Design of a Problem-Based Virtual Learning Environment

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Abstract. This study aims to develop a problem-based virtual learning environment with interactive scaffolding for junior high school mathematics learning. Although several virtual learning environments for problem-based learning have been developed in response to developments in information and communication technology and the need for innovation in learning, the inclusion of interactive scaffolding as external support needed by students during the problem-solving process still has not received special attention. The development in this research follows the stages of ADDIE: Analysis, Design, Development, Implementation, and Evaluation. Research results are still limited to the design stage.

1. Introduction

Strengthening problem solving skills is one of the most important features in forming individuals to be successful in life. To compete in the era of the industrial revolution 4.0 where information is widespread and technology is developing rapidly, technical skills are no longer sufficient but other skills are needed, such as the ability to solve non-routine problems [1]. The ability to solve non-routine problems is a key competency in a world full of change, uncertainty, and surprise [2]. Some previous research shows that students at the secondary school level have difficulty in solving non-routine problems. For example, students have many deficiencies in mathematical abilities such as the ability of number facts, visual space, and information [3]; students have not been able to explore the problems posed [4]; and students use less their logical thinking [5]. This is reflected in the results of the 2012 Program for International Student Assessment (PISA) which shows that Indonesian respondents have very low achievements in the cognitive dimension that emphasizes irregular thinking and problem solving skills where Indonesia is ranked 64th out of 65 countries [6]. This result also indicates that Indonesian students are not accustomed to solving non-routine problems, are not skilled in modelling real situations in the form of mathematics and vice versa, and are less able to analyse and draw conclusions. Even though the capability that is more needed in the 4.0 industrial revolution era is the ability to solve non-routine problems [7]. Therefore, learning innovations are needed that can develop students' problem solving abilities. One way that can be done is to integrate learning into a problem-based virtual learning environment (VLE) [8]. The success of PBM depends on the availability and skills of teachers in providing scaffolding during problem solving activities [9]. According to Vygotsky's socio-cultural theory, scaffolding is a form of support provided by a more capable teacher or colleague in the zone of student proximal development. Strategies that supports students' problem solving processes are: (1) encouraging questions; (2) peer
review; (3) expert modelling; and (4) reflective thinking [10]. Therefore, the integration of these strategies into VLE is believed to support teachers 'skills in providing scaffolding in the PBM environment which results in the development of students' abilities in non-routine problem solving.

2. Method

The development study in this research follows the process of developing the ADDIE model which consists of five phases: Analysis, Design, Development, Implementation, and Evaluation. This development model has a flexible and dynamic framework so that it can help create effective learning materials for various types of learning presentations, both printed and web-based.

3. Result

3.1. Analysis

At this stage an analysis of learning problems related to difficulties faced by students in solving problems, analysis of learning objectives, user analysis (students) related to students' readiness in using technology, and analysis of learning settings. Information collected in the analysis steps is used as a basis for decisions around the design and development of learning content.

3.1.1. Target audience

The target audience in this study were 30 students in class VIII-A of Imelda Private Middle School in Medan who registered in odd semester in academic year of 2019/2020. In the curriculum document used in the school, the objectives of learning mathematics in the subject matter of Relationships and Functions in class VIII are formulated as follows:

- Students are able to pay attention to demonstrations or daily activities related to relationships and functions.
- Students are able to observe several relationships that occur between two sets.
- Students are able to look at various functions based on their characteristics.
- Students are able to collect information about function values and function graphs on Cartesian coordinates.
- Students are able to present the results of learning relations and functions.

To identify the various factors that influence the design of learning aimed at the achievement of learning objectives, survey and analysis of the needs of the target audience. Students' initial knowledge is known through their formative test results in the previous subject matter.

![Figure 1. Final results of formative subject matter tests.](image)
especially in the use of social networks. From this finding, it can be determined the complexity of interactive computer-based activities that will not experience problems from students. To determine the amount of content that will be presented and divide it into small units, knowledge of the time availability of students is needed. From the survey results, it is known that the majority of students (82%) do not have other activities outside of study hours (Figure 2).

3.1.2. Learning content identification

The subject matter of Relationships and Functions taught in Class VIII of SMP is within the scope of Geometry and Measurement. The general objective of learning Geometry and Measurement in junior high is: Students are able to use lines and angles, flat shapes (rectangles and triangles), flat side spaces, flat sides of curves, circles, congruence and harmony, Pythagorean theorem, and transformation in solving problems of daily life. This general objective establishes an initial definition of learning content and focuses on learning design. Content identification and analysis in this research is carried out by applying the methods: (1) Task Analysis, namely identifying tasks that must be learned or improved by students and knowledge or skills that need to be developed or improved; and (2) Topic Analysis, namely identifying and classifying learning content.

| Orientation | Example of assignment |
|-------------|-----------------------|
| Remembering | How many mappings are possible from set \( \{1,2,3\} \) to set \( \{x \in \mathbb{R} \mid x \leq 3\} \)? |
| Understand  | Draw a graph of the function defined by the domain \( \{-2,-1,0,1,2,3\} \). |
| Apply       | Present the relation "less than" from \( \mathbb{N} \times \mathbb{N} \) to \( \mathbb{N} \times \mathbb{N} \) using the Cartesian diagram. |
| Analyse     | Mr. Mahir has three children named Budi, Ani, and Anton. Mr. Ridwan has two children named Alex and Rini. Mr. Rudi has a child named Suci. If \( A \) is the set of fathers and \( B \) is the set of children, explain whether the relation of "child from \( A \) to \( B \) is a function? Also explain what if the relation is from \( B \) to \( A \)? |
| Evaluate    | Masri together with his friends Udin, Kurnia, Anto, and Zulham went to a tutoring. The subjects provided by the tutoring are Mathematics, Natural Sciences, Social Sciences, PPKn, Indonesian, and English. From the six subjects it turns out that each of them is not the same as his passion. Masri likes Mathematics and science, but this time he wants to study science. Udin likes IPS, Indonesian and English, but this time he wants to learn Indonesian. Kurnia likes English and PPKn, but what she wants to learn is PPKn only. Anto studied social studies, even though he actually liked social studies, mathematics, and science. Zulham likes Mathematics |
and PPKn, but he only wants to study Mathematics. From this information, what forms of relationships can be made? How do you know for certain the forms of the relationship?

Create

| Create | Can you explain how to determine the number of possible mappings from a set of members of set A to another set of members of set B if the number of members of set A and B are the same? What if the number of members is different? |

Through the analysis of mathematics subject assignments, content for Bloom's Taxonomy-oriented learning was revised by Anderson & Krathwol [11] namely: remembering, applying, understanding, analysing, evaluating, and creating. This task analysis is carried out to identify the tasks that must be learned to develop or strengthen the problem solving abilities of junior high school students. The task analysis performed in this study consisted of four main steps:

- **Step 1:** Identify the task. Identify and describe tasks that students must learn or improve to achieve learning goals.
- **Step 2:** Classifying tasks. Tasks are classified as: procedural tasks (that is, tasks performed by executing a series of steps in succession); or principle-based tasks (that is, tasks that require affirmation and decisions to be applied in different situations under conditions that change at any time).
- **Step 3:** Sort out tasks. The tasks are sorted into: Steps (for procedural tasks) and Guidelines that should be applied to carry out tasks (for principle-based tasks).
- **Step 4:** Identify the knowledge and skills needed. Identify the knowledge and skills needed to carry out the steps in the best way or to implement the guidelines.

Table 1 presents an example of task analysis in the subject matter of Relationships and Functions in VIII grade of junior high school. Task analysis is completed by analysing the topic. Topic analysis aims to: Identifying learning content and Classifying content elements. Table 2 identifies four types of content: facts, procedures, concepts, and principles used in the analysis of the topic Relations and Functions.

**Table 2. Four types of content in the topic analysis Relations and Functions.**

| Content type | Information |
|--------------|-------------|
| Fact | Unique, specific information that answers questions like: What? When? These facts can be seen, exposed or indicated. |
| Procedure | Procedure is a series of steps that are clearly defined, aimed at solving a task or problem. Procedures for answering questions like: "How do you ...?"
| Concept | A concept is a collection of objects, entities, or ideas that are: defined by a single word or term; share the same characteristics; differ in unimportant characteristics; need a definition; and usually answers questions like: "Is ...?"
| Principle | Principles or rules describe the relationship between two concepts. Some principles can be translated into strategic instructions that can guide complex decisions and tasks. |

3.2. **Design**

By looking at the tasks and content elements that have been identified earlier in the analysis of tasks and topics, it is possible to translate the overall general learning objectives into more specific learning goals.
3.2.1. Learning objectives
Based on Revised Bloom's taxonomic cognitive domain [11], there are six types of cognitive performance in the learning objectives in this study, ranging from the lowest performance (remembering) to the highest performance (creating) as presented in Table 3.

Table 3. Six types of cognitive performance in the learning objectives.

| Performance | Learning objectives                                      |
|-------------|---------------------------------------------------------|
| Remembering | Students are able to recognize or remember information  |
| Understand  | Students are able to reformulate a concept              |
| Apply       | Students are able to use information in new ways        |
| Analyse     | Students are able to decompose and establish relationships between components |
| Evaluate    | Students are able to set a decision based on a criterion or standard |
| Create      | Students are able to realize a new product or a new approach |

3.2.2. Verifying the alignment of learning objectives, activities, and tests
Clear learning objectives allow the development of learning activities that are truly focused on the needs of students and become the basis for evaluation tests. It is important to ensure that learning activities and evaluation tests aim to develop and assess performance of the same type and learning content as expressed in learning objectives; in other words, learning activities and evaluation tests need to be aligned with learning objectives.

3.2.3. Establishing learning sequences
The method used in this study to rank learning objectives when creating learning structures is a prerequisite method. This method uses a hierarchy of learning objectives, first teaching skills that seem to be good prerequisites for other skills. To create a hierarchy of the results from the analysis of previous tasks and topics are used.

3.2.4. Establishing teaching methods
After the learning structure is established, the Teaching Designer proposes the best mix of methods and techniques for specific web-based learning. This web-based learning design involves using a combination of the following teaching methods.

- **Exposition** – which emphasizes the "absorption" of new information. This method includes presentations, case studies, working examples, and demonstrations.
- **Application** – which emphasizes the active process that students use to work on procedure and principle-based assignments and build new knowledge. This application method includes practice-demonstration methods, case-based exercises, guided research, and project work.
- **Collaboration** – which emphasizes the social dimension of learning and involves students sharing knowledge and doing collaborative assignments. This method includes guided discussion, collaborative work, and peer tutors.

Each method is delivered in a different format, using different types of media and communication devices. For example, a presentation can be delivered as a PowerPoint file or as a video presentation (recording or live). Online discussions take place in a discussion forum or through social media.

3.2.5. Establishing delivery strategy
In choosing the delivery format, the factors to consider are:
Factors related to students. The following are important factors to consider about students:
- They feel comfortable with the way it is delivered, their level of use of computers/gadgets, and the time available to them.
- Technological aspects. Student computer capabilities, infrastructure and connectivity need to be considered before making a technological decision. It is important to understand whether students have easy access to network systems. Some learning activities can be carried out only with the support of an internet connection, while other activities can be developed for independent learning.
- Institutional needs. One of the limitations associated with institutional needs is limited time and money. Developing independent learning, especially with a lot of multimedia, requires more time than preparing a virtual classroom.

3.2.6. Establishing an evaluation strategy
Another important decision in this design stage is the evaluation of web-based learning. First, the evaluation objectives must be set. The objectives of the evaluation in this study are:
- Check the quality of learning to improve it before it is implemented (formative evaluation);
- Measuring the effectiveness of learning shortly after implementation (confirmation evaluation);
- Evaluate old learning to see if the learning is still valid or needs to be modified (summative evaluation).

Next, an evaluation of student progress in learning is determined. This evaluation influences the choice of assessment tests which will be integrated into web-based learning. Assessment of students' knowledge and skills is carried out before learning begins, when the learning process runs, and after completing all stages of learning.

As stated earlier, it is important to ensure assessment tests are aligned with learning objectives. For this reason, it is necessary to prepare a draft assessment test from the initial stages of the development of this VLE, after setting learning objectives for each learning unit.

4. Conclusion
This study aims to develop a problem-based virtual learning environment with interactive scaffolding for junior high school mathematics learning. The development in this research follows the stages of ADDIE: Analysis, Design, Development, Implementation, and Evaluation. Research results are still limited to the design stage. The next is development stage. At this stage, prototypes are developed directly from design specifications. The development phase consists of three main steps, namely: 1) content development, 2) storyboard development, and 3) VLE device development.

5. Acknowledgments
This study and publication of the results have been supported by grants from the Ministry of Research, Technology, and Higher Education of the Republic of Indonesia. Support from Medan State University, Indonesia, is also greatly acknowledged.

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