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Simulations and Solutions of Calculus Problem: An Effort to Improve Students' Innovative and Quality Computing Skills

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ABSTRACT

One of the impacts of online learning that is not optimal is learning loss. Therefore, the aims of this study, we conduct computing practicum with Maple and Matlab to improve students' ability to develop learning media based on Network Virtual Laboratory (NVL). The implications of this practicum can improve students' innovative attitudes in developing various learning media NVL-based, with still through the validation process and field tests so that quality learning media is produced. The subject of this study consisted of 61 students who took the integrated mathematics computing course calculus. This is a development research (R&D), where each student develops learning media then validated and field trials. We assess each media resulting from the development using questionnaires and field observations. The results showed that as many as 85% of students have been able to innovate well in developing learning media NVL-based including function limit materials, derivatives, and integrals. The results of the assessment of the expert team showed that the ability of students in developing learning media reached an average score of 3.97 which is categorized as "innovative", while the results of product trials for early-level students obtained an average of 4.07 blessings "very qualified". Furthermore, the practicum module and all media results of student development have been uploaded to the University's Learning Management System Moodle-based for use in the learning process in the future. We hope that the learning media that has been developed can be applied to calculus learning in the future.

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A. INTRODUCTION

The purpose of learning science and technology according to Permendiknas No. 22 of 2006 is that students are able to conduct scientific inquiries to cultivate the ability to think, behave, act scientifically, and communicate (Arinda et al., 2019). This attitude is closely related to the quality of the process and learning outcomes determined by many factors, one of which is the availability of laboratory facilities (Potkonjak, 2016). Laboratory activities are important to be carried out in lectures, especially computing-based courses, because through laboratory activities aspects of products, processes, and attitudes students can be developed (Trnka et al., 2016).

Research on the development of virtual laboratories has been widely carried out such as the development of virtual laboratories for practicum activities and facilitating student character education (Jaya, 2013); facilitation of the creation of virtual and remote laboratories for the education of science engineering (Esquembre, 2015); development of mathematical learning media with macromedia flash (Masykur et al., 2017); development of contextual and ICT-based linear program teaching materials (Rizki & Linuhung, 2017); development of critical thinking skills of prospective mathematics teacher students through virtual practicum (Kurniawan et al., 2018); development of a commissioning learning platform based on virtual laboratories (Mortensen & Madsen, 2018). Hence, virtual laboratory is needed in improving student learning outcomes and training teachers or lecturers in using ICT-based learning media.

These studies show that information was obtained that the development of virtual laboratories is important as a support for the learning process. So that in basic courses where every problem resolution requires computerization assistance must be developed as an effort to support the implementation of learning based on the Indonesia National Qualification Framework (called KKNI). At least in the KKNI for the Mathematics Education Program, there are two courses that are interrelated and sustainable, namely Differential Calculus and Integral Calculus (Darari & Firdaus, 2020). The research team studied that this courses has an important role in facing the industrial revolution 4.0 which generally aims to instill an independent and quality attitude for students. This is in line with the design of these two course of standard operating procedure.

But the facts in the field and the results of various researches, especially in NTB province, Indonesia, the learning media or other computer programs are still minimal is used (Abdillah et al., 2018; Sobaih et al., 2016), this is due to the lack of expert teams of media developers and computer programs in learning the lecture (Negara et al., 2019). The application of learning media at the college level is also needed, especially in Calculus lectures. The results of the pre-test that have been given to students obtained information that the average level of understanding of students is still relatively low with a classical completion score of 38%. This problem is the impact of learning resources both institutionally and online that can be widely accessed is still minimal and even does not exist. From this problem, there must be an effort to develop student competence in developing virtual laboratory-based learning media.

Research on the use of virtual laboratory-based media in Calculus learning has been widely done. Virtual laboratories have the very good power of being a learning material. A good virtual laboratory has a positive positive impact on the theory and practice of learners and can provide a good experience through a variety of repeated experiments (Iovan et al., 2015). Vrána et al. (2015), confirmed that laboratories in the present have undergone many internet-based changes including tasks and practicum activities from the real world already using virtual laboratories so that students can access remotely via the internet. Watts et al. (2016), have examined the shifting levels of learning development of youth (learners) when interacting with virtual manipulative math applications on software screens (based on android). It is explained that various problems faced by learners related to tasks and difficulties in learning can be solved properly because they have adequate learning resources and are able to be accessed remotely and mobile-based (android) with many features in mathematics learning. Trnka et al. (2016), stated that the use of remotely accessible learning resources is increasing in education as a form of the electronic library for learners. On the other hand, there are virtual laboratories that allow learners to conduct many broader and more meaningful experiments without having to spend more time and cost. Finally, Muhajarah & Sulthon (2020), expressed the urgency of the laboratory as a learning medium and how the opportunities and challenges of virtual laboratories as a pedagogical framework overview. Virtual laboratories have a significant impact in terms of preparing students for real experiences, as well as savings in equipment procurement and maintenance costs, location flexibility, study time, and practice.

Calculus is a primary gateway to an engineering and engineering technology careers. Therefore, Maple software is used as a medium of calculus learning in instilling deeper concepts (Salleh & Zakaria, 2013). In addition, Salleh & Zakaria (2012) also said that it is very important to develop Maple-based learning modules as an effort to instill the concept of graph visualization and calculus problems. Here, students study in a computer laboratory so that a new atmosphere is obtained by students as a learning experience. Because, the learning of the calculus using computational tools has been shown positive result by many recent studies. Basic complex number, vector functions, partial derivatives, line integrals, double integral, triple integral, Green's theorem, Stokes' theorem are the common topics in vector calculus is recommended to use computational software in its learning process because it can innovatively help visualize graphs and understand difficult concepts in Vector Calculus (Lohgheswary et al., 2018). There is also another study using Mathematica software as a virtual laboratory-based learning medium on distance learning (Karim, Kamil, 2011).

The results of this study show that the use of software as a virtual laboratory is very helpful in improving the hard skills of students, teachers or lecturers during the learning process. So, we took the initiative to use Matlab as a priority software in improving students' ability to develop learning media. Media development results by students must certainly be validated and tested in the field to see the level of innovation that has been carried out by students in utilizing the attributes of the matlab graphical user interface (GUI).

If we look at the low initial ability of students, then in the early stages we will develop maple and Matlab practicum modules according to calculus competency standards. Furthermore, modules are used in project-based practicum processes so that students are trained in developing learning media. So in general, this study aims (1) to develop calculus learning devices in the form of Maple software practicum modules and GUI-based Matlab software, (2) to measure the level of student innovation in developing virtual laboratory-based learning media, and (3) to describe the quality of learning media developed after conducting validation tests and laboratory-scale product tests. The results of this study are expected to provide a positive contribution to the development and increased use of mathematical software integrated with the moodle-based Learning Management System (LMS).

B. METHODS

This research is development research (R&D). The development model used by each student, namely 4D, which is modified into 3D, includes define, design, and develop. The design stage is carried out in the Laboratory after practicum. Meanwhile, in the develop stage, students validate a team of experts and field trials in small groups. This research was conducted in the Mathematics Education Study Program. The subject of this study was an initial semester student of 61 people who programmed calculus courses. They are divided into 4 classes namely A, B, C, and D. The research stage is seen in Figure 1.

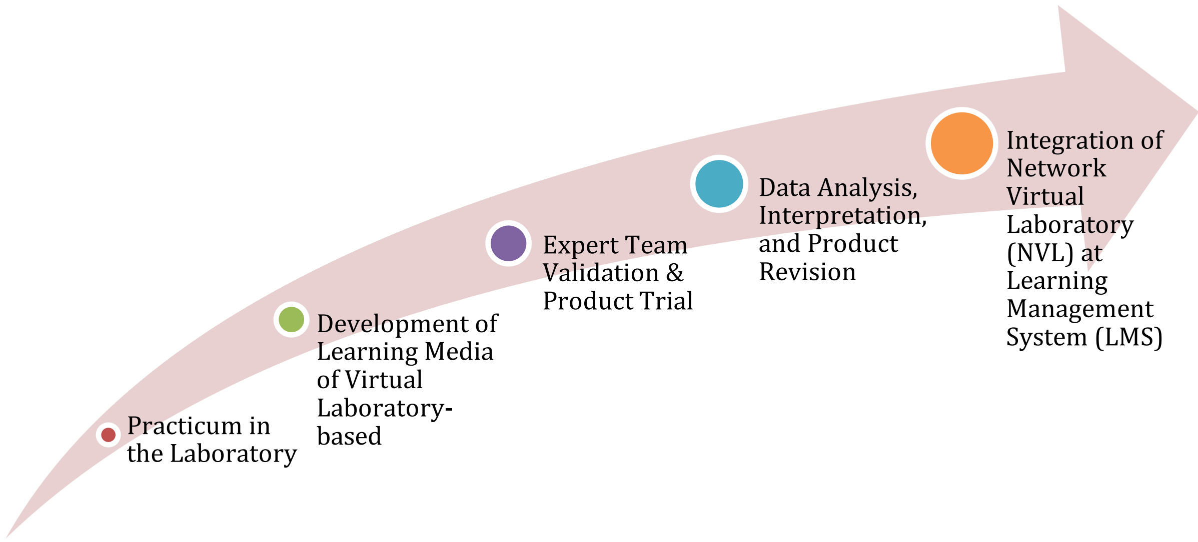

Figure 1. Research steps

1. Prakticum in The Laboratory.

In the initial stage, the research team conducted a needs analysis according to the competency standards of graduates in the Differential Calculus and Integral Calculus courses so that an outline of practicum material should be found. The second stage, determines the materials and tasks to be given to students both through the Windows Command menu and graphical user interface (GUI). The third stage, the practicum module is validated to a team of experts, namely learning media experts, Calculus materials, and mathematical computing experts. After the module is declared valid by a team of experts, the next step is to draw up a schedule and conduct a practicum in the laboratory. Practicum activities are carried out according to the number of meetings that have been compiled in the practicum module. After the practicum material is completed, students are given the final project according to their respective topics.

2. Development of Learning Media of Virtual Laboratory-based

At this stage, students create a Matlab GUI-based learning medium as the final project includes function materials, function limits, derivatives, and integrals. Each material is presented according to good simulation standards including understanding the case to be solved, input from all known variables from the problem, simulation buttons, function evaluation results, and graphs. In addition, it is also given other topics such as algebra, matrix, statistics, and discrete mathematics.

3. Expert Team Validation & Product Trial

The validation of the expert team is divided into two, namely the validation of the practicum module and the construct validation of computer programs developed by students after the practicum is completed. Therefore, after the learning media creation process is completed, then students validate to the expert team, namely learning media experts and mathematics computing experts. After the learning media is declared valid, then students conduct product trials to find out the level of quality or quality of the product by socializing or disseminating to other students who are or have taken calculus courses. As for the validation procedure of the expert team according to Figure 2.

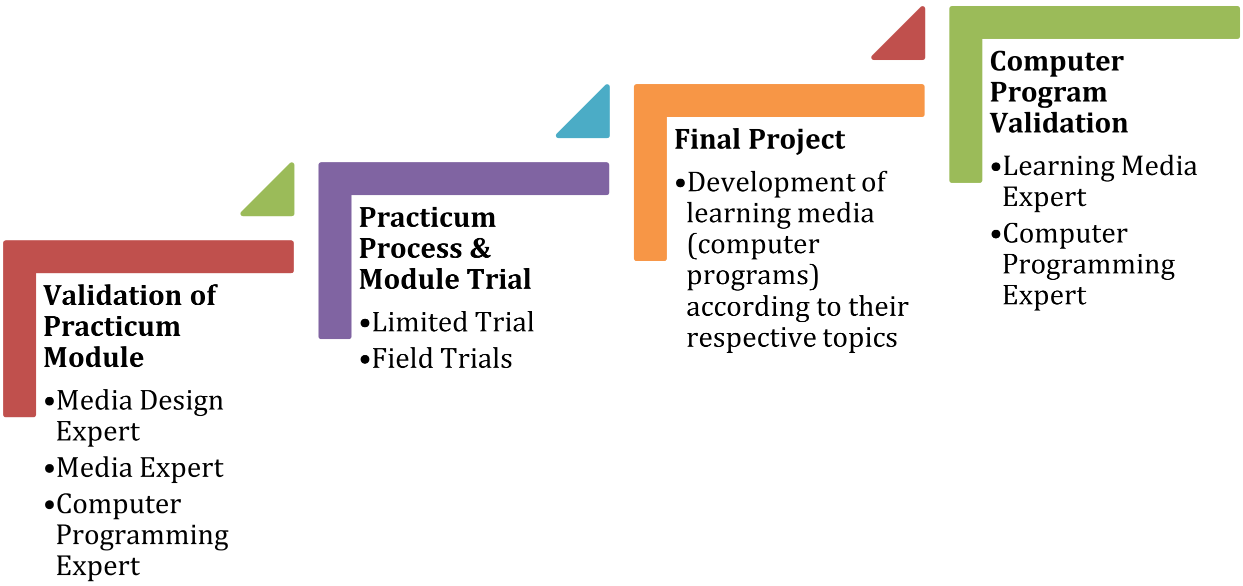

Figure 2. Expert team validation stages

4. Data Analysis, Interpretation and Product Revision

The data analysis stage is carried out (1) to find out the level of validity of both practicum modules and learning media that have been developed; (2) to find out the innovative level of students during the learning media development process based on questionnaires and observations at the time of practicum in the laboratory and field; (3) to find out the level of quality or quality of the learning media that has been developed. The validation category is determined from the average score of each validator from the results of product assessments of both modules and computer programs according to Table 1.

Table 1. Intervals and categories of validation results

Average Interval ($\overline{R_i}$)	Category
$\overline{R_i} = 5$	Very Valid
$4 \leq \overline{R_i} < 5$	Valid
$3 \leq \overline{R_i} < 4$	Enough
$2 \leq \overline{R_i} < 3$	Less valid
$1 \leq \overline{R_i} < 2$	Invalid

Table 1 is also a reference in determining categories based on the average score of innovative and quality test results on computer programs developed by students. The field test stage can be carried out if the learning media is included in the category of "quite valid" based on the results of the expert team's assessment. However, the category is changed according to the needs of the test conducted. Then the research team interpreted the data from the results of data analysis both from practicum module products and product results developed by students. Furthermore, the research team conducted an in-depth analysis of the constraints or shortcomings possessed by the modules and learning media that have been developed. Finally, the research team interprets and revises the product so that conclusions are obtained from the results of the study and provide advice for future research.

5. Construction of Network Virtual Laboratory (NVL) at Learning Management System (LMS).

This is the final stage of the development process, where practicum modules, and learning media that have been developed are uploaded to moodle-based Learning Management System (LMS) so that they can be used in the learning process in the future, especially in Calculus courses for students at the initial level.

C. RESULT AND DISCUSSION

1. Calculus Material Integrated Practicum Module

One of the outcomes to be accomplished in the study of calculus is that students can use information technology or mathematical software to solve learning problems in order to improve the quality of mathematics learning and for further learning purposes. From here, modules prepared for practicum needs to use Maple and Matlab as software that must be mastered by students in solving calculus problems. Because Maple software is ready-made software, the writing team only develops maple practicum modules without validating the expert team. While the Matlab practicum module contains the development of learning media of Matlab GUI-based, the writing team validates the expert team.

From the results of the development obtained the contents of the Maple practicum module including (1) Introduction, in this section students, are equipped with Maple History information; Maple Installation Process; Function tools in solving integral calculus problems; and basic operations, functions, and commands in Maple, (2) Simulations and Solutions, in this section students, are faced with simulations and solutions to Integral Calculus problems using Maple tools on Antiderivative materials using the Antiderivatives menu; Integral is indeterminate, determinate, and area using Integration Methods; Sigma notation uses Expression (sum); Integral Riemann using Riemann Sums; and Volume of rotary objects using Volume of Revolution.

Furthermore, the contents of the Matlab practicum module include (1) Matlab Introduction which contains component recognition, menus, and attributes along with functions in Windows Command and Matlab Guide; (2) Windows Command contains several basic operations, functions, and commands in Matlab; (3) The function contains an understanding of the sequence structure, as well as examples of function graph application programs and function calculators; (4) Limit Function, contains the logic structure for as well as examples of Limit Function application programs; (5) Derivatives contain the concept of sequenced logic structures and examples of derivative application programs in determining tangent equations; (6) Integral contains Students faced with examples of application programs that use sequence structures such as the application of integrals in dredging the area. After the process of preparing the module is completed, especially the Matlab practicum module, the writing team validates the module to the expert team. The results of the validation of the expert team are presented in Table 2.

Table 2. Validation result

Expert Field	**Sub Indicators**	**∑ Items**	$\overline{R_i}$ **(Item)**	$\overline{R_i}$ **(Total)**
Display (Design)	Graphic Quality	6	4.50	4.415
	Module shape	3	4.33	
Calculus Material	Material Quality	6	3.83	4.277
	Language Quality	2	5.00	
	Quality of Exercise	3	4.00	
Computer Programming	Material scope	6	5.00	4.500
	About exercises and final tasks	2	4.00	
Average				4.397

Based on Table 2, information was obtained that media design experts gave a "very valid" response with a score of 4.415 (88.3%), material experts gave a "very valid" response with a score of 4.277 (85.54%), and computer programming experts gave a "very valid" rating with a score of 4.500 (90%). Therefore, the modules that have been developed are suitable for use in the classroom both small and large scale.

The next stage, the trial of laboratory-scale practicum modules. The subjects that became practicants were 4th semester students who were studying mathematics computing as many as 61 people who were divided into two stages, namely as many as 5 students for limited trials and as many as 56 students for field trials. The results of student response to the module are presented in Table 3.

Table 3. Results of Trial from the Practicum Module

Sub of Assessment	**Item Number**	**Limited Trial**		**Field Trials**	
		$\overline{R_i}$	**Category**	$\overline{R_i}$	**Category**
Module Presentation	5	3,96	Good	3,98	Good
Language and Module Content	7	4,24	Excellent	4,09	Excellent
Module Shape	3	4,40	Excellent	4,22	Excellent
Average		4,20	Excellent	4,09	Excellent

Based on Table 3 obtained information that the results of product trials received a good response during practicum. This can be seen from the average score both during limited trials and field trials including the "excellent" category.

2. Practicum and Development of Learning Media Based NVL

Practicum activities are a form of validated module trials. This activity was held in the Computational Mathematics Laboratory during 12 meetings consisting of 4 Maple practicum meetings and 8 Matlab practicum meetings. After the Matlab practicum is completed, the activity continues with the development of Matlab GUI-based learning media as a final project for students on as many as 16 topics related to calculus theory such as (1) straight-line equations, (2) functions (squares, polynomial, trigonometry), (3) function calculators that present the results of function operations and graphs, (4) function cut-off points, (5) triangle concepts with trigonometry, (6) maximum and minimum values of a function, (7) the concept of limit functions and their applications, (8) the concept of derivative functions and their applications such as curve tangent equations, (9) integral concepts and their application in determining the area and volume of rotary objects. After students develop learning media or computer programs, they then conduct product validation, assessment of innovation levels, and field tests.

The results of the overall validation test of computer programs that have been developed by students are obtained in the "valid" category. This is obtained from an average score by media experts of 3.81 and an average score by computational experts of 3.22. From the results of this validation obtained also some records of improvements such as (1) placement of inputs, processes, and outputs that have not been precise, (2) the values of the root of the function have not been displayed in the output table, (3) the use of font types and sizes that have not varied, (4) the scope of incomplete material simulated, (5) the use of listboxes as simulated outputs has not been widely used. While the results of the assessment of the level of innovation in computer program development in accordance with Figure 3.

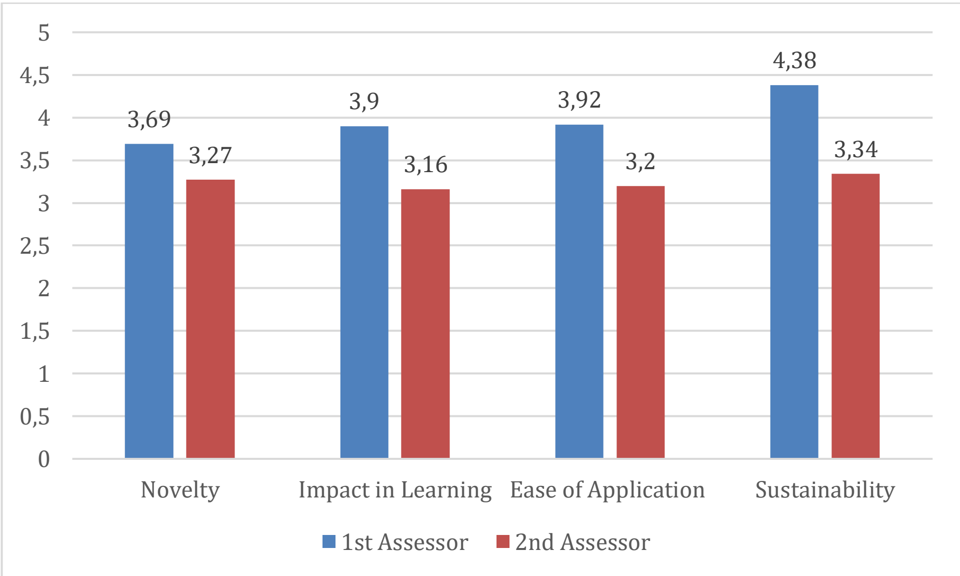

Figure 3. Results of Innovation Level Assessment

Figure 3 presents the average score of student innovative attitude assessment results in developing virtual laboratory-based learning media. In the "novelty" aspect, the assessment team gave an average score of 3.48; "impact in learning" aspect of 3.53; "easy of application" aspect of 3.56; Sustainability aspect of 3.86. That is, the ability of students in developing computer programs in the field of calculus is classified as "innovative". One of the indicators of the success of learning media development is the positive impact and sustainable benefits for users (Febriani & Prabowo, 2022). The results of this attitude assessment can be proven by the creativity of students in using the Matlab GUI attributes when the learning media development process as seen in Figure 4.

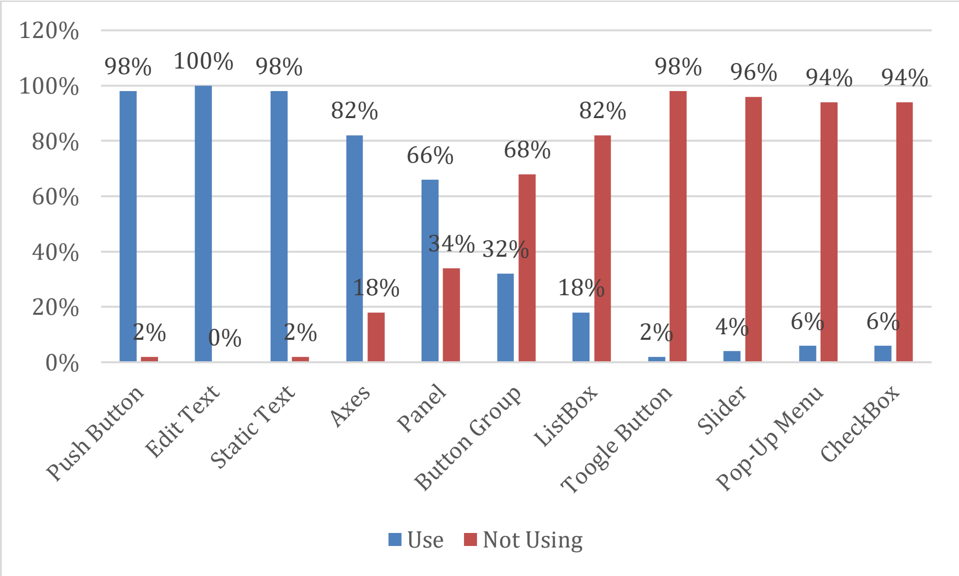

Figure 4. Percentage usage of Matlab GUI attribute

Figure 4 shows that the use of attributes such as Static Text, Edit Text, and Push Button is always needed every GUI creation as an input-process-output, so that a total of 98%-100% of students use it. While other attributes adjust to the computer program developed, because not all calculus cases must be solved with existing attributes. Because the use of inappropriate attributes proves that students are not creative in the use of Matlab GUI attributes. In the process of developing Matlab GUI-based learning media, students must be selective in using the right attributes (Sucipto & Irpan, 2022).

After the validation test process and assessment of the level of innovation, then students conduct product trials to early semester students who are studying calculus. Students who have been divided into several teams make presentations on how to use media and some calculus cases that can be completed using these learning media. After making a presentation, then students give an assessment of the computer program including aspects of programming, aspects of program content, and aspects of program appearance. As for the results of the assessment according to Table 4.

Table 4. Result of product assessment during field trials

Sub of Assessment	Item Number	Product Trial	
		$\overline{R_i}$	Category
Programming aspects	4	4.17	Very Quality
Content Aspects	6	4.01	Very Quality
Display aspects	6	4.04	Very Quality
Average		4.07	Very Quality

Table 4 shows that the user's assessment of the product that has been developed is classified as "quality". This can be seen from the assessment of programming aspects obtained an average value of 4.17 (83.4%); aspects of the content presented in the program obtained an average score of 4.01 (80.2%); aspects of the look or design of (80.8%). The results of this development require a high level of creativity and innovation to produce quality learning media based on field trials. However, during the development process, there are many obstacles faced by students such as (1) difficulty finding the right theory, especially mathematical formulas, (2) difficulty making programming algorithms, (3) there are often writing errors on computational scribes so that there are frequent errors, (4) references make computational scribes still minimal on the internet, and (5) laptops that are too melted during the running process of computer programs. This is in accordance with the results of Sidik et al. (2021) research which states that the obstacles faced by students during the online learning process are the lack of internet networks. Besides, Mariana & Fauzi (2018) also explained that the difficulty of compiling computational scribs is due to students' lack of understanding of the general formula of mathematics. Therefore, the importance of learning materials is developed a type of programming module that is able to train students independently (Syaharuddin & Mandailina, 2017).

D. CONCLUSION AND SUGGESTIONS

ICT-based learning has a positive impact on instilling concepts in students. This is shown from this study that simulation and completion of calculus problems using Maple and Matlab software are very helpful in improving students' understanding. Especially Matlab software certainly needs the development of learning media based on Graphical User Interface (GUI) so that it is easy to use by users. The results of media development that have been carried out by students when viewed from the innovative level obtained an average score of 3.97 (innovative category) with the level of use of Matlab GUI attributes by students reaching 98%. While at the product trial stage to see the quality or quality of the media that has been developed reaches an average score of 4.07 (very quality category). These results show that the importance of instilling virtual laboratory-based learning media development mechanisms in students is an effort to improve their skills in the field of computing. Therefore, we suggest that in the future media development can be done for wider topics and wider product trials.

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