International Journal of Education
Vol. 9 No. 1, August 2016, pp. 17-23

doi: dx.doi.org/10.17509/ije.v9i1.3713

THE EFFECTIVENESS OF COLLOID MODULE BASED ON GUIDED INQUIRY APPROACH TO INCREASE STUDENTS' COGNITIVE LEARNING OUTCOMES

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First draft received: 30 April 2016 Final proof received: 24 August 2016

Abstract
Colloid is one of the chemical topics taught in high school. Actually, the characteristic of Colloid topic is contextual. Colloid topic is taught by expository and discussion methods. Based on observations in SMA Negeri 4 Malang and SMA Negeri 16 Surabaya, these methods could not improve students' ability to construct their own knowledge; as a result, students did not have a good understanding in the Colloid topic. An alternative way to increase students' understanding, especially in the cognitive aspect is using innovative teaching materials like a colloid module based on guided inquiry approach. The previously mentioned module was developed by the author. The feasibility percentage of the Module was 85.66%. The aim of this research is to find the effectiveness of the Colloid Module to increase students' cognitive learning outcomes. This research used one group pretest-posttest experimental design. The sample of this research consisted of 33 students of X-MIPA 3 SMA Negeri 2 Malang in the 2015/2016 academic year. The effectiveness of The Colloid Module to increase cognitive learning outcomes was determined by the results of paired sample *t*-test analysis and the gain score of students' pretest and posttest using cognitive test instrument. This cognitive test instrument had content validity index of 92.04%. Based on the trial result of 36 students in SMA Negeri 3 Malang, 30 questions were considered valid and had a reliability coefficient of 0.866 based on Spearman-Brown. The result of this research showed that the Colloid Module was effective to increase students' cognitive learning outcomes. It was indicated by the analysis of paired sample *t*-test, with *t* score (-38.525) lower than *t* critical (-2.037), so there was a significant difference between pretest and posttest scores after using the Colloid Module. The effectiveness of the Colloid Module was also determined by the gain score of pretest and posttest scores of students' cognitive skills of 0.688, categorized as a medium gain.

Keywords: Module, guided inquiry, cognitive learning outcomes, colloid topic

To cite this paper (in APA style):
Novilia, L., Iskandar, S. M., & Fajaroh, F. (2016). The effectiveness of colloid module based on guided inquiry approach to increase students' cognitive learning outcomes. *International Journal of Education, 9*(1), 17-23. doi: dx.doi.org/10.17509/ije.v9i1.3713

INTRODUCTION

Colloid is one of the chemistry topics taught in high school. The basic competence of Colloid topic is to analyse the role of colloid in life based on its characteristics (Ministry of Education and Culture [MoEC], 2013). The Colloid topic consists of Colloidal System, Colloid Characteristic, Colloid Preparation, and Colloid Application in Life subtopics. Actually, the characteristic of Colloid topic is contextual. The colloid system talks about kinds of colloid such as milk, mayonnaise, dust, fog, air pollution and also hydrophilic and hydrophobic colloid. The substances mentioned previously are directly involved in students' life, but in the implementation, Colloid topic tends to be memorized by students (Chittleborough & Treagust, 2007). Rohma (2013) stated that in the Colloid topic, students are usually required to memorize its content, even though students can get any kind of learning sources. The memorizing method causes several misconceptions. Trigunarti (2008) said that there were several misconceptions in Colloid topic, such as: Students assume that solution is a mixture which is composed by kinds of substances and water; solution is always thin; and colloid is always thick. Purtadi & Sari (2011) found several misconceptions in the Colloid topic, such as colloid precipitates; colloid is solid; solution always dilutes; and solution is a mixture of matter and water.

Based on the interview to chemistry teachers in SMA Negeri (State Senior High School) 4 Malang and SMA Negeri 16 Surabaya, the Colloid topic was taught by expository and discussion methods. The expository method has some advantages in learning. The research of National College for Leadership (2013) revealed that the reason for the success of students in China in their international tests such as PISA (Program for International Student Assessment), TIMMS (Trends in International Mathematics and Science Study), and PIRLS (Progress in International Reading Literacy Study) was the chalk and talk or expository learning method. Miao et al. (2015) said that Chinese students taught with expository method had higher learning outcomes than British students who were taught with group discussion method. However, the expository learning method does not only have advantages, but also some disadvantages. The disadvantages of expository method are that the expository method makes students passive; it can increase the competition between students rather than promoting students' teamwork; and it gives a little chance to students to acquire the ability of problem solving and communication skills.

The second learning method that was used by the teachers to teach the Colloid topic was discussion method. The discussion method such as buzz group and role play is one of active learning (Revell & Wainwright, 2009). Based on Revell & Wainwright's research, the discussion method can spark ideas from students and encourage them to think about issues from fresh perspectives. Then, the group discussion helps students internalize and understand what they have read and explore different perspectives and opinion within the group. Based on *Direktorat Tenaga Kependidikan* [Directorate of Educational Personnel] (2008), the advantages of discussion method are that it can encourage students to actively express their opinion, and it can make students pay attention to other students' opinion. The discussion method also has disadvantages, in which the discussion method can be controlled by only two or three students, and sometimes the discussion is expanded out of the topic; in addition, during the discussion process there can be some disagreement between students which can make students get offended by each other, and the discussion method needs more time in learning.

The authors did some observations in two classes at SMA Negeri 4 Malang, 2013/2014 academic year, focusing on students' understanding of the Colloid topic taught with previously mentioned methods. It was shown that the means of cognitive learning outcomes from the two classes were 72.47 and 76.91. Based on these data, one class did not reach the minimum completeness criteria (Indonesian, KKM) for chemistry in senior high school. The percentages of students who passed the passing grade or minimum criteria of completion for cognitive learning outcomes in the Colloid topic were 41.17%, and 65.71%, respectively. Based on previously mentioned data, it can be seen that teaching the Colloid topic with expository or discussion method was not effective, proven by the fact that there were students who did not pass the minimum criteria of completion for Colloid topic.

Learning outcomes are the results students achieve after they go through a learning process (Arikunto, 2012). Sukmadinata (2010) said that learning outcomes are the realization of an individual's potential skills or capability. Therefore, learning outcomes are the results which have been obtained by students in a learning process as a manifestation of students' capability. The learning outcomes are divided into cognitive learning outcomes, affective learning outcomes, and psychomotor learning outcomes (Anderson et al., 2001). The cognitive learning outcomes cover the abilities which are related to environment, consisting of knowing, understanding, applying, analysing, evaluating, and creating. The affective learning outcomes cover the ability of emotional understanding of something. The psychomotor learning outcomes are students' motoric ability and coordination of movement.

An alternative way to increase cognitive learning outcomes is using learning models based on investigation such as guided inquiry (Maikristina et al., 2013; Wahyudin et al., 2009; Vlassi & Karaliota, 2013). Guided inquiry is one type of inductive teaching methods, which begins with the application to construct the theories (Prince & Felder, 2006). Prince & Felder (2006) further stated that the inductive methods such as guided inquiry, problem-based learning, and project-based learning are more effective than traditional deductive methods to achieve a broad range of learning outcomes, where guided inquiry is more efficient for learning new tasks and transferring learned skills. Vlassi & Karaliota's research (2013) shows that with guided inquiry-based learning, students' posttest scores were greater than their pretest. Sund & Trowbridge (1973) explained that inquiry is a process to define and investigate problems, formulate hypothesis, design an experiment, collect data, and make conclusion of the problems. Qing & Yan (2010) explained the guided inquiry-based learning's components are definition of the problem, hypothesis, planning and performance of the experiment, observation of the phenomena, and organising and analysing of data.

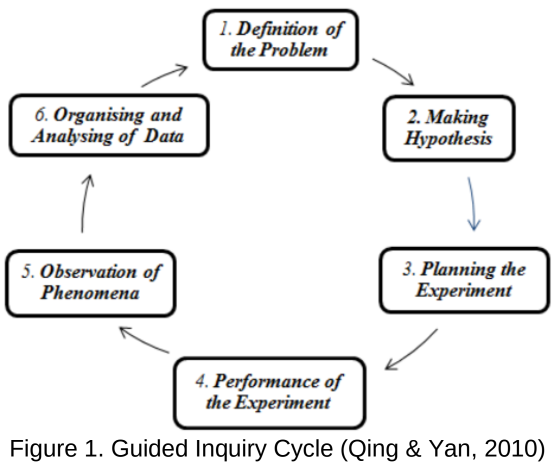

Figure 1. Guided Inquiry Cycle (Qing & Yan, 2010)

The application of guided inquiry to increase cognitive learning outcomes can be assisted by suitable learning materials such as a module. Module is a learning material that can encourage and give students a chance to study independently and to study appropriately according to students' ability (Mbulu, 2001). Module is selected to assist guided inquiry-based learning because students can construct their own knowledge appropriately according to their ability. Setyosari (1991) said the advantages to use module in learning are students' motivation can be increased, students' task can be identified quickly, students' learning outcomes can be suited to students' ability, and it is more effective and efficient in learning. On the other hand, using modules in learning has some disadvantages, such as students become distant and students' social skills are not trained. Therefore, the success of chemistry learning, especially in the Colloid topic, depends on the content of the module and how the teacher teaches the Colloid topic using the module.

Chemistry learning based on the guided inquiry module has been proven to increase learning outcomes. Munawaroh (2013) reported that 89.3% students could reach the criteria of minimum completion or passing grades after using guided inquiry module of intermolecular forces topic. Fatmawati (2013) said that 84.6% students reached the criteria of minimum completion, with 83.3% for the cognitive aspect, 82.3% for the affective aspect, and 83.8% for the psychomotor aspect, after using a guided inquiry module of electrochemistry topic.

Based on the previous research explained above, it is known that the module based on guided inquiry can increase cognitive learning outcomes. In this research, the authors developed a module based on guided inquiry model in colloid topic. The development of the Colloid Module was based on *Panduan Penulisan Modul dari Direktorat Tenaga Kependidikan Departemen Pendidikan Nasional* [Guidelines for Module Writing from the Directorate of Educational Personnel of the National Education Department] (2008). The procedure of the module development consists of need analysis, designing a draft, validation, trial, and revision.

The aim of the Colloid Module development is to find the feasibility and effectiveness of the Colloid Module to increase cognitive learning outcomes. The feasibility of the Colloid Module was 85.66%, consisting of construct feasibility for 91.20%, display feasibility 86.11%, language feasibility 85.92%, and graph feasibility 79.40% (Novilia, 2016). Based on the feasibility percentages, it is known that the Colloid Module is feasible to be used. The students' responses to using the Colloid Module were highly positive, namely 83.40%.

However, it is not only the feasibility of the Colloid Module, but also its effectiveness that should be known. The effectiveness of the Colloid Module was found through a trial to 33 high school students. The effectiveness was determined by paired sample *t*-test result and gain score of pretest and posttest of students' cognitive ability. The Colloid Module is effective when there is a difference between pretest and posttest based on paired sample *t*-test and gain score result.

METHOD

Design

The sample of this research consisted of 33 students of X-MIPA 3 SMA Negeri 2 Malang in 2015/2016 academic year. The experimental design of this research was one group pretest-posttest which is showed on Table 1.

Table 1. Research Design

Pretest	Treatment	Posttest
O_1	X_1	O_2

(Creswell, 2012)

X_1 represents learning using the Colloid Module based on guided inquiry. O_1 is pretest before using Colloid Module, and O_2 is posttest after using Colloid Module.

Instrument

The instrument used to collect data was cognitive test. This instrument had 92.40% content validity. The test instrument was trialed to 36 SMA Negeri 3 Malang students. Based on the trial, 30 questions were found to be valid, and the Spearman-Brown reliability coefficient score for the instrument was 0.886. The r score was high when it was between 0.70 – 0.9 scale (Guilford, 1985).

The data were analyzed with descriptive quantitative analysis technique. Data of paired sample *t*-test and gain score from students' pretest and posttest results were used for analysis. The Colloid Module is said to be effective when there is a difference between pretest and posttest scores based on paired sample *t*-test and gain score result.

The gain score can be measured with this formula:

$$gain\ score\ (g) = \frac{\text{posttest} - \text{pretest}}{\text{total score} - \text{pretest}}$$

(Hake, 1999)

Hake (1999) said that gain score has three criteria, which are explained in Table 2.

Table 2. Gain Score Criteria

Gain Score Scales	Gain Score Criteria
$g \geq 0.70$	High
$0.30 \leq g < 0.70$	Middle
$g < 0.30$	Low

Procedure

The research procedure to find the effectiveness of the Colloid Module to increase students' cognitive learning outcomes is explained below:

1. The development of the Colloid Module and research instrument;
2. Validity test of the Colloid Module and research instrument to know their feasibility;

3. Trial of the Colloid Module in a small scale, trial of test instruments;
4. Trial of the Colloid Module in real class setting (X-MIPA 3 SMA Negeri 2 Malang); and
5. Test of students' cognitive learning outcomes to find the effectiveness of the the Colloid Module to increase students' cognitive learning outcomes.

Hypotheses

In this research, the hypotheses are:

H_0 : There is no significant difference between pretest and posttest results after using the Colloid Module based on guided inquiry.

H_1 : There is a significant difference between pretest and posttest results after using the Colloid Module based on guided inquiry.

Hypothesis test was used to find the effectiveness of the Colloid Module to increase students' cognitive learning outcomes. If the significant value > 0.05, or –t critical score ≤ t ≤ t critical, then H_0 is accepted, and if the significant value < 0.05, or –t < - t critical, or t > t critical, then H_0 is rejected (Priyatno, 2009).

FINDINGS AND DISCUSSION

The increase in students' cognitive pretest and posttest scores

The aim of this research is to find the effectiveness of the Colloid Module which has been previously developed. The effectiveness of the Colloid Module is showed by an increase in the pretest to post-test scores, the paired sample *t*-test analysis result, and gain score analysis of students' cognitive test (pretest and posttest). Table 3 shows the students' cognitive pretest and post-test scores.

Table 3. Students' Cognitive Pretest and Posttest Score

Student Number	Pretest Score	Posttest Score	Student Number	Pretest Score	Posttest Score
1	47	93	18	47	90
2	30	80	19	27	53
3	33	77	20	57	90
4	27	83	21	27	75
5	27	77	22	40	80
6	17	80	23	43	80
7	30	75	24	30	75
8	37	75	25	40	75
9	37	83	26	30	75
10	40	83	27	33	80
11	40	75	28	33	75
12	40	87	29	27	87
13	30	77	30	30	75
14	40	80	31	30	75
15	23	75	32	37	73
16	27	80	33	23	75
17	30	77	**Mean**	**33.61**	**78.61**

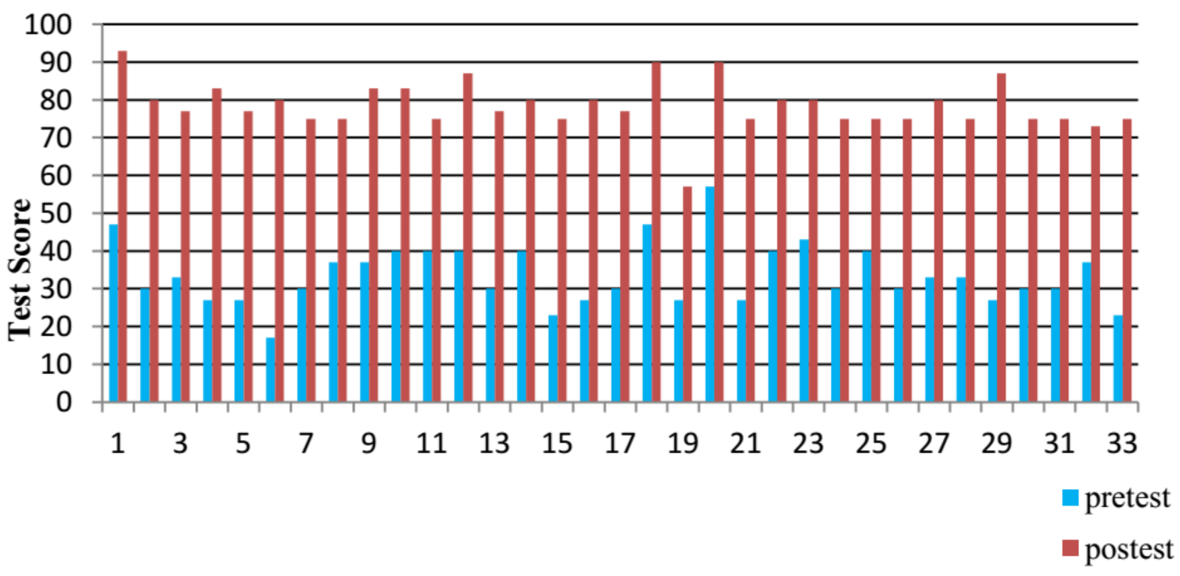

Figure 2. Graph of Students' Pretest and Posttest Score

Table 3 and Figure 2 above show the pretest and posttest scores of the 33 students of X-MIPA 3 SMA Negeri 2 Malang. The mean of pretest scores was 33.61 and the mean of posttest scores was 78.61. From those data, it is known that the increase in the test score mean after using the Colloid Module was 45.00. Based on Figure 2, it is found that all students' posttest scores experienced an increase from the pretest.

Based on Table 3 data, it can also be observed that there were two students (number 19 and 32) who could not pass the passing grade. The cognitive completion percentage of X-MIPA 3 students was 93.94%. This finding correspondences to those of Munawaroh's (2013) and Fatmawati's (2013) research.

The paired sample *t*-test result

The effect of the Colloid Module to increase cognitive learning outcomes was also determined by paired sample *t*-test. The aim of paired sample *t*-test is to find the difference of students' learning outcomes. Table 4 shows paired sample *t*-test analysis result calculated using *SPSS 16 for Windows* program based on students' cognitive pretest and posttest scores.

Table 4. Paired Sample *t*-test Results

	Paired Differences							
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	Df	Sig. (2-tailed)
				Lower	Upper			
Pair 1 pretest cognitive–posttest cognitive	-45.606	6.800	1.184	-48.017	-43.195	-38.525	32	.000

***t* critical: -2.037**

Based on Table 4, it is known that t (-38.525) was lower than t critical (-2.037), so H_0 was rejected. It can be concluded that there was a significant difference in students' cognitive ability before and after using the Colloid Module based on guided inquiry.

This result was supported by Howard & Miskowski's (2005) research, which reported that 79% students were helped to understand Biology Cell topic using Guided Inquiry Module-based Laboratory. Howard & Miskowski (2005) also mentioned that students' performance after using the module was better than before. Bethel & Lieberman (2014) said that using a learning module based on guided inquiry could increase the mean of posttest on the Protein Structure topic. Hatzikraniotis et al. (2010) also reported that there was an increase from the pretest to the post-test scores after using an inquiry module in the Thermal Conduction topic. The research of Gazali (2014) similarly revealed that 80% students who studied using worksheet based on guided inquiry fulfilled the criteria for minimum completion with a cognitive score mean of 83.7.

Based on the previous explanations, it is found that the Colloid Module had influence on students' cognitive pretest and posttest scores.

The students' cognitive gain score results

The effectiveness of the Colloid Module was not only determined by paired sample *t*-test analysis result, but also gain score analysis result. The gain scores for students' cognitive pretest and posttest scores are displayed in Table 5.

Table 5. Gain Scores of Students' Cognitive Pretest and Posttest Scores

Student Number	Cognitive Gain Score	Student Number	Cognitive Gain Score
1	0.868	18	0.811
2	0.714	19	0.411
3	0.657	20	0.767
4	0.767	21	0.658
5	0.685	22	0.667
6	0.759	23	0.649
7	0.643	24	0.643
8	0.603	25	0.583
9	0.730	26	0.643
10	0.717	27	0.701
11	0.583	28	0.627
12	0.783	29	0.822
13	0.671	30	0.643
14	0.667	31	0.643
15	0.675	32	0.571
16	0.726	33	0.675
17	0.671	**Mean**	**0.680**

Based on Table 5, it can be seen that the mean gain score for students' cognitive learning outcomes was 0.680. Table 2 also shows the gain score was categorized into a moderate level.

The gain score for students' cognitive learning outcomes that was only at the middle level or moderate category was due to the fact that students in SMA Negeri 2 Malang were not familiar with chemistry learning using a module based on guided inquiry independently. It was showed in the students' correct answer to each concept in the Colloid topic, displayed in Table 6.

Table 6. Percentages of Students' Correct Answers to Each Concept in the Colloid Topic

No.	Concept	Percentage of Correct Answers	
		Pretest	Posttest
1	Solution, Colloid, and Suspension	43%	86%
2	Dispersed phase and dispersing medium	54%	83%
3	Liophylic and liophobic colloid	36%	86%
4	Preparation of Colloid by dispersion-peptization method	18%	42%
5	Preparation of Colloid by mechanical dispersion method	33%	79%
6	Preparation of Colloid by Bredig arc method	9%	61%
7	Preparation of Colloid by condensation redox reaction method	15%	70%
8	Preparation of Colloid by condensation- double decomposition reaction method	21%	82%
9	Preparation of Colloid by condensation-hydrolysis reaction method	39%	100%
10	Preparation of Colloid by shaking two immiscible liquids	42%	85%
11	The properties of Colloid	27%	91%
12	Tyndall Effect	67%	97%
13	Coagulation of Colloid	6%	39%
14	Adsorption of Colloid	20%	59%
15	Electrophoresis of Colloid	21%	48%
16	Brownian Movement	30%	42%
17	Dialysis of Colloid	33%	79%
18	Protector Colloid	24%	67%
19	The application of colloid	15%	64%

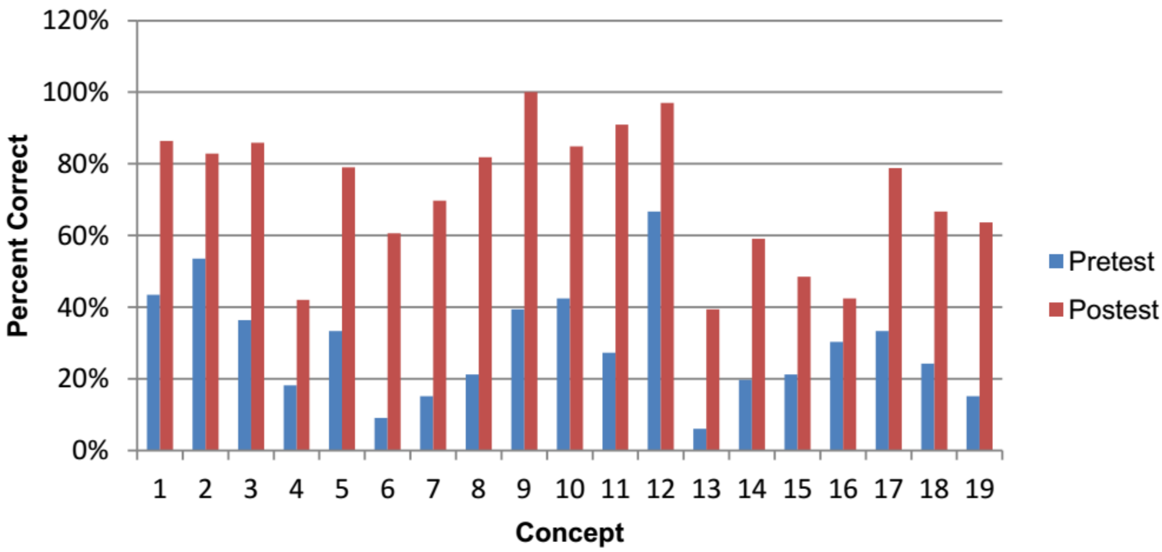

Figure 3. Comparison of correct responses for pretest and posttest concept questions.

Based on Table 5, it can be observed that the mean gain score for students' cognitive learning outcomes was in the moderate category. It probably happened due to the difference of students' understanding of each concept. Table 6 displays the percentages of students' correct answers to each concept on cognitive pretest and posttest. Based on Table 6 and Figure 3, it is clear that all the percentages for correct answers increased from the pretest to the posttest.

Based on the data in Table 6, it is also clear that the preparation of colloid by hydrolysis reaction method concept had the highest correct percentage of 100%, meaning that all students could answer the questions on this concept. The other concepts which had high rates of correct answers were solution, colloid, and suspension, dispersed phase and dispersing medium, liophylic and liophobic colloid, the preparation of colloid by condensation-double decomposition reaction method, the preparation of colloid by shaking two immiscible liquids method, the properties of colloid, and Tyndall effect concepts.

The lowest correct percentage was 39% in the sub-topic of coagulation of colloid concept. It could have happened due to the interrelatedness of the concept of coagulation of colloid to other concepts, such as the adsorption of colloid or charged colloid; thus, students must have the ability to relate those concepts. The relation of colloid coagulation concept and colloid adsorption concept is that coagulation process is started with an adsorption process. Colloid adsorbs positive or negative charges on its surface. Then, because of the addition of an electrolyte or heating, the dispersed colloid particles will collide to form an aggregate and thereby get separated from the dispersing medium. This phenomenon is called coagulation of colloid (Effendy, 2008). Furthermore, the coagulation of colloid is an abstract concept, in which students must imagine how in the dispersed phase colloid particles collide with each other and form an aggregate.

The other concepts which had low correct percentage were the preparation of colloid by dispersion-peptization method, the electrophoresis of colloid, and Brownian movement concepts. The low correct percentage could affect the students' cognitive gain score which was in the moderate category.

Meanwhile, the authors found some difficulties while doing this research. The first difficulty was time management when implementing the Colloid Module to the trial subjects. The second difficulty was that students were not familiar with chemistry learning using guided inquiry. Based on the authors' observations in SMA Negeri 2 Malang, Colloid topic was taught using the expository model; in addition the students did not use any module, and they only used worksheet as required by the Curriculum 2013. This finding is supported by Hartanto's (2012) research which mentioned that the difficulties of guided inquiry based learning lie on students' hesitation to do the guided inquiry activities.

CONCLUSION

Based on the research findings and discussion, it can be concluded that the Colloid Module based on guided inquiry which was developed in the research was effective to increase students' cognitive learning outcomes. It was shown by: 1) the increase from pretest to posttest scores with an increment value of 45.00 and students' cognitive completion of 93.94%; 2) The paired sample *t*-test analysis result which shows -t (-38.525) was lower than –t critical (-2.037), so there was a significant difference between students' cognitive pretest and posttest after using the Colloid Module, and 3) The gain score of pretest and posttest for students' cognitive skills was 0.680, or in the moderate category.

Some suggestions for the next research related to the effectiveness of the Colloid Module are: First, the effectiveness of the Colloid Module can be found through posttest-pretest control group experimental design using two classes, where the first class uses the Colloid Module and the second class not using it; second, the effectiveness of the Colloid Module to increase science process skills can also be conducted in the future; and third, Research and development of any kind of innovative learning materials such as worksheet, handout, media, etc., should be conducted.

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