Instructional design in mathematics for undergraduate students based on learning by mistakes approach utilizing scilab assistance

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Abstract. The issue related to making mistake while learning such as negative emotion is found while students learn mathematics with the aid of a computer. When the computer output showed a mistake message, the students considered it as a computer software malfunction. Based on this issue, the writer designs an instructional model based on learning by mistake approach and which is Scilab assisted. The method used in this research is research design involving undergraduate students in matrix algebra courses. The data collected through survey with questionnaire to gain feedback about the approach implemented. The data analyzed using quantitative descriptive. The instructional design proposed is the student act as a mistake corrector while the teacher acts as a mistake maker. Teacher deliberately makes mistakes with the help of Scilab software. On the other hand, students correct, analyze and explain errors resulting from Scilab software. The result of this research is an ICT based instructional design which is expected to be applicable as an alternative learning in directing students to think positively about mistakes in learning. Furthermore, students are also expected to improve their ability in understanding and thinking critically while solving problems and improving themselves in learning mathematics.

1. Introduction
According to conventional pedagogy, students are encouraged to avoid making mistakes while learning. As explained by Jerinic [1] in a report by Lindsey E. Richland, Nate Kornell and Liche Sean Kao about the advantages of learning through mistakes. It was found that mistakes-free learning process inefficient. It turned out that when students make a mistakes they learn lessons much faster. Therefore conventional view about avoiding mistakes in learning needs further discussion.

For many students and teachers, mistakes in learning are related to negative feelings [2]. To them, a mistake is a very shameful act, will only show their inadequacy, will only make them feel foolish and various other negative feelings and views related to mistakes. These feelings are caused by the fact that they think emotionally about mistakes.

Unlike teachers, most students feel greater pressure when making mistakes. To them, a mistake is a very shameful act, will only show their inadequacy, will only make them feel foolish and various other negative feelings and views related to mistakes. These feelings are caused by the fact that they think emotionally about mistakes. Furthermore, It is difficult for students with fewer resources (due to
In addition, students also showed a negative attitude toward mistakes while learning mathematics with the aid of a computer. When the computer output showed a mistake message, the students considered it as a computer software malfunction. This proves that they don't have a good reasoning skill since they didn't do any effort to find out what had caused the display of that mistake message.

Nevertheless, making mistakes is part of the learning process. Students in particular need to be aware that mistakes can have a positive impact. Like the English proverb, "Mistakes are the best teachers" or as a proverb in Germany, "Aus Fehlern wird man klug" and "Aus Fehlern lernt man" (You will learn from mistakes) [7]. These three proverbs mean that mistakes are the best teachers. You will be smart by making mistakes and you will learn from mistakes. In addition, teachers in teaching and learning activities always provide other positive motivations, for example when the teacher asks the students to solve a mathematical problem in front of the class, the teacher always gives the message "Please don't be afraid of giving a wrong answer". This certainly shows that mistakes can serve as a means of learning and reflection. According to Neuhaus [8], such reflection helps colleagues avoid similar missteps and enhances their teaching effectiveness. However, although there have been improvements, some of the studies carried out with teacher candidates have shown that they consider students’ mistakes something that should be avoided, because if not abolished immediately the mistake would stay in the students’ minds and gain resistance [9].

Because of the above issues, this study examines an instructional model of learning mathematics based on learning by mistake approach using Scilab assistance. The instructional model used is similar to the one developed by Huynh [10]. The student acts as a mistake corrector while the teacher acts as a mistake maker. Teacher deliberately made mistakes with the help of Scilab software. On the other hand, students correct, analyze and explain errors resulting from Scilab software.

The purpose of this study is to develop an ICT based instructional design which is expected to be applicable as an alternative learning in directing students to think positively about mistakes in learning. Students are also expected to improve the ability of understanding and thinking critically in solving problems and improving themselves in learning mathematics.

2. Methods

The research method used in this study is design research. This design aimed to design and develop an intervention (such as programs, teaching-learning strategies and materials, product and system) or alternatively to design and develop educational intervention [11]. To achieve this aims, this research is divided into the following steps: (1) identifying the problem, formulating ideas, identifying existing knowledge in the literature; (2) creating an instructional models. The instructional model examined in this study is applied to the subject about matrix; (3) the model begins to be applied in the classroom using Scilab for teaching and learning matrix, making conclusion, and giving suggestion; (4) spreading the results that have been developed.

To find out the students’ responses on instructional design, 26 students were asked to fill 9 items questionnaire. The questionnaire is Likert-like scale on which 1 represents “completely disagree” and 4 “completely agree” [12]. The questionnaire covers 2 dimensions, they are belief about learning by mistakes (items 1, 2, 3 and 4) and advantage of software assisted learning (items 5, 6, 7, 8 and 9). The data were analyzed using quantitative descriptive by considering the mean score and standard deviation of each item.

3. Result and Discussion

Through this instructional model, students are given some questions about the matrix. Students have been given the task to input the problem on Scilab software. From the output of software obtained, students are asked to explain what mistakes are in the problem and provide solutions to the problem.
3.1. Problem 1

Given two matrices $A = \begin{bmatrix} 4 & 8 & 7 & 4 \\ 3 & 12 & 6 & 9 \\ 11 & 4 & 1 & 5 \end{bmatrix}$ and $B = \begin{bmatrix} 7 & 8 & 4 & 1 \\ 3 & 5 & 7 & 9 \\ 8 & 9 & 12 & 2 \\ 3 & 1 & 13 & 7 \end{bmatrix}$. Use the Scilab software to determine what value $C = A + B$, $D = A \times B$ and $E = B \times A$, is $D = E$? Describe the results obtained!

If the command was executed, the results were shown in Figure 1 and Figure 2.

![Figure 1. Sum of Scilab result](image1)

![Figure 2. Results Scilab Multiplication](image2)
Learning Objectives to be achieved in sample problem 1 is that students understand the nature of the addition, subtraction and multiplication operation of the matrix, i.e. the sum of matrices $A$ and $B$ can only be operated if $A$ and $B$ have the same number of columns and rows [11]. Students who understand the nature of the addition operation, subtraction and multiplication of the matrix, can explain the location of the mistake and can provide a solution to the mistake.

3.2. Problem 2

Use Scilab software to determine the inverse of the matrix $A = \begin{bmatrix} 1 & 2 & 3 \\ 1 & 2 & 3 \\ 0 & 0 & -3 \end{bmatrix}$

If the command was executed, the results would be shown in Figure 3.

![Figure 3. Inverse Scilab Results](image)

In the determinant of the matrix, there is a property that if $A, B \in \mathbb{R}^n$, then $\det(AB) = \det A \det B$. The nature of this determinant needs to be known by the student to understand the mistake result on the Scilab output. Thus, the goal in this study is that students can understand the determinant properties of the matrix, explain the location of the error and can provide the correct answer solution.

3.3 Students response about instructional design

Since the design is relatively new to the students, it is necessary to find out the students’ response on the matter. Questionnaire consisting 9 items were distributed to 26 students after the instructional design was implemented. Table 1 presents about mean and standard deviation on all items.

The data show that subscale belief about learning by mistakes has average 2.64 and subscale advantage of software assisted learning has average 2.84. Although the mean on both dimensions are low, there are positive feedback on item 2 and item 9. This indicates that students become aware that making mistake while learning helps learning better.
Table 1. Descriptive data of the items in the questionnaire

| No. | Items                                                                 | Mean | SD  |
|-----|----------------------------------------------------------------------|------|-----|
| 1.  | I became knowledgeable about the advantages of making mistakes        | 2.23 | 0.99|
| 2.  | Making mistakes while learning has helped me understand mathematics   | 3.00 | 0.75|
|     | lesson better                                                         |      |     |
| 3.  | Learning by mistakes can promote positive attitude in learning process| 2.50 | 0.95|
| 4.  | After participating in this learning process, I am not afraid and     | 2.81 | 0.57|
|     | hesitant for making mistakes while learning                           |      |     |
| 5.  | I like studying using mathematics software assisted learning         | 2.23 | 0.95|
| 6.  | I like asking questions about the utilization of the software being   | 2.38 | 1.06|
|     | used                                                                  |      |     |
| 7.  | Teaching and learning becomes more interesting and interactive with   | 2.73 | 0.92|
|     | software                                                              |      |     |
| 8.  | Software helps me understand mathematics subject                      | 2.88 | 0.77|
| 9.  | After participating in this learning process, I understand the message | 3.00 | 0.57|
|     | notifying about my mistakes in computer software                      |      |     |

4. Conclusion
Based on the above discussion, it can be concluded that inputting mistakes and mistake messages from computer programs can be used as a tool for learning. Students can understand the input mistake in question and can provide an explanation of the correct answer. For teachers, this model can be used as a learning approach to determine the level of students' understanding ability.

Teaching and learning mathematics through mistake using Scilab is an instructional design that needs to be developed in subsequent research. This model of learning needs to be studied experimentally to see the effect on students' learning outcomes. Furthermore, this instructional is still limited to the model of theories about the basic properties of matrices. For further research, the model can be applied to other mathematical materials. Affective aspects of students also need to be researched to determine the student's response to learning through mistake using Scilab.

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