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# Developing Metacognition of Teacher Candidates by Implementing Problem Based Learning within the Area of Analytical Chemistry

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**Abstract:** ***This research is intended to improve chemistry teacher candidates' metacognition and mastery over the concept of spectrometry and electrometry by implementing Problem Based Learning strategy. Quasi-experimental method along with pretest – posttest controlled group was employed in Laboratory practices of Analytical Chemistry Instrument Class. The assessment of metacognition was undertaken through content-based descriptive written test, questionnaire, and interview; and that of the mastery was undertaken only through descriptive text. The result of the research shows that %N-gain of descriptive test of metacognition and concept mastery from experimental group is higher than that of controlled group. The result of questionnaire and interview also supports metacognitive development of experimental class, with the highest metacognitive indicator achieved in identifying information and the lowest in developing procedure. The development of metacognition followed by the mastery of concept or vice versa can be much higher if the contributor is committed to constant innovation in changing the paradigm of verification-based laboratory practices to open-ended laboratory practices, and optimizing guiding process with more solid and consistent contributing team in every stage of problem based learning implementation.***

**Keywords**: Metacognition, analytical chemistry, problem based learning, *open-ended experiment, spectrometry, electrometry*

## 1. Introduction

In higher education, laboratory practices are usually intended to support lectures for building concept and/or validating knowledge gained in relevant lectures. For the candidates of chemistry teachers, laboratory practices aims to increase their competence in developing chemistry concepts in chemistry by means of technology and arts, and in utilizing chemistry instruments in the process of developing chemistry concepts (Indonesian Ministry of National Education, 2004). Moreover, the candidates are expected to get the experience of the method to manage laboratory activity that will be useful for their future career as chemistry teachers. On the other hand, chemistry laboratory practices with verification-based guideline becomes of interest of a number of researchers, such as Pasha (2006); Adani (2006); Kipnis & Hofstein (2007); Amarasiriwardena (2007), Rollnick & Davidowitz (in Cooper, 2008); and Haryani, (2011). Some of them asserted that verification-based laboratory practices guideline that is commonly used and includes detailed instructions tends to be boring and simply completes the laboratory practices, but does not provide an opportunity to process information profoundly and to solve a problem; so that students are not able to develop a considerable skill to find facts and concepts by themselves. About problem solving, Bransfort, *et al*; (in Tan, 2004), and Anderson & Krathwol (2001) suggest that students ideally are able to make up their mind before, during, and after a process of problem solving in such a particular assignment as a laboratory practices. During the process, students struggle to identify the problem, to elaborate ideas from varied sources, and to evaluate procedures, and those all are metacognitive activities (McGregor, 2007).

The development of metacognition is important since students' comprehension on cognitive process can provide them with guidance to foster learning environment and to pick out sound strategies for improving cognitive performance in the future (Hollingword, 2002). Similarly, Samson (in Cooper 2008) states that metacognition is the key for a more valuable and enduring teaching and learning process in chemistry education. Furthermore, Kipnis & Hofstein (2007) affirm that similar to another high-level process of thinking, students' metacognition, to this point, has not been encouraged eagerly in the process of teaching and learning at school, even if metacognition is a significant component for upcoming process of teaching and learning science as it not only creates independent students, but also sustain comprehension in their study, and make them proficient to adjust themselves during the planning, directing, and evaluating processes of a duty.

Hollingword (2002) and Livingston (1997) suggest that similar to a skill, metacognition will be successful if it grows through practices. Therefore, students need to learn problem solving, which means that they learn a method of learning that can develop and train their metacognition. Problem Based Learning (PBL) provides favorable learning environment to develop students' metacognition. Problem given in PBL process is ill-structured, open-ended, or ambiguous (Fogartty, 1997). Problem Based Learning process demands strategies directing goals and students themselves, as they are influenced by the context of the problem (Samford, 2003). This account asserts that PBL provides an ideal environment of learning to develop students' cognition, and this is in line with the ideas from Rickey & Stacey (2000); Cooper (2007); & Downing (2010) that metacognition is the foundation for comprehending chemistry and draws close connection with the development of problem solving skill.

Based on the arguments and research findings presented, the process of teaching and learning *Praktikum Kimia Analitik Instrumen* (*PKAI*) should be conducted with the intention that the candidates of teachers are trained to develop metacognition and to frame concepts by providing a challenging and valuable experience of research-based laboratory activity as appearing in PBL process. Problem-based learning of *PKAI* becomes a constructive environment for the intention cited since analytical chemistry is not only a sort of problem solving discipline, but also a course that involves varied processes, a range of variables, and some methods of measurement. Spectrometry and electrometry were selected within this research because they related to the materials of chemistry at high school, for instance atomic structure, chemical compound, solution, and redox and electrochemistry. Due to the importance of developing students' metacognition as mentioned before, as the candidates of teachers, thus, they will have to become a model for determining learning environment. Besides, a teacher must be able to monitor the design of classroom activity, to settle on necessary and unnecessary actions, and to modify such condition for different materials. As a result, the teacher will also be involved in his or her own metacognition (Stepien, in Weinert & Kluwe, 1993). Building teacher candidates' metacognition through laboratory practices is considered as a potential since around 50% of chemistry classes (especially in skill courses) in higher education is complemented by laboratory practices.

## 2. Method

Quasi experimental method with *pretest – posttest control group* design was implemented in this research and the gap between pretest and posttest was assumed as the treatment effect. Experimental class was treated with problem-based learning of *PKAI*, but controlled class learned through laboratory practice with standardized laboratory practices procedure. The category of laboratory practices conducted was based instrument available in the laboratory, including potentiometric method, conductometry, and spectrometry. The research was carried out in Chemistry Department of FMIPA in one of LPTK State or Teacher Training Institutions in Central Java, and with Chemistry Education Study Program students taking *Kimia Analitik Instrumen* (*KAI*) or Analytical Chemistry Instrument course in 2011/2012 academic period as the research subject.

Metacognition was tested in descriptive written test, questionnaire, and interview as supporting data. The development of metacognition by means of descriptive written test and questionnaire was analyzed with *N-gain* comparison between experimental group and controlled group, and the interview was analyzed descriptively. The indicators of metacognition were adopted from Kipnis & Hofstein (2007); Anderson & Krathwol (2001); and Mc Gregor (2007) covering: (1) identifying information, (2) elaborating information, (3) applying comprehension, (4) selecting procedure, (5) developing procedure, (6) interpreting data, and (7) evaluating procedure. The stages of problem-based learning were adopted from Shamford (2003); Pasha (2006); and Adani (2006); i.e. the process of teaching and learning was initiated by course contract, and followed by practicing using the instruments and analyzing the result. The next stages are: (1) orienting students to the problem and conducting pretest, (2) organizing students to study, (3) supervising group examination, (4) presenting the result of research, (5) analyzing and evaluating problem solving process, and (6) students fulfilled questionnaire responding to the implementation, had an interview, and took the posttest.

Additional quantitative data that were the test scores on concept understanding were also analyzed with N-gain, while the qualitative data on students' response over the implementation of problem-based learning obtained from the questionnaire were analyzed with descriptive presentation. The characteristics of teaching and learning process and the benefits and difficulties of the implementation of problem-based learning of *PKAI* were analyzed from the result of the implementation as a whole and from students' response as well.

## 3. Result and Discussion

The problem-based learning of *PKAI* in this research was designed to develop metacognition and concept mastery of teacher candidates on the topic of spectrometry and electrometry. Problem to be solved by students through the laboratory practices may be given by lecturer or from peer students after they consulted to the lecturer. Afterward, students held discussion in groups to determine the *open-ended* problem and resulted in following topics:(1) Determining Acid or Alkaline pH Using Natural Indicator Stick through Simple Kit-Assisted Experiment, (2) Creating a Simple Kit of Ag/AgCl – Comparison Electrode Using Gel Membrane, (3) **Utilizing Used Battery as a Simple Conduction, (4) Determining** Pb Content in Drinking Water, (5) A Simple Experiment on Textile Coloring in Children's Beverages, (6) Identifying Glucose Content in Urine by Semi-Quantitative Method, and (7) Qualitative Test on Formalin and Borax Content in Foods (*Bakso* and *Siomay*) Available around Campus. Students in controlled and experimental groups were given pretest and posttest on concept mastery and metacognition as presented in Figure 1 and Figure 3.

The attainment of concept mastery development (% N-*g*) of experimental and controlled groups is in moderate category. However, the achievement of experimental group is quite significant as the result of paired sample t-test supports that problem-based learning of *PKAI* for both groups shows significant difference ($p$ <0,05). This development varies for each concept, but the general average is considered as moderate category, and both present a significant difference. From Figure 2, it can be identified that the highest % N-g on concept mastery is on the making of standard solution and the lowest is on the type of absorbing substance. The highest development in making standard solution was expected as a result of problem-based learning in which not only were teacher candidates discipline in moving through the stages described verification-based guideline, but students were also required to plan the experiment comprising the making the solution. Students were demanded to prepare some reagents to be used in the experiment, and the making of the solution has become a particular agenda from basic laboratory practices of analytical chemistry and laboratory practices of the basics of analytical separation. In contrast, for the type of absorbing substance, though students wrote it as theoretical study either in proposal or in research report, students did not get an exact learning experience from this concept, so that the *memory of even*t, or the outlook of experience with long-term effect, also became different (White, 1996).

The low degree of basic concepts such as the type of absorbing substance in classroom experiment was initiated in the stage of proposal composition in which students more focused on exploring procedures related to problems to solve. Nevertheless, not all basic concepts were in low degree. For instance, absorbing substances were not directly related to research procedure, and its proportion in reference was not exceedingly urgent to be inserted. According to former research (Haryani, 2011), concepts without direct relation to the laboratory practices, such as the definition and basic principles of spectrometry, show the lowest % N-g. Therefore, the interview in this research was not structured, and was emphasized not only on research procedure, but also on the basic.

The highest achievement of % N-g for controlled group directly related to the implementation of laboratory practices shows relatively lower development than that related to the laboratory practices. This condition is different from the result of experimental group. The highest increase of %N-gain is on Lambert-Beer principle, and the lowest is on the concept of calculation of content determination. For the meantime, the low degree of the concept of calculation of content determination may appear because for all this time, students compile their report by copying their elder's work, and moreover, they are not required to give presentation on the result. In addition to the calculation, the relatively low %N-gain in controlled group is on the making of standard solution. In every form of laboratory practices, students are frequently asked to prepare reagent in group beforehand, but typically the standard solution in spectrometry is prepared by one group only, and other groups just measure its absorbance. Hence, it is not surprising that the level of development is not significant. The duty given to one particular group is meant to save time and to save the supply of *titrisol*, which is the commonly used standard solution.

The findings of the research indicate that problem-based learning of PKAI provides an encouraging environment for developing students' concept mastery over materials related to spectrometry and electrometry, and the result of the research is in proportion to previous findings reported (Akinoglu & Tandogan, 2007; Dylan, et al, 2010); and Larive (2005). In the stage of orienting to the problem, students in group were dealing with *open-ended* problem that encouraged their curiosity and motivated them to solve it (Fogarty, 1997). According to Tan (2003), the evidence suggests that PBL process can improve concept transfer within new situation, concept integration, intrinsic learning interest, and learning skill. In the meantime, Mitchell (in Tan, 2003) puts forward that PBL process can assist students better in constructing knowledge and reasoning skill than that through traditional learning approaches. Gijselaers (1996), on the other hand, points out that PBL process is derived from constructivism learning theory, meaning that learners actively construct the knowledge.

The average data of pretest, posttest, and % N-*g* of students' metacognition in controlled and experimental groups is presented in Figure 3. The result of metacognitive % N-*g* of controlled and experimental groups is still within low and high categories. Similar to concept mastery, the achievement of % N-*g* resulted on metacognition is adequately significant, and is supported by significant result of paired sample t-test ($p$ >0,05) between both groups. This fact shows that problem-based learning of *PKAI* for spectrometry and electrometry materials develop metacognition better than common learning process.

The development of metacognition from each indicator in both groups is indicated by the average of % N-g presented in Figure 4. The average of %N-g for those seven indicators of experimental group demonstrates higher development than those of controlled group; with the highest indicator on identifying and elaborating information, and the lowest on developing procedure. The result of this research is different from that of Haryani's research (2011), in which both indicators illustrate the lowest point for the materials of either UV-Vis spectrometry or chromatography. Multiple useful steps to develop the indicators, identify information, and elaborate information in this PBL process were facilitated starting from compiling design/proposal and laboratory practices implementation, writing report, and presenting the result. In contrast, in an earlier research (Haryani, 2011), lecturers supervised student groups' activity by focusing more on research procedure.

Identifying and elaborating information is categorized as metacognitive level 1, which is being aware of thinking process and being able to describe it (McGregor, 2007). Both indicators of metacognition can be developed optimally because many steps in problem-based learning of laboratory practices, such as the composition of proposal, the compilation of report, and the presentation of result, are able to develop them. In addition, in an unstructured interview, lecturer puts students on the right track to comprehend metacognitive level 1. The development of indicators for experimental group is lower than the development of others. Developing procedure is included as metacognitive level 3, which is reflecting procedure in evaluative manner. As formulating the proposal, students develop procedures for various ideas gained from a collection of varied information, for instance, theoretical study and laboratory operational procedure. If those procedures do not fit, then students in groups should try to manipulate instruments, materials, or operational procedure. However, students usually prefer to make different reference or look for new information, so that their ability of developing procedure cannot be improved optimally.

To notice that the stages in problem-based learning of laboratory practices are able to develop metacognition on spectrometry and electrometry materials as described in this research, following is an example of correlation of the stages with metacognition developed. The data were collected through unstructured interview intended to discover what students perform and think during the problem-based learning of laboratory practices. Kipnis & Hofstein (2007) also made an interview for enquiry-based learning of laboratory practices to expose students' metacognition. The first stage is orienting students to the problem, in which students in groups were asked solve a problem in a laboratory research project. The next one was the process of organizing students to learn; groups of students were asked to formulate a proposal for solving the problem given. In this stage, students realized that the assignment needs to be supported by a lot of references to identify and elaborate necessary information. Below is an example of statement of two students from high level class (a category for above average GPA hereafter mentioned as A), and low level class (a category for below average GPA hereafter mentioned as B).

**Student A**: The problem to be solved was to determine acid or alkaline pH using natural indicator stick by means of a simple kit-assisted experiment. Firstly, we discussed the problem and we needed to solve it using the main instrument of UV-Vis Spectrometry and pH meter (*identifying and elaborating information*), and the second step was utilizing spectrometry and potentiometry methods (*selecting procedure*). Afterward, we consulted the method, and then we shared responsibility to collect as much information as possible about both methods and operational procedure from various sources.

**Student B**: After having discussion in group and with the contributing lecturer, finally we had to solve a problem entitled **the utilization of used battery as a simple conduction covering conductometry method (identifying information).** Furthermore, we shared the job to figure out the operational procedure (*elaborating information*).

Then, in the stage of organizing students to study, students are asked about the objectives of the research, as well as necessary steps to compose a design/proposal of research project.

**Student A**: Before composing the proposal, I tried to determine the objectives and discussed them with my partners, along with organizing theoretical foundation, problem for the laboratory practices, and the operational procedure designed (*applying comprehension*). Furthermore, we consulted those points to our contributing lecturer, especially on the operational procedure, instruments, and materials used.

**Student B**: We looked for materials and information needed for solving the problem. It could be from the internet or library providing academic paper and research journals, and we also tried to figure out the procedure (*elaborating information*).

In comparison to student A, student B did not try consult the main research method or the procedure, but he just followed the direction of the group, which will answer when being questioned.

The stage of guiding group research was initiated by collecting samples, then preparing them, measuring them, recording observation data, and finally analyzing the data. In the beginning of sample preparation stage, lecturer gave a question: How do we collect samples? What should you do after collecting the samples? The students responded as follow.

**Student A**: After consulting the proposal, our group searched for various flowers, which were not categorized as turmeric. Then, we made solution with pH 1 -12, some using strong acid solution, combination of acid buffer, combination of alkaline buffer, strong alkaline and salt solution. We made flower extract to check its pH and to figure out its changing for acid and alkaline colors. Subsequently, I was wondering the area between acid and alkaline pH can be observed by using UV-Vis spectrometer? Thus, I got the answer from my lecturer. During the measurement stage, I just realized the operational procedure of UV-Vis spectrometer, and it turned out that the instrument can be used not only to determine the level of absorbance, but also to depict its spectra (*interpreting data and evaluating procedure*).

**Student B**: At first, we looked for used battery, assembled the instrument, and made a range of standard solution to measure its conductive potential. I could not answer lecturer's question on the reason for the use of solution conductive potential instrument, but after triggered by questions, I started to understand (selecting and evaluating procedure).

Based on some examples of statements from student A representing high level class and student B representing low level class, it can descriptively inferred that starting from investigation stage, student A was more active to ask and to lead the group. This is in line with Livingstone's view (1997) that metacognition can draw a distinction between a specialist and non-specialist. In this case, high level class is considered to be more competent than low level class. Furthermore, Figure 4 shows that the highest % N-g is on the indicator of identifying and elaborating information. Students in group or individually must think about the necessary steps intensely, so that the problem solving process will not be misleading. This condition can be reflected from the result of interview for all students, including the examples provided. Other indicator improvement from experimental group seems to be better than that from controlled group, as well as from the interview, in which students always made up their mind in the beginning, in the middle, and in the end of the implementation.

White and Mitchel (Kipnis and Hofstein, 2007) link up laboratory activity with metacognition, and they assert that students with proper learning behavior are those able to develop certain metacognitive skills. Some of the behaviors are interconnected to laboratory activity, such as asking questions, checking laboratory work, evaluating observation data, adjusting opinion, exploring sufficient reasons for the aspects of operation, suggesting new activity and alternative procedure, working in small group, providing opportunity for group discussion, and designing general strategy in advance. The development of metacognition through problem-based laboratory activity in this research is relevant to the result of researches from Cooper et al. (2008, 2009)., Downing (2010)., & Dylan at al(2010). It suggests that presenting problem over scientific research to be solved in chemistry laboratory can develop students' metacognition. Moreover, Kipnis & Hofstein (2007) conclude that in laboratory, students train metacognition in many stages within the process of enquiry-based learning of laboratory practices. Similar to Kipnis & Hofstein, Baind and White (Kipnis & Hofstein, 2007) also says, "with full consideration, laboratory activity can develop intended metacognition; people will know about effective learning strategy and its requirements, and they will realize and understand the adequate progress of teaching and learning work.

The development of metacognition from the result of the research is followed by the development of concept mastery, or vice versa, and both have positive correlation. Costa (1985) argues that by recognizing problem given, students will focus their attention to what is necessary, and determine suitable information to solve it. Meanwhile, in problem-based learning, the problem is the starting point to figure out the concept. Students have opportunity to evaluate initial selection of certain strategies, and to develop their understanding on the best choice that potentially solves the problem. Students will then realize that they do not comprehend the problem and try to find solution to solve it. According to Schraw (2012), constructivism learning environment is closely related to metacognition. Lecturer as facilitator will encourage the development of students' conception, so that they will use their prior knowledge and think about ideas of other students. In addition, Schraw states that a set of activities may assist students to control their learning, involving planning, monitoring, and evaluating, including metacognitive component, i.e. metacognitive principles.

Winn & Snyder (1998) consider the importance of metacignitive strategy. When students are better trained to employ metacignitive strategy, they will be confident and become independent learners. The students realize that they can meet their intellectual needs and collect much information by themselves. The awareness to govern, control, and examine certain tasks is a process of metacognition. The role of the educator is to provide, utilize, and improve metacognition of all students.

Metacognition in this research was measured by means of descriptive written pretest – posttest and pre-treatment – post-treatment questionnaire; each with metacognitive indicators as supporting data. Responses to the questions in the questionnaire were *sangat setuju* (SS) or fully agree, *setuju* (S) or agree, *tidak tahu* (TT) or no idea, *tidak setuju* (TS) or disagree, and they were in sequence and with Likert score for each item 4, 3, 2, and 1. Furthermore, each item is summed up and calculated into percentage to determine total score and % of score improvement. Table 1 presents metacognitive score improvement from questionnaire of experimental group in 14,56%, which is fairly different from that of controlled group in 1,22%. The result of metacognitive measurement by means of questionnaire of experimental class is compliant with Livingston notion (1997), that students' metacognition can differentiate specialist and non-specialist category, which in this case asserts that experimental class is more competent than controlled class after the implementation of teaching and learning process.

The implementation of problem-based learning of *PKAI* on spectrometry and electrometry materials is advantageous to develop students' metacognition, concept mastery, and performance quality that can be identified from the improvement of basic skills in conducting laboratory practices activity. The *open-ended* problem given can motivate students to gather information from various sources. Students in groups can attempt to arrange operational procedure to solve the problem. In the meantime, unstructured interview in each stage of PBL process functions to explore basic concepts of laboratory practices studied, identify, and elaborate students' comprehension to construct meanings and connect new concepts with prior knowledge obtained from analytical chemistry instrument course. As a result of problem solving process, students can raise questions about categories of knowledge necessary to explain the mechanism underlying the problem. Afterward, they can do research in laboratory utilizing a range of instruments correlating to the problem. During the laboratory practices, students are directly guided and their performance is observed using corresponding observation form. The PBL process will complete as students report what they have learned, and present the result of problem solving process in group. As facilitator, lecturer will encourage productive interaction among students, assist them to identify knowledge necessary to solve the problem, facilitate teaching and learning process by bringing up questions, and monitor and evaluate their performance in problem solving process (Gijselaers, 1996). The result of problem-based learning of laboratory practices in this research is the development of metacognition, the mastery of concepts, the development of performance quality, and better activity, that is in line with Woolnough and Allsop idea (Rustaman, 2002) about the objective of laboratory practices activity. Therefore, that activity can provide broader opportunity for *the development of competencies,* but to obtain good result from teaching and learning process, excellent planning, preparation, and evaluation instrument become compulsory.

From the response to the questionnaire of students in experimental group, students responding *setuju* (S) or agree makes up the highest percentage with 67,89 %, followed by the percentage of *sangat setuju* (SS) or fully agree. The difficulty faced by students in the unstructured interview is that they need to have constant consulting with their lecturer, and it requires the arrangement of extra hours. However, based on responses in the questionnaire, students perceive the research as a pleasant one and expect it to be applied in other laboratory practices courses, and they also consider this experience to be useful for developing teaching and learning process at high school in the future.

## 4. Conclusion

The teaching and learning process of laboratory practices of analytical chemistry instrument developed in this research adopted the stages of problem-based learning with following characteristics: (a) *open-ended* problem related to spectrometry and electrometry materials; (b) unstructured interview to assist the problem solving process, develop students' metacognition, and improve concept mastery; (c) metacognition tested by means of test and questionnaire. The *open-ended* laboratory practices develop teacher candidates' metacognition and concept mastery better than conventional laboratory practices. Metacognition developed in problem-based PKAI are identifying information, elaborating information, applying comprehension, selecting procedure, interpreting data, and evaluating procedure. The highest achievement of metacognition is on the indicator of identifying information, and the lowest is on developing procedure. The advantages of problem-based teaching and learning of laboratory practices of analytical chemistry instrument are: (a) involving students during teaching and learning process, (b) providing the lecturer with an opportunity to offer individual guidance and counseling, and to present an example of problem-based laboratory practices; and (c) being useful for developing metacognition and concept mastery of chemistry teacher candidates within all levels of achievement. In general, students' response on the implementation of this process is highly positive, for instance it is considered to provide real experience by means of modeling method and to have favorable practices of research.

**Note:** The future scope of this study is Development of Character Education through Learning Model of Instrumental Analytical Chemistry Lab Work-Based on Problems.

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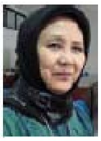
## Author Profile

**Sri Haryani** is a doctor on Chemistry Education of graduate school-Indonesia University of Education. She is now a lecturer in State University of Semarang (UNNES)-Indonesia. Her Expertise is in teaching-learning on chemistry. Her recent research is in developing models of teaching chemistry, especially with practical problem based learning and metacognition.

**Agung Tri Prasetya** is a magister on Chemistry of graduate school-Gajahmada University. He is now a lecturer in State University of Semarang (UNNES)-Indonesia.



**Anna Permanasari**, Professor on analytical chemistry, a lecturer in chemistry education Department of Science and Mathematics Faculty–Indonesia University of Education since 1983. Since she do her research in adsorbent for organic and inorganic residues, she also involve in science educational research. Some doctorate students of science education program of graduate school were under her supervision. The field of research in education is on science literacy.

**Figure Legend**

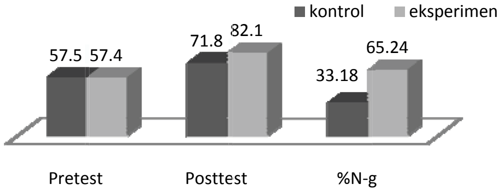


**Figure 1:** The comparison of entire students' concept mastery as between controlled and experimental classes on the topic of spectrometry

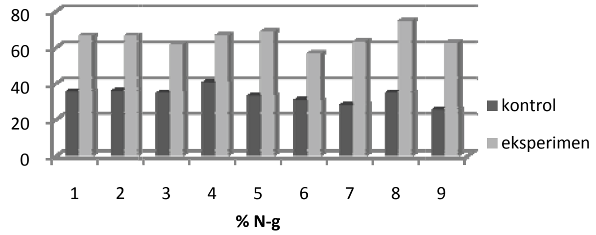


**Figure 2:** The average of %N-gain of spectrometry concept mastery from experimental group for subtopics: 1. the basic principles of spectrometry, 2. the difference of atomic and molecular spectrometry, 3. spectrometry components, 4. Lambert-Beer principle, 5. sample preparation, 6. absorbing substance, 7. optimization of measurement, 8. the making of standard solution, and 9. the calculation of content level.

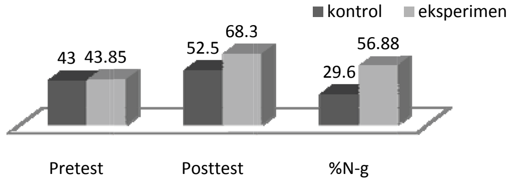


**Figure 3:** The comparison of whole students' metacognition between controlled and experimental groups on spectrometry and electrometry materials.

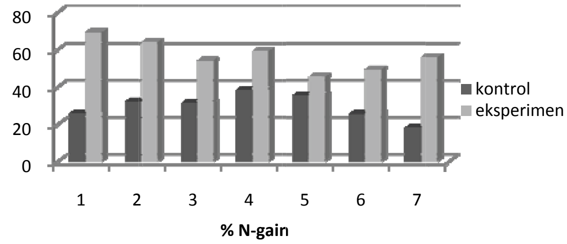


**Figure 4:** % N-gain of Each Metacognitive Indicator for Control and Experimental Groups, Indicator Numbers: 1. identifying information, 2. elaborating information, 3. applying comprehension, 4. selecting procedure, 5. developing procedure, 6. interpreting data, 7. evaluating procedure

**Table 1:** The Comparison of Score and % of Score Improvement from Metacognitive Questionnaire between Controlled Group and Experimental Group

| *Group* | *Score* | | *% of Score Improvement* |
|---|---|---|---|
| | *Pretest* | *Posttest* | |
| Controlled | 296,53 | 300,17 | 1,22 |
| Experimental | 297,20 | 340,50 | 14,56 |