LKM has not been optimally tested on a broader scale, thus affecting the results of this LKM product development. Based on the findings from the research conducted, the researcher recommends that further research be carried out regarding the development of personalized learning LKM on a broader material scale and applying levels of inquiry.

## Conclusions

This research has produced a personalized learning LKM suitable for practicing inquiry skills on leaf characteristics. Research has made three types of LKM that facilitate three student learning styles: visual personalized learning LKM, auditory personalized learning LKM, and kinesthetic personalized learning LKM in leaf characteristics practicum activities. The developed personalized learning LKM could not fully fulfill students' wishes in the practicum on plant structure and development. This customized learning LKM can be designed to be even more exciting and have a broader range of materials. Therefore, this LKM needs to be developed again by conducting further research.

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## Declaration statement

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