Modelling testlet instrument in blended learning design to assess students’ metacognition in the environmental chemistry course

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Abstract. Metacognition is one of the skills in the 21st century learning and defined as someone awareness of their own knowledge and regulation of their own thinking. Metacognition is needed in chemistry learning and everyday life to understand matter and solve problems. Learners need to know their own metacognition in order to improve and develop their metacognition. This paper aimed to prescribe metacognition indicators that used in the instrument and modelling a proper testlet instrument in blended learning design to assess students’ metacognition in the Environmental Chemistry course. This instrument is in e-learning website to support blended learning and the application of ICT in the 21st century learning. Participants in this study were 9 experts who tested the validity of metacognition indicators and the validity of the instrument. The Delphi technique and Aiken’s Formula with 9 experts used to measure the content validity. The results were: (1) Metacognition indicators measured were declarative knowledge, conditional knowledge, procedural knowledge, planning, and evaluation; (2) The instrument validity test results showed that each item was valid and matching with the metacognition indicators. Based on the results, the valid testlet instrument can be used to measure students’ metacognition level.

1. Introduction
Metacognition is one of the 21st century learning skills. The term was introduced by Flavel stating that metacognition is thinking about the process of thinking [1]. Metacognition can be categorized into two aspects: cognitive knowledge and cognitive regulation. Metacognition can be defined as someone’s awareness of their own knowledge and regulation of their own thinking. Metacognition is useful in education because it can lead learners to determine the best learning strategies for themselves so as to improve learning achievement [2]. Metacognition also implements the Meaningful Learning Theory by Ausubel. Therefore, learners should know the percentage of their own metacognition indicators. The results of these measurements can be used as a reflection to improve and develop their own metacognition skills.

The instrument to assess students’ metacognition should contain metacognition indicators. Each aspect has several indicators developed by experts. Determination of appropriate indicators is needed if researchers want to assess metacognition skills. Selection of this indicator must be aligned with the characteristics of the course. The selected indicators validated by experts. Usually, the instruments for assess metacognition is the questionnaire, such as Metacognitive Awareness Inventory (MAI) [3] and...
Learning Strategies Survey (LSS) [4]. There are few instruments that can be used to measure both metacognition and cognition in a course [5,6], especially in learning chemistry. Environmental Chemistry is one of the courses taught to students in Chemistry Education program at Universitas Sebelas Maret (UNS), Surakarta. This course is very applicable, closely related to the environment, and has a very wide coverage of the subject. This course discussed the problems that occur in our environment. Students’ metacognition skills are needed in order to design a most effective strategy to overcome these problems. So, students’ metacognition skill is appropriate when assessed in this course.

The result of the preliminary study showed that the instrument that can be used is testlet instrument. Testlet is a group of questions consisting of one major case and followed by several questions [7]. Testlet instruments have been used to measure reading comprehension [8], measuring affective and personal spheres [9], and measuring cognitive as well as process science skills [10]. In this study, testlet instrument developed in addition to assess metacognition skills and also measure cognition in Environmental Chemistry course. This course was delivered in blended learning design, so this instrument can be done directly by students in UNS’s e-learning website. The instrument that has been made must be tested the validity of its contents by the experts before it is tested to participants.

Based on the explanation, this study aimed to prescribe metacognition indicators that used in the instrument and modelling a proper testlet instrument in blended learning design to assess students' metacognition on Environmental Chemistry course.

2. Method
This research is second phase of design-based research, which is modelling or development product and followed by content validity test. The first step was to determine the metacognition indicators to be measured by synthesis theory. The second step was to test the validity of metacognition by 9 experts with Delphi technique. The third step was modelling a testlet instrument that can assess both students’ metacognition and knowledge level in the environmental chemistry course. The final step was to test the content validity of the testlet instrument by 9 experts with Delphi technique.

2.1. Participants
Participants in this study were 9 experts who tested the validity of metacognition indicators and the validity of the instrument. The 9 experts selected were: 2 practitioners of environmental chemistry course; 2 experts in content of the material; 2 experts on the learning assessment; 1 expert in learning media; and 2 practitioners in blended learning research in the university.

2.2. Instruments
The instruments used in this study were the questionnaire to measure the validity of metacognition indicators and the questionnaire to measure validity content of testlet instrument. Both questionnaires used Likert scales (1-4), which are highly relevant (score: 4), relevant (score: 3), less relevant (score: 2), and irrelevant (score: 1). Experts may also provide suggestions for each metacognition indicator and each question item in the testlet instrument.

2.3. Data analysis
Data analysis was done by descriptive-quantitative. Determination of metacognition indicators was done through synthesis theory and analysed descriptively. Modelling testlet instrument aligned to competency indicators of the environmental chemistry course and validated the metacognition indicators. Both validation results were calculated by Aiken formula presented in figure 1. An indicator of metacognition or an item question in the testlet instrument is valid if the validity score or Aiken’s validity index (V) is more than 0.74. This value was obtained from the table of validity coefficient by Aiken with 9 experts and 4 scales category on the questionnaire [11].

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V = \frac{s}{[n(c-1)]} \quad \text{with} \quad s = \sum n_i (r - \ell_o)
\]

Notes:

- \(V\) : Aiken’s validity index
3. Result and discussion

3.1. Determination and validation results of metacognition indicators

In this study, determination of metacognition indicators used the synthesis theory. The study of literatures from various sources about metacognition was done at this stage. The selected indicators to be used are presented in table 1.

Table 1. Metacognition indicators.

| Metacognition Component | Metacognition Indicator | Reference | Description |
|------------------------|-------------------------|-----------|-------------|
| Cognitive Knowledge    | Declarative Knowledge   | [12]      | Students must understand their factual information. This indicator can be measured through the provision of answers in the form of factual theory in the Environmental Chemistry course. |
|                        | Procedural Knowledge    | [13]      | Students must know and well understand their procedural knowledge. It can be measured by procedural assignment whose sequence is randomized. |
|                        | Conditional Knowledge   | [14]      | The students must know why and when any information can be used. It can be measured by giving a diagram than the students can define the relationship between each aspect on diagram. |
| Cognitive Regulation   | Planning                | [12–14]   | The students must be trained in planning the best strategy for problem-solving. It is also useful when they want to reach their goals. |
| Evaluation             |                         | [12–14]   | Students must be able to evaluate or reflect on what they have done. |

The validation result showed the valid results for each of metacognition indicators. This showed that all of the metacognition indicators in table 1 could be measured in the environmental chemistry course. These five indicators are also part of the metacognition indicators on the standard instruments to assess metacognition, which is called MAI.

3.2. Modelling and validator Result of testlet instrument

Modelling testlet instrument in this study must be aligned to the competency indicators of Environmental Chemistry course and metacognition indicators that have been validated. The competency indicators on Environmental Chemistry course are presented in table 2.

Table 2. The competency indicators of environmental chemistry course.
There are five metacognition indicators and five competence indicators in the environmental chemistry course. The testlet instrument to be created contains 30 questions and divided into 10 testlet (1 testlet contain 1 STEM/main case and followed by 3 questions). Each question below can measure 1 metacognition indicator. The modelling of the testlet instrument is shown in figure 2 and example of testlet instrument is presented in figure 3.

| Number | The Competency Indicators                                                                 |
|--------|------------------------------------------------------------------------------------------|
| 1      | Explaining about global environmental issues and biogeochemical cycle.                   |
| 2      | Explains the role of Environmental Chemistry in the implementation of environmental ethics.|
| 3      | Explains the biogeochemical cycle.                                                       |
| 4      | Describe the environmental quality standard.                                             |
| 5      | Describe the waste treatment.                                                            |

Figure 2. Modelling testlet instrument.

The description bellows is used to answer question 25-27.

Mr. Charlie is an owner of a restaurant and a lecturer of Environmental Chemistry course. As a lecturer of Environmental Chemistry course, he wants to apply the appropriate waste treatment to his restaurant.

26. Based on the answer before, the order of waste management site passed by the waste stream in sequence is... (Metacognition indicator measured: planning).
   A. Initial treatment – oil filter – anaerobic reactor – sinks – advanced filtration
25. Based on the illustration, the resulting waste includes the category of waste…(Metacognition indicator measured: declarative knowledge).
   A. Industry
   B. Agriculture
   C. **Domestic**
   D. Mining
   E. Farms

27. The waste treatment site passed by the waste stream in the first stage above serves to…(Metacognition indicator measured: procedural knowledge).
   A. Reduce the reactant’s active level
   B. Reduce heavy metal content
   C. Filtering dirt or unsolved debris
   D. Degradation of organic matter content
   E. **Reduce the fat and oil content**

**Table 3.** Scoring guideline of integrated testlet.

| Score | Scoring Guideline                                      |
|-------|--------------------------------------------------------|
| 0     | If the first answer is wrong in one STEM               |
| 1     | If just the first answer is right in one STEM          |
| 2     | If just the first and second answers are right in one STEM |
| 3     | If all of the answers are right in one STEM            |

**Table 4.** The improvement process in the testlet modelling.

| Number | Issues to improve                                           | The Solution                                           |
|--------|-------------------------------------------------------------|--------------------------------------------------------|
| 1.     | Researcher should consider ways that students couldn’t cheat each other. | The students will do the assignment at the same time, same place, with their own laptop, and supervised by lecturer and researcher. |
| 2.     | Researcher should consider navigating question in the website to minimize the questions that have been missed by students. | Navigation on assignment is turned off, so the students have to answer the questions in sequence. |
| 3.     | The researcher should provide detail instruction before the students do the assignment. | Detail instructions are already written in the introduction of assignment. |

The difficulty experienced when modeling testlet was when aligning between integrated testlet with metacognition indicators and course characteristic. Metacognition indicators are usually developed in the explicit statements. In this study, we tried to develop a cognitive question that can measure metacognition skills. Another difficulties is scoring testlet in e-learning website that use Moodle. The weakness of the quiz feature in Moodle is that scoring just for multiple-choice type, so each right item gets point, while the integrated testlet scoring guidelines differs according table 3. The solution is to use another feature like quiz in iSpring.
4. Conclusion
This study showed that metacognition indicators measured in testlet are: declarative knowledge; procedural knowledge; conditional knowledge; planning; and evaluation. Each metacognition indicators is valid based on validity test result with Delphi technique and Aiken formula. Each items in the testlet instrument is valid based on the content validity test. Some suggestions are given as described in the results and discussion above. Based on the results, the valid testlet instrument can be used to assess students’ metacognition in the environmental chemistry course in blended learning design.

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