The validity of vector analysis module using \textit{wxMaxima} software

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Abstract. Teachers should have the competence in applying Information and Computer Technology (ICT) in the learning process. One of the ICT application is the use of learning software such as \textit{wxMaxima}. This research aimed to develop a valid module using \textit{wxMaxima} software. This research used the Plomp development model consisting of three phases, namely preliminary research, prototyping, and assessment. However, this research was conducted for preliminary research and prototyping phases only. The result of data analysis in the preliminary research shows that the module is feasible for further development. The validation results at the prototyping stage performed by four validators gave a score of 4.5. This score shows that the developed vector analysis module using \textit{wxMaxima} software was highly valid. Therefore, the module as a result of the development of this research can already be tested.

1. Introduction

To train competent teachers in applying Information and Computer Technology (ICT) in the teaching and learning process, the student teacher must be familiar with the lecturing activities using ICT. Living in a technology-based community makes the learning activity applying ICT become the best method [2]. The use of ICT is not only limited to the use of powerpoint but also to the use of mathematics software which can assist the learning process. Mathematics software includes \textit{Maple}, \textit{Autograph}, \textit{wxMaxima}, \textit{Geogebra}, \textit{Matlab}, and others. The software is mainly divided into two categories, paid and free software. One of the free mathematics software is \textit{wxMaxima}.

ICT application in the lecture activities not only facilitates the learning process but also improves students’ motivation towards the learning activities [7]. Naturally, it will affect the learning outcome, it can improve the understanding, and the lecture will be more meaningful. The student teachers’ better understanding leads to the better quality of the teachers produced.

In the Indonesian National Qualification Framework (\textit{KKNI}), it is mentioned that one of the expected competency of the bachelor degree is the capability of applying his/her competences by utilizing Science and Technology to solve the problem as well as adapting to the new situation. Meanwhile, the Mathematics Study Program of the teacher training and education faculty (FKIP) in Syiah Kuala University (Unsyiah) has not utilized ICT in the vector analysis subject. In addition, students’ motivation and initiative also need to be improved.

Vector analysis subject is one of the subjects in Mathematics program study of FKIP Unsyiah provided in the 5th semester. This two credits subject has some prerequisite subjects including Calculus I, Calculus II and Solid Geometry course. However, based on the field observation, it is found that the...
students taking Vector Analysis Subject are still constrained by the precondition materials, even though they have passed those prerequisite subjects.

In the lecturing process, the students’ independence is the most important factor. One of the factors supporting the independence is the availability of module. The module allows students to improve their learning intensity outside the classroom. In particular, for the module using software, students can conduct the exercise questions manually and then match the answers with the software output. Based on the above description, the research problem is “how can the module using wxMaxima Software in the vector analysis course be valid?”

2. Method
This research is the development research using the Plomp, development model. The Plomp development model consists of three phases, namely preliminary research, prototyping and assessment [5]. However, this paper is limited to the prototyping phase.

In the preliminary research phase, the curriculum was analyzed to examine the factors related to the research location. The university condition analysis was carried out to examine the supports, and obstacles found related to the university environment, infrastructure, and facilities. The students’ characteristic analysis was carried out to investigate the basic concept and students’ learning motivation. The user analysis was done to investigate the user’s expectation related to the module developed. In addition, in the prototyping phase, the module was designed based on the result of the preliminary research phase to be validated.

The criteria used to assess the module developed are based on Nieveen’s [8]. The module developed will be valid if it meets the following criteria: (1) the validator assessment results acknowledge that the module using wxMaxima software in vector analysis subject is developed based on a strong theoretical basis, and (2) validator assessment results acknowledge that the module components using wxMaxima software in vector analysis subject are consistently interrelated. While the criteria of validity score (VS) obtained is presented in the picture as follows:

| VS ≤ 5 | VS ≤ 4 | VS ≤ 3 | VS ≤ 2 |
|--------|--------|--------|--------|
| Highly valid | Valid | Less valid | Not valid |

**Figure 1.** Criteria of validity score

3. Result and Discussion
This section presents the development processes carried out in the following two phases.

3.1 The Preliminary Research Phase
The preliminary research phase has been started since October 2016. The activities conducted were the analyses of curriculum, university condition, student characteristic, and need assessment. The analysis processes are explained in the following section.

3.1.1 Curriculum Analysis. In this phase, the curriculum analysis was carried out based on the curriculum applied in mathematics study program of FKIP Unsyiah. The curriculum used was Indonesia National Qualification Framework (KKNI). The module contents were divided into two basic competencies, namely: vector differential and vector integral. The indicators of the vector analysis subject were: (1) Using differential operator; (2) Determining the scalar function gradient; (3) Determining vector Area; (4) Determining the vector function divergence; (5) Calculating line integral; (6) Calculating surface integral; (7) Calculating volume integrals.
3.1.2 Student’s Characteristic Analysis. Student characteristic analysis was conducted to adapt the students’ condition to the product developed. Student characteristic analyses obtained are: (1) students’ attitude concerning vector analysis subject such as being enthusiastic and actively engaged; (2) students only use one guideline source; (3) students were having problems in basic mathematics concepts.

3.1.3 University Situation and Condition Analysis. University situation and condition analyses were carried out to examine the supports and obstacles found in the environment. The university situation and condition analyses showed that: (1) The location of Mathematics Study Program was quite strategic; (2) the situation and condition of Mathematics Study Program strongly supported the implementation of learning; (3) Physical condition of Mathematics Study Program was feasible for the learning activities; (4) The media supporting the courses of mathematics study program was strongly supported even though it was less maintained.

3.1.4 User Analysis. The user analysis was conducted to investigate the module requirements in vector analysis subject. The analysis results were: (1) there had been no module for vector analysis subject of Mathematics Study Program involved in the study. The students utilized the guidelines published by other universities; (2) the guideline used was not utilizing any software and the lectures had never used software in learning activities; (3) the lecturers were willing to master the module in the vector analysis subject and to apply in the learning activities, should the module was available; (4) The learning idea expected by the lecturers was that the students first learned the concept manually and followed up using the software.

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(%i1) load(vector)$
    div([x^2*y*z,3*x*y*z^3,(x^2-z^2)])
(%o2) div([x^2*y*z,3*x*y*z^3,x^2-z^2])

(%i3) express(%);
(%o3) \frac{d}{dy}(3*x*y*z^3)+\frac{d}{dz}(x^2-z^2)+\frac{d}{dx}(x^2*y*z)

(%i4) ev(%diff);
(%o4) 3*x*z^3+2*x*y*z-2*z 
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Figure 2. Examples of working with wxMaxima software

3.1.5 Material analysis. The course chosen in the learning software development was vector analysis. This material is in the 5th semester. It is the mandatory subject (not optional) consisting of 2 SKS (2 units). It is the difficult subject especially for the students who have a less basic concept.

3.2 Prototyping Phase. The module was designed by developing module framework, consisting of (1) introduction, (2) basic competency, (3) indicator, (4) the material and exercise for each section, and (5) the answer of exercise. This framework was adopted from the module of Open University. The materials were started by manual problem solving and followed by software problem-solving. The module prototype can be summarized as follows.

3.2.1 Identifying the Learning Objectives. This identification aimed to obtain the description of students’ competency after participating in the lecturing activities using the module using the software in vector analysis subject. Therefore, the module developed comprised of the exercises using both manual and software process.
3.2.2 Analyzing the Learning Objectives. The learning objective analysis aimed to examine the competency of students’ understanding based on the learning objective. The learning objective analysis was started by classifying the pattern of the cognitive learning objective. Thus, the analysis results of learning objectives found were the learning process including student cognitive competency in vector analysis subject.

3.2.3 Formulating the Learning Objectives. The learning objective in this development was students’ cognitive competency after participating in the learning activities of vector analysis using wxMaxima Software. The results of the learning were that students were able to: (1) use differential operator; (2) determine scalar function gradient; (3) Determine vector area; (4) Determine the vector function divergence; (5) Calculate line integral; (6) Calculate surface integral; (7) Calculating volume integral.

3.2.4 Developing the Learning Strategy. The learning strategy developed was estimating learning time allocation and learning activities. Learning strategy applied in the modules using wxMaxima software in vector analysis subject included software introduction, basic competency, indicator, the material and exercises for each section, and the answer of exercises, prerequisite materials, material explanation, the example of manual problem solving, the example of the software problem solving, exercises for students, and the conclusion.

3.2.5 Developing the Module. The module development was conducted by presenting the basic competencies, indicators, and explanation. In the material explanation section, the material was divided into two subsections including the material explanation with the example of the questions both manually solved and using software, and one subsection for reviewing the exercises as the final preparation (testing the understanding test question).

3.2.6 Validity Test. In this validation phase, the validator conducted the assessment of the content, format, and language. In the comment column, the validator wrote the feedbacks that were used as the main consideration for revision before conducting the limited trial test.

3.2.7 Validity Test Analysis. The module validation results from this aspect included: 1) the validity of the content, 2) the compatibility of the basic competencies and indicators, 3) the logical grouping sections, 4) the guidance in using the software clearly formulated, 5) the compatibility with the allocation time used, and 6) the feasibility of the learning software (the validity average scores were
Meanwhile, the results of the format aspects included: 1) the validity of the distribution, 2) the clear numbering system, 3) the layout setting, and 4) the font type and size, obtaining the average validity scores of 4.5. Furthermore, the language aspects included: 1) the validity of language setting, 2) the simplicity of sentence structure, 3) the clarity of guideline and instruction, and 4) the communicative language used, obtaining the average validity scores of 4.5. The total average scores were 4.5. The average value indicates that the module development criteria are classified as highly valid. Therefore, the module meets the content validity criteria. However, some minor revisions were needed to improve the module such as being less precise in the writing aspect; the use of "for" at the beginning of the sentence; in the format aspect, there were images without a caption; and the working steps without numbers. Both aspects have been revised incorporating the feedbacks, more proper sentences used, the caption provided for each image and the number in the working step.

| Table 1. Module validation results |
|------------------------------------|
| Aspect                            | Criteria                                                                 |
|                                   | Validator 1 | Validator 2 | Validator 3 | Validator 4 | Average of each criterion | Average of each aspect |
| Content                           | 1. The truth of the content of the vector analysis material presented in the module |
|                                   | 5 4 4 5     |             |             |             | 4.5                        | 4.5                     |
|                                  | 2. Compliance with basic competencies 5 5 4 5 |             |             |             | 4.75                       |                         |
|                                  | 3. Grouped in logical sections 5 4 5 5 |             |             |             | 4.75                       |                         |
|                                  | 4. Student activities are formulated clearly, so easy to be implemented by lecturers in lectures 4 4 4 5 |             |             |             | 4.25                       |                         |
|                                  | 5. Clarity example of a problem worked with software maxima 5 5 5 5 |             |             |             | 5                          |                         |
|                                  | 6. Compliance with module criteria |
|                                   | a. Self-instruction 5 4 4 5 |             |             |             | 4.5                        |                         |
|                                  | b. Self-contained 4 4 4 5 |             |             |             | 4.25                       |                         |
|                                  | c. Standalone 5 4 4 5 |             |             |             | 4.5                        |                         |
|                                  | d. Adaptive 4 4 4 5 |             |             |             | 4.25                       |                         |
|                                  | e. User-friendly 4 4 4 5 |             |             |             | 4.25                       |                         |
|                                  | 7. Eligibility as a learning tool 5 5 5 5 |             |             |             | 4.5                        |                         |
| Format                           | 1. Clarity of material distribution 4 4 4 5 |             |             |             | 4.25                       | 4.5                     |
|                                  | 2. The numbering system is clear 5 5 4 5 |             |             |             | 4.75                       |                         |
|                                  | 3. Layout settings 5 5 3 5 |             |             |             | 4.5                        |                         |
|                                  | 4. Type and font size 5 5 3 5 |             |             |             | 4.5                        |                         |
| Grammar                          | 1. The truth of grammar 4 4 4 5 |             |             |             | 4.25                       | 4.5                     |
|                                  | 2. The simplicity of sentence structure 5 5 4 5 |             |             |             | 4.75                       |                         |
|                                  | 3. Guidance clarity and direction 4 4 4 5 |             |             |             | 4.25                       |                         |
|                                  | 4. Communicative language used 4 4 4 5 |             |             |             | 4.25                       |                         |
| Average of Validity             | 4.5         |             |             |             |                            |                         |

3.3 Discussion

The product of this research should be evaluated to examine the validity level by the expert validation. As proposed by Sugiyono [8] that validate the product is done by presenting experts or experienced experts to assess the product developed. The experts assessed the validity of the module developed. The experts presented in this development were the subject expert, ICT expert, mathematics lecturer, and other colleagues researching ICT product development. According to the validation process, the module developed in this research is categorized as highly valid.

The module validation results obtained from four validators, reaching the validity score of 4.5. This validity value summarizes that the module criteria is highly valid. In each learning process, the basic competencies to be achieved and the detailed indicator for each section are mentioned. Then, the
explanation of the material was given together with the examples of manual and software problem-solving, in line with the expectation of the lecturer as mentioned in the analysis of users. Although students work with the software, they should also work without the software. At the end of each section, there were some exercises must be solved by the students. These exercises benefit the students in the form of reinforcement in each session. The exercises allow students to examine their difficulties. In addition, the main advantage of using the module is that the exercises accompanied by the key answers attached at the end of the module. Thus, students should be able to measure their level of understanding. The learning using module not only improved the independent learning leading to students’ motivation but also allowed students to review the material independently which in turn reducing the time required in the next meeting.

4. Conclusion

The preliminary analysis of this study showed that a module of wxMaxima software in vector analysis subject needed to be developed. Meanwhile, in the prototyping phase, the module using the wxMaxima software in vector analysis subject that was developed in this study meets the validity criteria, whose a score of 4.5. This score indicates that the module is highly valid. Therefore, the module can be tested in teaching and learning process.

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