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The development of question instruments to access concepts mastery, critical thinking, and metacognitive skills

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ABSTRACT

Biology education in the current era is expected not only to be able to improve the knowledge about biology concept, but also to empower students' critical thinking and metacognitive skills. This study aimed to analyze the characteristics to develop a question instrument that can access these. This study aimed to analyze the characteristics as well as develop a question instrument that can access these three parameters three parameters. The instrument developed was tested in high schools in Malang involving 89 respondents. The results of item test were analyzed for validity using Pearson product moment and reliability using Cronbach's alpha. The results of this study concluded that the instruments developed consisted of ten items that were valid and reliable to measure mastery of concepts, critical thinking skills, and students' metacognitive skills.

INTRODUCTION

Biology is one branch of science that has been taught from elementary school to college. In elementary and junior high schools, biological concepts are taught through science subjects. Furthermore, in senior high school, biology is taught in separate subjects with other branches of science. Furthermore, in several departments in higher education, biology is also being studied by undergraduate as well as postgraduate students.

Biology is an important branch of science to learn (Fleischner et al., 2017). Various concepts learned are closely related to human daily life. Various fields of human life, such as agriculture, the environment, and the health sector cannot be separated from biological concepts (Reiss, 2018). Therefore, although it contains various concepts that are considered difficult by students (Agboghoroma & Oyovwi, 2015; Ozcan, Ozgur, Kat, & Elgun, 2014; Oztas, 2014; Topçu & Şahin-Pekmez, 2009; Zikra, 2016), biology learning is expected to be able to encourage students to master those various concepts.

However, in the era of 21st Century education, mastery of concepts is not the only learning goal that must be achieved. Learning must be designed to be able to empower various skills needed by

students to compete in the 21st century. These skills include critical thinking skills (Scott, 2015; Strauss, 2016) and metacognitive skills (Ait, Rannikmäe, Soobard, Reiska, & Holbrook, 2015; Perry, Lundie, & Golder, 2018).

Critical thinking skills are one of the essential skills that must be possessed by every graduate in the current era (Karakoç, 2016). Through critical thinking skills, one can understand the situation and overcome the real problems they face by applying the knowledge they have (Browne, Hough, & Schwab, 2009). A person with good critical thinking skills will be able to see gaps and solutions that might not be thought of by individuals who have low critical thinking skills (Moon, 2008; Strauss, 2016).

Beside critical thinking skills, metacognitive skills also play an important role in life in the current era. Through metacognitive skills, a person can understand his position and know what they have to do to improve their quality (Rahman, Yasin, Ariffin, Hayati, & Yusoff, 2010). This skill also facilitates graduates to be able to provide appropriate and complete solutions and systematic and clear explanations of the problems faced (Hargrove, 2013; Kim & Lee, 2018). Metacognitive skills also train students to be able to set their learning goals and manage their learning environment (Cera, Mancini, & Antonietti, 2013). Therefore, related to its essential role, empowerment of metacognitive skills needs to be optimized during learning (Valeyeva, Kupriyanov, Romanova, & Nugmanova, 2017; van der Stel, Veenman, Deelen, & Haenen, 2010).

The existence of research in the biology education field is an essential condition to ensure the quality of learning process (Cai et al., 2017; Goktas et al., 2012; Ion & Iucu, 2015; Tseng, 2012). In this regard, research in the biology education field continues to develop every year. Various studies try to examine the current learning conditions of biology (Coşkun, 2018; Huber & Kuncel, 2016; Kisac & Budak, 2014; Kumar.R & James, 2015). In addition, various other studies try to provide recommendations for learning conditions that are able to optimally empower mastery of concepts (Ulfa, Anggraeni, & Supriatno, 2017) as well as students' thinking skills (Al-Mubaid, Abukmail, & Bettayeb, 2016; Ritter & Mostert, 2016; Surya & Syahputra, 2017).

In various educational studies, the instrument for collecting data is an important component that cannot be underestimated (Canals, 2017; Hsu, 2005; Leedy & Ormrod, 2013; Peersman, 2014). The quality of the instrument will determine the quality of the data obtained (Chen, Hailey, Wang, & Yu, 2014). Therefore, good research is research that uses instruments composed of valid and reliable items (Bajpai & Bajpai, 2014; Eldridge, 2017; Mohajan, 2017; Ouzouni & Nakakis, 2011; Singh, 2017). Unfortunately, several research articles that have been published in several journals do not inform the quality of the instruments used by researchers.

This study aimed to provide information related to the characteristics of questions that can be used to access students' concepts mastery, critical thinking, as well as metacognitive skills. In addition, this study also aimed to develop instruments consisting of valid and reliable questions. This research is different from similar research, because previous research focuses on designing scoring instruments (Corebima, 2009; Zubaidah, Corebima, & Mistianah, 2015), while this study focuses on the design of questions.

RESEARCH METHODS

This study consists of several stages, i.e. (1) analyzing the criteria of questions that are able to access students' concepts mastery, critical thinking, as well ass metacognitive skills; (2) choosing topic that could represent biological concepts in high schools; (3) preparing the question grid; (4) preparation of a list of question; (5) instrument testing; (6) the scoring of the results of the item test using a scoring instrument (7); analyzing of data obtained from item test.

The items test involved two high schools in Malang. In total, there were 89 respondents involved in the item test. Items test were conducted from September to October 2018.

The scoring of students' concepts mastery was used a Likert scale consisting of three scales: (1) incorrect answer; (2) some components were correct; and (3) correct answers. Scoring critical thinking skills were using the rubric of critical thinking skills developed by Zubaidah et al. (2015). The rubric consists of five scales. Furthermore, scoring the metacognitive skills were using the metacognitive skills rubric developed by Corebima (2009) and consists of seven scales.

The validity of the instrument was analyzed using the Pearson product moment, while the reliability of the instrument used Cronbach's alpha. Validity and reliability tests were carried out using SPSS 24.0. The basis for determining the validity of question items was determined on the p-value obtained from each item. If the p-value was <0.05, then the question item was valid. In the reliability test, the decision was determined from the value of Cronbrach's Alpha obtained. The value was then matched with the reliability coefficient category which includes: 1) very high reliability (0.81 - 1.00); 2) high reliability (0.61 - 0.80); 3) moderate reliability (0.41 - 0.60); 4) low reliability (0.21 - 0.40); and 5) very low reliability (-1.00 - 0.20).

RESULTS AND DISCUSSION

Question Criteria

Concepts mastery

The concepts mastery level illustrates how many concepts are mastered by students after following certain learning. Some researchers associate mastery of concepts as achievement of cognitive learning outcomes. Based on the analysis that has been conducted, the following are some criteria for question items that can be used to access the level of students' concepts mastery.

1. The kind of questions can be multiple choice, essay, or other forms of questions.
2. Questions are able to access mastery of students' concepts of subject matter.
3. Questions can be either low-level or high-level questions.

Critical thinking skills

Critical thinking skills are one of the high-level thinking skills that can be accessed using high-level questions. The following are some criteria that can be used as guidelines in preparing questions for critical thinking skills.

1. It is recommended to use essay questions.
2. Questions describe mastery of students' concepts of learning topic.
3. Questions are classified as high-level thinking questions that encourage students to solve problems critically.
4. Questions are able to access students' language skills in composing sentences.
5. Questions are able to assess students' ability to provide reasons for answers that have been written.

Metacognitive skills

The following are the criteria that need to be considered in compiling questions to access students' metacognitive skills.

1. It is recommended to use essay questions.
2. Questions describe mastery of students' concepts of learning topics.
3. Questions are classified as high-level thinking questions.
4. Questions can access students' ability to use grammar when composing sentences.
5. Questions can access the flow of students' thinking in solving problems.

6. Questions are able to access students' ability to provide arguments that support written answers.

Question Topics

After reviewing high school biology subject matter, several biological topics were chosen as representatives of the overall biological topics studied at school. The following are selected topics.

1. The role of biology in life.
2. The relation between biology and the other branches of science.
3. Scientific attitude and scientific method.
4. Cells as the smallest unit of life.
5. Tissue as one level of the organization of life.
6. The role of the virus.
7. The role of biotic components in the ecosystem.
8. Difference between fungi and plants.
9. The relation between biodiversity and evolution.
10. The role of abiotic components in life.

Question lists

The following is a list of questions which were the results of the development that have been carried out.

1. *Seiring dengan kemanuan ilmu dan teknologi, biologi semakin memposisikan dirinya sebagai ilmu yang sangat berperan dalam berbagai aspek di kehidupan manusia. Analisislah, apakah pernyataan tersebut tepat!*
2. *Bila ada seorang temanmu yang menyatakan bahwa "biologi merupakan cabang dari sains yang tidak memiliki kaitannya dengan cabang sains lainnya", bagaimana pendapat Anda akan pernyataan tersebut?*
3. *Beberapa tahun yang lalu, Indonesia pernah digegerkan dengan dukun ciliki Ponari yang memliki batu ajaib yang dapat menyembuhkan berbagai macam penyakit. Sebagai seorang calon ilmuwan, apakah Anda dapat mempercayai hal tersebut? Uraikan alasan jawaban Anda!*
4. *Sel merupakan unit fungsional terkecil pada tingkatan kehidupan. Hal apa yang mendasari pernyataan tersebut?*
5. *Jika suatu jaringan mengalami kerusakan, apa yang terjadi dengan tingkat organisasi kehidupan di atas maupun di bawahnya?*
6. *Apakah Anda setuju bila virus hanya dapat memberikan dampak negatif bagi kehidupan manusia? Utarakan alasan dari jawaban Anda!*
7. *Apa yang sebenarnya akan terjadi bila salah satu komponen biotik di dalam suatu ekosistem tiba-tiba mengalami kepunahan?*
8. *Jika Anda diberi sebuah objek yang mirip jamur, analisislah dua ciri yang dapat meyakinkan Anda bahwa objek tersebut termasuk tumbuhan atau jamur!*
9. *Apakah Anda dapat menerima bila seseorang mengatakan bahwa keberagaman makhluk hidup yang ada di dunia ini merupakan hasil dari mekanisme evolusi? Uraikan alasan jawaban Anda!*
10. *Tanpa udara, kita akan segera mati dalam hitungan menit; Tanpa air, kita dapat bertahan lebih lama daripada tanpa udara; Tanpa makanan, kita dapat bertahan hidup lebih lama bila dibandingkan dengan hidup tanpa air. Apakah Anda setuju dengan pernyataan tersebut? Berilah alasan dari jawaban Anda!*

Item Test Results

In this study, high-level questioning instruments have been developed. A summary of the validity test results is

presented in Table 1, while a summary of the reliability test results is presented in Table 2.

Table 1. The summary of validity test results using the Pearson product moment

Items	Pearson Correlation		
	Concept Mastery	Critical Thinking Skills	Metacognitive Skills
1	.396**	.239*	.601**
2	.246*	.440**	.376**
3	.231*	.465**	.277*
4	.633**	.374**	.461**
5	.436**	.494**	.420**
6	.377**	.526**	.230*
7	.215*	.455**	.468**
8	.482**	.627**	.352**
9	.422**	.315**	.229*
10	.529**	.248*	.229*

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Based on the results of validity test using Pearson product moment, it can be seen that all items in all parameters have p-value <0.05. Thus, the ten questions are valid when used to measure the level of students' concept mastery, critical thinking skills, and student metacognitive skills. Furthermore, based on the results of the reliability test, the Cronbach's Alpha values of mastery of concepts, critical thinking skills, and metacognitive skills were 0.431; 0.471; and 0.248, respectively. Thus, the question instrument was categorized as a moderate reliability when used to measure the level of mastery concepts and critical thinking skills. On the other hand, the instrument was categorized as low reliability when used to measure students' metacognitive skills.

Table 2. The summary of reliability test results using Cronbach's Alpha

Parameters	Cronbach's alpha
Concepts Mastery	.431
Critical Thinking Skills	.471
Metacognitive Skills	.248

At present, mastery of concepts is not the only main goal of learning. Learning is expected to be able to empower critical thinking skills and student metacognitive skills. These two skills are important features needed by graduates in this 21st Century era (Ait et al., 2015; Christou, 2016; Perry et al., 2018; Scott, 2015; Strauss, 2016). Through critical thinking skills, students will be able to solve the problems they face critically and through metacognitive skills students will be able to face problems and evaluate their actions. To ensure learning in schools has empowered these skills, the existence of instruments that are able to access the level of student competence in these parameters is needed.

The instruments developed in this study can be used as a tool to find out how far biology learning in secondary schools is able to empower critical thinking skills and student metacognitive skills. This instrument can also be used to find out how well of concepts mastery in middle school students. The results of the item analysis in this study also informed that the instruments that had been developed could be used by teachers and researchers in the biology education field.

CONCLUSION

In this study, the development of question instruments has been carried out to measure mastery of concepts, critical thinking skills, and metacognitive skills of students in biology learning. The results of the item analysis concluded that the instrument consisted of ten valid questions in measuring mastery of biological concepts, critical thinking skills, as well as metacognitive skills. Question instruments were also categorized as moderate reliability when used to access mastery of concepts as well as students' critical thinking skills and low reliability when used to measure students' metacognitive skills.

The instrument developed in this study is expected to be used as an instrument to access student competencies in subsequent studies. It is also expected there are other subsequent

studies that can design instruments with better levels of reliability.

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