Development of innovative teaching and learning module in linear algebra course assisted by Maple

C Novtiar and A Y Fitrianna
Institut Keguruan dan Ilmu Pendidikan Siliwangi, Cimahi, Indonesia

E-mail: chandramathitb07@gmail.com

Abstract. The aim of this study is to develop an innovative teaching and learning module in Linear Algebra assisted by Maple. This study used Research and Development (R&D) with 4D (Define, Design, Development and Dissemination) model as its methodology developed by Thiagarajan, but in this study, the methodology is limited up until Development stage only. Two instruments were used in this study: expert validation sheets and students response sheets. These instruments were used to determine the validity of this module. Validity analysis on three expert validator gave draft I as the result meanwhile validity analysis on the students response gave draft II as the result. In this study we used 4 months research on 2015 Mathematics Education Department students, IKIP Siliwangi. The result of this study show that expert validity learning module is said to be valid with the results of validation from three expert validators having a value of 4.1 on a scale of 5 with very high validity of 58.82%. Limited trial for students showed a value of 3.44 on a scale of 5 with moderate validity of 63.16%.

1. Introduction
Mathematics as one of the sciences that underlies the development of technology, having importance in our daily activity. Starting from simple things to the existence of an idea that communicated by mathematical language. Mathematics is related to our daily activity, so students can apply mathematics for their useful matters, both in their daily lives and also work [1]. Learning Mathematics is like learning to think systematically because this material is interrelated with one another and cannot be separated. Mathematics consists of definitions, axioms, and arguments, where the arguments that have been proven to be valid before it can be applied in general, so mathematics is often referred to as deductive science [2]. In mathematics education, developing algebraic reasoning is important goal [3].

Generally, mathematics consists of Arithmetic, Geometry, Algebra, Trigonometry, Calculus, and Statistics. The most important is Algebra that learned and needed in daily life. Algebra is a branch of mathematics that deals with the study of quantities, relationships and interconnected structures. According to Kismanto [4], algebra usually interpreted as a language of symbols and relations. One of the importance of learning Algebra is maximize profits of the companies. In this part, the symbols and discussion in Algebra will be used to reduce the variables that affect the company's profits. NCTM argues that Algebraic competencies are very important to be developed in the later for working and continuing study to the next level [5].

Linear Algebra as one part of Algebra in Mathematics that studies the Linear Equation System (LES), Vectors, and Linear Transformation, is a method needed to deal with several variables and as a base of theoretical to design algorithms. Linear Algebra courses were also studied in the Mathematics
Education Program of IKIP Siliwangi. Linear Algebra is important to be mastered by prospective teaching students because Mathematical material contains algebraic topics such as linear equations, equations of two variables, and equations of three variables, which are material that must be mastered by students. In general, the aim of students studying Linear Algebra is to prepare students to be able to solve problems that are connected with matrix algebra and vector space concepts.

Data in the field taken by researchers in the 2014/2015 academic year of the Linear Algebra course found that the average final score was 63. This low value is possible in solving problems with Linear Algebra requiring very long elaboration and description. Students are still having difficulty connecting one concept with another concept. Linear Algebra material is related to one another and cannot be separated, so it requires students to think systematically. Limited time allocation is an obstacle to solving existing problems. So we need teaching materials (modules) that can be used by students to study independently. Learning module is the smallest unit of teaching and learning program that can be learned by students individually [6]. Learning modules are teaching materials that are arranged in a systematic and interesting manner that includes material, methods, and evaluations that can be used independently to achieve the expected competencies [7]. The use of modules can also facilitate lecturers in delivering lectures so that the achievement of learning objectives can be achieved properly.

Linear Algebra courses that require precision, skill, and accuracy in thinking also equip students with logical reasoning and mathematical abstraction. Therefore the active involvement from students is very necessary. The learning module that will be developed is an Innovative learning module. One of the Innovative Learning Modules in Linear Algebra courses can be realized with the assist of mathematical software. Mathematical software at Education is a part of Information and Communication Technology (ICT). At Makerere University, ICT became an integral part of managing educational services in the early 2000s [8]. Mathematical software that can be used in learning Linear Algebra is Maple. Kartono [9] said that the Maple program has the ability to make mathematical computing easily and quickly, helping to accurately display, calculate and also explore. In addition, the Maple program can help mathematical solutions easily and quickly without having to get caught up in mathematical computing difficulties. For students, Maple can be used as an independent learning media because of its speed, accuracy, and ease in helping to solve algebraically, vector, matrix, calculus and so on [10].

Based on the description above, the author was interested in developing the Maple Software Linear Algebra course module. In the module that will be developed, problem-solving is given in two ways, namely the theory that is in Linear Algebra and using Maple. So the purpose of this research is to develop a module that is valid, effective and practical. Some previous studies have developed modules similar to different software, namely, with the following results, such as elementary linear algebra modules with constructivism assisted by ICT can attract students’ attention, make students actively learn and help students improve learning outcomes [11]. This is related to which said that the learning process is said to be effective if the learning process of the students can achieve the expected learning goals.

2. Method
The research method used in this study is a research and development (R&D). Educational R&D is an industry-based development model in which the findings of research are used to design new products and procedures [12]. The R&D research model used in this study is 4D, known as Define, Design, Development, and Dissemination [13]. But, in this study, the methodology limited up until development stage only. The instruments used in this study were expert validation sheets and student response sheets. This research was conducted at IKIP Siliwangi in the 2015 students of Mathematics Education with a period of 4 months. The following steps carried out in this study are four phases.

Researchers conduct several activities in define phase. The front end analysis is carried out to determine the basic problems that arise in the learning process in the Linear Algebra course so that it is necessary to develop Linear Algebra teaching materials that can support the learning process. Learner analysis is done to see the characteristics of students in the learning process in the Linear Algebra course, which includes basic algebraic abilities and basic abilities in operating a computer. The conceptual analysis carried out in this study is to identify Linear Algebraic material that has been
systematically compiled and in accordance with the syllabus and RPS. After conducting a material analysis, an analysis of the tasks that must be completed by students during the learning process is carried out, based on the objectives to be achieved. Lastly, based on the analysis of material and assignments, obtained several specific objectives (indicators achieved) that will be achieved by students in a learning process.

Researchers conduct several activities in design phase. Firstly, media selection is done to determine the learning media to fit the material characteristics and specific objectives (indicators) to be achieved. Media selection is done so that learning can run optimally in accordance with the indicators to be achieved. This activity is in the form of designing learning modules that will be developed. The format to be developed in this study is a learning module assisted by Maple software. Lastly, the activity carried out at this stage was to design an innovative learning module in Linear Algebra courses assisted by Maple software.

At the development stage, the product will be produced through several steps. The first step is expert appraisal. Modules that have been compiled as a preliminary draft, in this phase will be conducted by a number of people who are considered experts in their fields. Suggestions from the validator are used to correct the initial draft assessed. The second step is developmental testing. Tests conducted on students to obtain input in the form of student comments on modules that have been prepared based on aspects of language, content and writing format.

3. Result and Discussion
Linear Algebra Learning at IKIP Siliwangi has not been fully optimal in achieving predetermined learning goals. Based on observations made by researchers (as instructors), a learning module is needed that is adapted to the characteristics of students of the mathematics education study program IKIP Siliwangi. Modules developed using mathematical software that has been studied by students. Observation and study of literature study methods found that most of the students already have laptops and have received instructional media courses where learning is emphasized in the application of mathematical software such as Maple. The previous module used by students did not accommodate students in understanding the concept.

Based on the discussion with the lecturer advisory group (KBK), developing teaching materials with material adapted to the syllabus used in the Mathematics Education program in IKIP Siliwangi. After analyzing the material, the material to be developed is Matrix, Determinants and Inverse Matrices, Linear Equation Systems, Vector Space, Inner Product Space, Linear Transformation and Eigenvalue. Based on these materials, task analysis is carried out to determine the tasks based on the material that student must complete during the learning process to achieve the learning objectives.

Based on material analysis and assignments, specific learning objectives are produced which form the basis for compiling and designing learning materials. The analysis that has been done at the define stage is obtained that the material in the module to be developed is starting from the matrix material as a pre-requisite material.

After conducting the define phase, the learning module is developed, in the design stage. Analysis of selected media was carried out at the define phase, then it was chosen to make the Linear Algebra course module assisted by Maple software. The purpose of using maple, because students can solve linear algebra problems systematically as when working without using maple help. Format selection is done to determine the design and the design of the module which includes the contents of the module and learning media. The format chosen for the innovative learning module, in addition to the material is also equipped with steps to use the Maple software in the material application. Initial design activities are carried out by following a predetermined format, namely each material and sample questions included in the module, complete with the use of Maple software. The analysis that has been carried out in the design stage is obtained by a module content design as follows in Figure 1.
Matriks adalah suatu susunan unsur-unsur yang berbentuk persegi panjang. Unsur-unsur tersebut disusun pada baris dan kolom yang dibatasi oleh tanda kurung dan dapat berupa bilangan maupun suatu peubah. Nama matriks menggunakan huruf besar seperti $A, B, C$ dan seterusnya. Sedangkan unsur (anggota) dari matriks yang berupa huruf ditulisikannya menggunakan huruf kecil. Tanda yang digunakan untuk mengurung unsur-unsur matriks menggunakan tanda $( )$ atau $[ ]$.

Contoh 1.1 :

$$A = \begin{pmatrix} -1 & 2 & 1 \\ 3 & 5 & 4 \end{pmatrix} \text{ dan } B = \begin{pmatrix} -\sqrt{2} & \pi \\ 1 & \frac{1}{2} \\ 0 & 0 \end{pmatrix}$$

Maple Code

Membuka beberapa fungsi dalam Aljabar Linear

```maple
with(LinearAlgebra) : with(MTM) : with(linalg) :
with(Student[LinearAlgebra]) :
```

Menyusun matriks $A$ ukuran $2 \times 3$ dengan elemen baris pertama yaitu $[-1 \ 2 \ 1]$ dan elemen baris kedua $[3\ 5\ 4]$

$$A := \text{Matrix}([[ -1, 2, 1 ], [ 3, 5, 4 ]])$$

Menyusun matriks $B$ ukuran $3 \times 2$ dengan elemen baris pertama yaitu $[-\sqrt{2} \ \pi]$, elemen baris kedua $[1 \ \frac{1}{2}]$ dan elemen baris ketiga $[0 \ 0]$

$$B := \text{Matrix}([[ -\sqrt{2}, \pi ], [ 1, \frac{1}{2} ], [0, 0]])$$

Figure 1. Content Design of Linear Algebra Course Modules

In the development phase, the learning module is developed by validating modules that are already in the design stage. This validation was carried out by expert lecturers as validators who assessed draft I, then carried out repairs and obtained drafts II. Then a limited trial was conducted for students to see the students’ response to the learning module developed so that the final draft was obtained. The results of the Development Phase that have been carried out, are explained in the following discussion.

Validation carried out in this study is validation by lecturers who are experts in their fields. The expert lecturers involved were 3 people. The aspects validated by experts include Aspect I, which is the Format of Teaching Materials, aspects II, namely the Content of Teaching Materials and aspects III, namely the Language used in teaching materials. Each validated aspect contains several statements. Each statement contains 5 answers, namely 1: Not Good, 2: Poor, 3: Good enough, 4: Good, 5: Very Good. The following are the results of the validation of the lecturers presented in the Table 1.

| No | Lecturer Code | Average |
|----|---------------|---------|
| 1  | D-1           | 4.59    |
| 2  | D-2           | 3.53    |
| 3  | D-3           | 4.18    |
|    | Average       | 4.10    |

Table 1. Average Recapitulation of Lecturer Validation
Table 1 shows that the average of the three validators for the draft I teaching material is 4.10 which means it has a Good category. Then the validity test was carried out on draft I. The results of the validation of draft I by experts are presented in Table 2.

### Table 2. Results of Expert Validation

| Aspect               | No. | Rated aspect                                      | Rxy | Interpretation          |
|----------------------|-----|--------------------------------------------------|-----|-------------------------|
| I                    | 1   | Clarity of order based on syllabus               | 0.92| Very high validity      |
|                      | 2   | Has appeal                                       | 0.92| Very high validity      |
|                      | 3   | Layout settings                                  | 0.13| Very low validity       |
|                      | 4   | Type and size of letters accordingly             | 0.80| High validity           |
|                      | 5   | Clear numbering system                           | 0.99| Very high validity      |
| II                   | 1   | The truth of the content or material in accordance with the syllabus | 0.92| Very high validity      |
|                      | 2   | An essential material                            | 0.80| High validity           |
|                      | 3   | Compatibility of material with the help of Maple software | 0.80| High validity           |
|                      | 4   | The use of Maple software helps students understand the material | 0.99| Very high validity      |
|                      | 5   | Suitability of tasks with material sequences     | 0.80| High validity           |
|                      | 6   | Feasibility as a learning device                 | 0.80| High validity           |
| III                  | 1   | The truth of grammar                             | 0.92| Very high validity      |
|                      | 2   | Simplicity of sentence structure                 | 0.92| Very high validity      |
|                      | 3   | The sentence in the module content is easy to understand | 0.92| Very high validity      |
|                      | 4   | Encourage interest in work                       | 0.80| High validity           |
|                      | 5   | Clarity of instructions and direction            | 0.92| Very high validity      |
|                      | 6   | The language used is communicative               | 0.92| Very high validity      |

Based on Table 2, the results of the validation are obtained in several aspects, namely those that have low validation: 0 aspects, which have very low validation: 1 aspect, which has a high aspect: 6 aspects, which have very high aspects: 10 aspects. The following percentage of validation presented in Table 3.

### Table 3. Percentage of Validation Results

| No. | Criteria  | Total | Percentage (%) |
|-----|-----------|-------|----------------|
| 1   | Very high | 10    | 58.82          |
| 2   | High      | 6     | 35.29          |
| 3   | Is being  | 0     | 0.00           |
| 4   | Low       | 0     | 0.00           |
| 5   | Very low  | 1     | 5.88           |
|     | Total     | 17    | 100.00         |

Based on Table 3, it is found that only one aspect has low validation, which is the aspect of the instructional material format in the layout regulation statement. In other aspects, it has a high validity of 35.29% and is very high at 58.82%, so the draft I of teaching materials can be said to be valid.

After obtaining a revised draft I by the validator, improvements were made to aspects that were considered to have a very low level of validity. Then the second draft was produced and limited trials were conducted for students, to see the students' response to the teaching materials developed. Response sheets given to students include Module Quality, Module Display, Practical Quality, and
Language. Each aspect contains several statements. Each statement contains 5 answers, namely 1: Not Good, 2: Poor, 3: Good enough, 4: Good, 5: Very Good.

| Table 4. Percentage of Students Response |
|-----------------|-----------------|-----------------|
| No. | Student Code | Average |
|---|---|---|
| 1 | M-1 | 4.00 |
| 2 | M-2 | 3.26 |
| 3 | M-3 | 4.00 |
| 4 | M-4 | 3.11 |
| 5 | M-5 | 2.64 |
| 6 | M-6 | 3.74 |
| 7 | M-7 | 3.27 |
| 8 | M-8 | 3.53 |
| 9 | M-9 | 3.47 |
| 10 | M-10 | 4.00 |
| 11 | M-11 | 3.11 |
| 12 | M-12 | 3.53 |
| 13 | M-13 | 3.42 |
| 14 | M-14 | 2.84 |
| 15 | M-15 | 3.21 |
| 16 | M-16 | 3.47 |
| 17 | M-17 | 3.21 |
| 18 | M-18 | 3.58 |
| 19 | M-19 | 3.58 |
| 20 | M-20 | 3.32 |
| 21 | M-21 | 3.32 |
| 22 | M-22 | 3.53 |
| 23 | M-23 | 3.53 |
| 24 | M-24 | 3.53 |
| 25 | M-25 | 3.21 |
| 26 | M-26 | 3.32 |
| 27 | M-27 | 3.42 |
| 28 | M-28 | 3.63 |
| 29 | M-29 | 3.95 |
| **Average** | **3.44** |

Based on Table 4, the average student response to draft II is 3.44 so that the teaching materials module can be said to be in a good category. Then the validation test for each statement is obtained, the results in Table 5 are obtained.

| Table 5. Results of the Validation of Student Response Sheets |
|-----------------|-----------------|-----------------|
| Aspect | No. | Statement | Rxy | Interpretation |
|---|---|---|---|---|
| I | 1 | The learning material has been presented in full on the Maple-assisted Linear Algebra Course learning module | 0.5573 | Moderate validity |
| | 2 | The procedure for using Maple software helps to | 0.5511 | Moderate validity |
Based on Table 5, the results show that the validity of student responses in draft II is in the moderate category of 63.16%. Based on the results of these calculations carried out final repairs so that the final draft is obtained. From the field notes and student responses, it was found that students had no difficulty in using the module because it was equipped with instructions for use, this statement obtained a high validity of 0.7189.

4. Conclusion

Development of learning modules that have been carried out with the Thiagarajan 4D method, to obtain the required development requirements and adapted to the conditions of Mathematics Education Study Program Students of IKIP Siliwangi, which then obtained draft I and then validated by the Expert Validators (Expert Lecturers), so that the second draft was obtained the trial is limited to students to see the practicality of the contents of the module. Based on the development of Learning Modules in ICT-based Innovative Linear Algebra subjects the results of validation from the three validators were 4.10 from a scale of 5 and with a very high level of validity of 58.82%, based on these results, the learning module could be said to be valid. Furthermore, limited trials were conducted for...
students of the class of 2014 to see student responses to the Learning Module, obtained an average of 3.44 on a scale of 5 and with a medium validity level of 63.16%.

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