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# BUILDING THE CHARACTER OF PRE-SERVICE TEACHERS THROUGH THE LEARNING MODEL OF PROBLEM-BASED ANALYTICAL CHEMISTRY LAB WORK

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**ABSTRACT**

This research aims to apply and find out the characteristics of Problem-Based Instrumental Analysis of Chemistry Lab Work Learning Model (IACLLM) which is able to build the characters, improve the conceptual mastery and the ability of problem solving. The research using experimental quasy with 2 student groups of pre service chemistry teachers as the subjects of the research applied the treatment of problem-based IACLLM for the experimental class and lab work learning with standard lab work procedure in control class. Conceptual mastery was measured using essay test; problem solving skills were measured using assessment of problem solving reports, presentation of the results, and kit making products; whereas the emerged characters were observed during the learning process. The result of this research showed that problem-based IACLLM had open-ended problem characteristic, had produced local material kit, and characters were observed in every stage of problem-based learning model. The implementation of the model could improve the spectrometric and electrometric conceptual mastery, the problem solving skills on a very good level and also some characters were developing during learning process, including religious, discipline, honest, curious, creative, critical, cooperative, communicative, independent, and able to appreciate other people's opinions and achievements, leadership, democracy, and able to be thorough and careful, and hardworking.



**Keywords:** IACLLM; teacher characteristics; problem-based lab

## INTRODUCTION

Lab work in universities is usually conducted during or after theories is given to support and validate students' knowledge on the certain course. The verification of lab work manual with gradually specific directions does not invite students to solve problems, therefore, the students' abilities to actually obtain some facts, as well as concepts of their own findings cannot be realized (Urena et al., 2012; Adani, 2006; Jalil, 2006; Haryani, 2011). Besides that, verification of working procedures in the lab work manual are also less giving opportunities for students to process information thoroughly, and students' main concern is only how to finish lab work assignments and report making (Hicks & Bevsek, 2012; McDonnell et al., 2007; Cooper & Urena, 2008). Even twenty years ago, Nakhleh (1996), reminded that chemistry in many parts of the world had invested a big amount of money to give some lab work experiences for students; however, it rarely evaluated on what should be achieved in lab work. Meanwhile, Haryani (2011) recommended that the lab work activities should be able to generate learning motivation, support conceptual mastery, develop basic experimental skills, and improve the skills of problem solving.

It is important for students to be trained on problem solving skills, and students of pre

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service chemistry teacher are needed to face assignments and challenges in the working world. On daily basis, students also often face many complicated problems (ill-structured/unstructured). Some reality that describes the students' low skill in handling problems are shown from the brawls happened between schools and students, drug abuse, and abortion. To overcome this moral crisis, problem solving as one of high level thinking skills is necessary to be trained through well-planned learning. Problem-based lab work learning model is highly assumed to be able to give good learning environment to improve problem solving skills (Haryani, 2011; Urena et al., 2012; Ferreira & Trud, 2012).

The design of lab work learning program does not only pay attention to the aspects of conceptual mastery (cognitive) and basic experimental skills (psychomotoric), but also to the students' affective aspects and problem solving skills. The affective ability is related to the attitude or characteristic of responsible, cooperative, discipline, committing, confident, honest, also related to respecting other people's opinion and having self-control (Aisyah, 2014) (Chan & Bauer, 2016; Popham, 1995). Those values are closely connected to the development of cultural and character education. The formation of strong and solid students' characteristics is very strategic in the nation's sustainability and excellence in the future, as well as very important to be owned by students to face the future challenges. We need to do a lot of efforts to face the challenges seriously, especially now that UNNES has established itself to be a University of Conservation. Conservation here means how UNNES and all academic activities have conservation and concern toward environment, socio-cultural, and conservation on knowledge (science). To enable the learning model of problem-based analytical chemistry lab work supporting conservation and developing students' characteristics, it is necessary in implementing Green Chemistry principles.

Based on arguments described above and according to various research results, the learning of instrumental analysis of chemistry lab work should be conducted so that students are trained to solve problems and grow their scientific attitudes (character education) by giving laboratory experience based on challenging and meaningful research as mentioned in PBL. Problem-Based Instrumental Analysis of Chemistry Lab Work Learning Model (IACLLM) gives a very accommodating environment to achieve its purpose, since the essence of this analytical chemistry as a science is to solve problems (Adani, 2006), this subject is also a process subject, which has various variables, consisting of several measuring methods (Mataka & Kowalske, 2015; Tosun & Senocak, 2013). Furthermore, to support UNNES as a university of conservation, this problem-based instrumental analysis of chemistry lab work learning model developed is using local material based on Green Chemistry principles. The equipment limitation both in numbers and kinds as well as the expensive materials often become obstacles faced by teachers (Haryani et al., 2010). Therefore, pre service teachers need to be equipped with modeling on how to overcome equipment limitation. The briefing of pre service teachers appropriate with this subject is making simple measurement tools (kit), portable, but the observation data have good responsibility. This capacity of responsibility is obtained by comparing the measurement results using available laboratory instruments.

From previous descriptions, the main problem that becomes the focus of the research is "How do we develop conservation-based character education model through the implementation of problem-based IACLLM using local material". To manifest that idea, a lecture on instrumental analysis chemistry lab work is conducted with the strategy of problem-based instructional learning; that is proven to be able to improve the problem solving and conceptual mastery, as well as to build scientific attitude/character.

## METHODS

This research is an experimental research that outlines the quantitative and qualitative data collection done simultaneously. Experiment class was given problem-based IACLLM treatment, whereas learning in lab work control class was using the standard procedure. This research was conducted in Analytical Chemistry Laboratory in Chemistry Department FMIPA UNNES, with the subjects of one study group as the control group and one study group as the students' experimental group. All were the students of Chemistry Education Department who were having the subject of Instrumental Analysis Chemistry (IAC).

The learning of problem-based IACLLM implemented had four stages, adapted from Arends (2004). The first stage, students were oriented on problems and on the second stage students were organized to study. Next, on the third stage, investigation group was guided; and finally on the fourth stage, the results of problem solving were presented. Before conducting lab work, training was given to three lab work assistants and one technician. Lab work assistants were assigned to help the researcher in conducting the lab work, observing during lab work process, and assisting in correcting pre-test and lab work reports.

The quantitative data collection was using essay test to measure conceptual mastery of spectrophotometry and potentiometry. Qualitative data were collected using assessment column; through observation during learning process to encompass the emerged character. Besides that, an interview was conducted to explore the students' knowledge related characters built in every step of problem-based lab work learning. The measurement of problem solving adapted from Fogarty (1997) that covered the assessment of problem solving report, presentation of the results, and kit making products in which all used columns.

Quantitative data in the form of spectrophotometry and potentiometry conceptual mastery of pre service chemistry teacher was analyzed using the formula of normalized gain, while the qualitative data was analyzed using descriptive percentage. After N-gain for the second group was obtained, it was then compared to see the difference of conceptual mastery improvement. The results of the observation were characters emerged and the performance during learning process was analyzed descriptively. Besides that, a supporting interview was also used to see characters built on every problem-based learning step.

## RESULTS AND DISCUSSION

The learning of problem-based IACLLM in this research was designed to improve the conceptual mastery of spectrophotometry and potentiometry materials, problem solving skills, and develop students and teachers' characters. The initial step in the problem-based IACLLM was to have students oriented on the problems. Problems were categorized into groups according to available instruments/tools; it can be from students or teachers. Next, in groups, students decided the title of the research with these results: (1) The determination of Acid-Base pH using Natural Indicator Stick with Kit aid Simple Experiment; (2) The Making of Simple Comparative Electrode Kit of Ag/AgCl using Jelly Membrane; (3) The Used Battery Utilization as A Simple Conductor; (4) The Determination of Pb Level in Drinking Water; (5) Simple Test for Fabric Dyes in various drinks in Primary School; (6) Semi quantitative Urine Test for Diabetic Mellitus Patients; and (7) Qualitative Test of Formalin and Borax content in Foods (Meatball and Dumplings).

Figure 1 shows the percentage of N-gain from the conceptual mastery of spectrophotometry and potentiometry as a whole concept in control and experimental groups. The data from both groups were normally distributed, with variants of % N-gain between homogenous groups. The results of % N-gain from control and experimental groups each for spectrophotometry and potentiometry were shown in Figure 1. Although 3 from 4 data were included in medium category, but the result achievement of this % N-gain was quite meaningful, supported by the different test result that % N-gain from the learning of problem-based instrumental analytic of chemistry lab work showed a significant difference ($p<0.05$).

Table 1 shows the average % N-gain on every concept of spectrophotometry and potentiometry materials in control group and experimental group. The average result of % N-gain spectrophotometry material from experimental group was categorized as medium with two concepts categorized as high, while for various control groups; the average was categorized as medium with each concept categorized as low and medium. In contrast to spectrophotometry, the average % N-gain from control group potentiometry was categorized low, whereas experimental group was categorized medium.

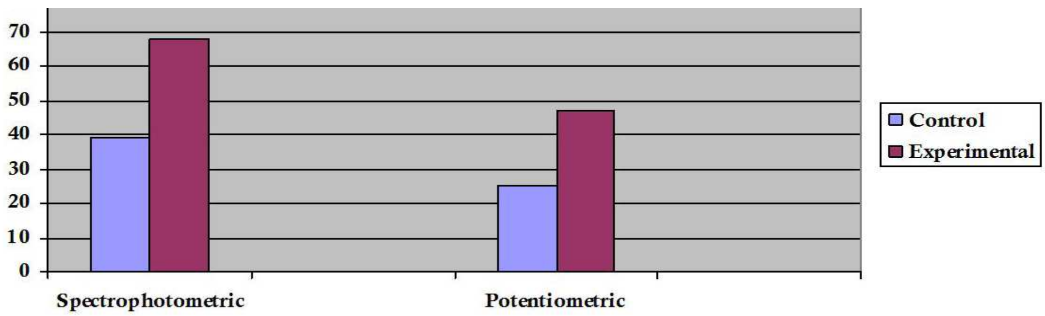


**Figure 1.** The average % N-gain from Students' Conceptual Mastery as A Whole between Control Group and Experiment Group in Spectrophotometry and Potentiometry Materials

Based on the finding of the research, it seemed that spectrophotometry and potentiometry of problem-based IACLLM provided a good learning environment to improve the conceptual mastery of pre service teacher. The learning was initiated by students' orientation stage on problems. Students, in groups, were asked to solve open-ended problems in a laboratory research project, and were ended by presentation of the results and display of the research posters. The improvement of conceptual mastery was varied for each concept, but the average of all including medium category for both experiment and class control showed a significant difference (Table 1). Based on the comparison of pre-test and post-test results, there are not any students whose conceptual mastery decreased, as well as remained stable. Although there were various improvements, the data obtained showed that there was a successful improvement (medium category).

**Table 1.** Data of % N-gain from every spectrophotometry and potentiometry concepts of control and experiment groups

| Concept | % N-gain | |
|---|---|---|
| | **Control** | **Experiment** |
| **Spectrophotometry** | | |
| Basic principles of spectrophotometry | 39,05 | 79,00 |
| Spectrophotometry classification | 39,75 | 69,00 |
| Spectrophotometry components | 39,50 | 72,15 |
| Lambert Beer Law | 49,24 | 67,00 |
| Sample preparation | 36,22 | 68,50 |
| The difference between atom dan molecule spectrophotometry | 35,08 | 54,50 |
| Standard solution production | 34,35 | 63,56 |
| Level measurement | 33,00 | 62,08 |
| **Potensiometri** | | |
| Electrochemistry cells | 20,05 | 40,00 |
| Electrode potential | 32,65 | 48,05 |
| Nernst equation | 33,75 | 46,55 |
| Comparative electrode | 19,85 | 41,50 |
| Indicator electrode | 19,67 | 40,50 |
| Quantitative aspect | 20,50 | 63,16 |
| Potentiometric titration | 16,50 | 40,00 |

In Table 1, it was shown that the highest % N-gain of conceptual mastery occurred on the basic principles of spectrophotometry and the lowest was on the difference of molecule and atom spectrophotometry. The highest potentiometry was quantitative aspect/Faraday law, and the lowest was potentiometric titration.

The acquisition of the highest improvement for basic principles of spectrophotometry was because in this concept students started to write theoretical study both in their proposals and research reports, so that students got their learning experience directly that caused memory of event, a description of experience having long term effect more optimally (Hackathorn et al., 2011). This result was the revision from the research result of Haryani (2011), with the lowest % N-gain. This success was strongly assumed because at the presentation, students were asked to write the basic principles of measurement. Then, the low % N-gain of understanding and difference of molecule and atom spectrophotometry, were suspected because at the start of problem solving orientation stage, students focused more on the searching procedure related with problems to be solved. Besides that, this concept was accidentally written on literature review during proposal writing as it was in the concept of spectrophotometry basic principles.

The achievement of the highest concept in potentiometry was quantitative aspect/Faraday law. This concept was learned frequently started from Basic Chemistry, Basic of Analytical Chemistry, and on other skillful group such as Physics Chemistry. On the contrary, the low potentiometric titration concept was assumed that because students were lacked of skills in changing the initial data to be the first and second derivative data, which was prepared to make curves. Besides that, students were generally weak in volumetric titration that became prerequisite of this material.

For both spectrophotometry and potentiometry materials, the concept that directly connected to the research procedure had been relatively good in results, this was corresponding with the previous research findings (Haryani, 2011). The obtained value of spectrophotometry was higher than potentiometry; it was possible that the analysis using spectrophotometry methods was also obtained through organic chemistry lab work, as well as an organic chemistry. Besides that, students also got spectroscopy material from Physics Chemistry subject.

On the contrary, the highest improvement of % N-gain for control group which was directly connected with the implementation of lab work was relatively low compared with the basic concepts which were not directly related with the lab work. The highest improvement of % N-gain for control group occurred in Lambert-Beer law, and the lowest one occurred in the measurement concept of level determination. The low level of level measurement concept was possible because during the report making, students adopted their senior's works; also, they were required to present their results. Besides the measurement of level determination, % N-gain whose improvement was relatively low in the control group was the production of standard solution. In every lab work, students were given tasks in groups to prepare pre-reaction before the lab work. However, so far the standard solution in spectrophotometry was prepared by one group, and the other groups were only measuring its absorbance. That was why it was normal for the bad quality of the improvement result. The tasks given to certain groups in preparing the standard solution was meant to save the time as well as to save the standard solution of titrisol which was frequently used.

The findings in this research showed that problem-based IACLLM provided a good learning environment in improving the students mastery on spectrophotometry and potentiometry materials; and these results were in accordance with the findings reported before (Tandogan & Tandogan, 2007; Hicks & Bevsek, 2012). In the problem orientation, students in groups will be given open-ended problems that would encourage students' curiosity and motivate them to be able to solve problems (Urena et al., 2012). According to Tan (2003), evidences recommended that problem-based learning could improve students in constructing knowledge and reasoning ability compared with the traditional teaching approach. Akcay (2009) on the other hand, revealed that problem-based learning was derived from constructivism learning; it was the learners constructed knowledge actively.

The data of problem solving from students of experimental group showed were obtained from reports/results of the problem solving, and the kit product as results of problem solving with the average were simultaneously 85; 86,12; and 86,11, and the whole average was 85,75. Based on the results obtained, it showed that the total score of problem solving reached the highest criteria; it was that each aspect was bigger than 85%. The indicator of minimum success in this research was 80%. Indicators for the report of problem solving referred to the pattern of problem solving which was developed by Fogarty (1997). The problem solving skills were measured as a whole through the working performance assessment using column. Table 2 shows the score summary of problem solving results.

**Table 2.** The summary of problem solving score of experimental group

| Groups | Reports | Presentations | Products | Average |
|---|---|---|---|---|
| I | 86,50 | 87,71 | 87,71 | 87,31 |
| II | 85,33 | 86,72 | 86,72 | 86,26 |
| III | 85,17 | 86,14 | 86,14 | 85,82 |
| IV | 85,00 | 85,86 | 85,86 | 85,57 |
| V | 84,00 | 84,67 | 84,67 | 84,45 |
| VI | 84,23 | 85,65 | 85,65 | 85,17 |
| VII | 84,25 | 85,81 | 85,80 | 85,28 |
| VII | 85,50 | 86,40 | 86,40 | 86,10 |
| Mean | 85,00 | 86,12 | 86,11 | 85,75 |

To enable solving the unstructured, contextual, and open-ended problems in PBL, students must be digging up and understanding much information; students must also design and do some researches in order to do problem solving. Students must become "architect" for the learning process they did. However, students were used to do learning method of "listen and take some notes as well as do actions whenever there is an instruction from the lecturers". The implementation of problem-based IACLLM accompanied with the measurement tools of this problem solving, students obtained lab work learning model directly that would be very useful to be applied in the future (Hicks & Bevsek, 2012; McDonnell et al., 2007).

The observation results by observers (research members) toward the learning conducted by a lecturer (the head of research) showed that the relevant problem presented with competency learned in the lecture, accurate lecture time management, and students cooperation were doing well. Meanwhile, students' motivation to discuss, ask questions, communicate, argue, facilitate, lead the discussion, and responsible in learning were still needed to be improved.

The use of unstructured, contextual, and open-ended problems, in fact, could improve students' skills in problem solving. These problems could trigger students to be involved actively in group discussion to find and determine the best problem solving for the groups. This learning required students to use their intelligence to decide real issues started with defining problems, collecting useful information, restating problems, producing alternatives, suggesting solutions, and determining recommendation (Urena et al., 2012). Besides that, these problems could also train students to solve contextual problems so that they had experience in solving problems that they faced in their real lives. This finding was in accordance with the previous finding (Gunter & Alpat, 2017; Ferreira & Trud, 2012; Akcay, 2009; Demirel & Dagyar, 2015; Downing, 2010; Bilgin et al., 2009).

Students' characteristics developed through problem-based lab work were obtained from the observation results during learning process in every meeting using students' observation form. There was also interview in every learning stage. Based on that observation, analysis was then conducted toward the emerged/developed character, and the percentage of its emerging/development was counted in every PBL step.

Character of discipline was observed and built through punctuality in attending the lecture according to the deal agreed during lecture; wearing lab work coat; borrowing equipments; arranging lab work timetable, and collecting the lab work report. This discipline aspect emerged started from introduction until stage four with the total average of 90%. Meanwhile, religious aspect also emerged started from introduction until stage four, which was built by greeting in the beginning and at the end of lecture as well as praying with the total average of 95%.

Students' curiosity detected, started from the introduction stage, was the curiosity of how an unknown thing worked, stage one and two during the problem given, from the proposed questions especially about how to find procedure and determine the proper procedure from all procedures obtained. Besides that, curiosity was also detected on stage three during the consultation of observation data. The average percentage of curiosity aspect appearance was 60. Next, honest characteristic was observed and built on stage three and . Honesty could be built through how students measured materials, as well as borrow some equipments. Students must be honest whenever they did mistakes in laboratory; such as telling the truth when they broke glasses, and telling the real report and presenting results based on data. For this honest aspect, the total average obtained was 90%.

Thinking critically and creatively occurred in stage one and two. Students were demanded to think critically while doing exercises/pre-test and thinking about the problems and how to solve them. Students should also think creatively, while choosing effective and efficient types of lab work/ research so they could obtain the result maximally. They should also creatively design products to make KIT. The total averages of critical and creative thinking were 60 and 80% respectively.

Cooperating appeared on stage two until four. Students must cooperate in their groups to find working procedure, also to do lab work in order to solve problems. Leading characteristic was also built on stage two until stage four, started from task division on finding information to design proposal until lab work arrangement. The total average for cooperative and leading characteristic were 90 and 60% respectively.

The characteristics of hardworking, independent, thorough and careful were dominantly built on stage three. Lab work to solve problems really needed hard work in achieving the experimental purpose. This hard work was carried out by students started from doing preparation/sample preparation in experimental activities.

Students were demanded to be able to make solution independently based on the task division from their own groups. In preparing the equipments which were going to be used, they must be careful because the equipments were made from glasses; if they were not careful, those equipments would endanger themselves and people around them. It was also applied to chemicals; they must always be careful since some chemicals were corrosive, poisonous, and could cause itchy on their hands if they touched them; and some were even flammable. Next, for careful characteristic, it was built when the practitioner prepared some materials such as measuring substances, measuring the volume of solution, and observing results. The total averages for hardworking, independent, thorough and careful characteristics were 90; 80; 90; and 90% respectively.

On stage three, students communicated their observation result both in tables and figures. This communicative characteristic was also built by communicating the research result through report writing, power point making, as well as oral presentation which occurred on stage four. The total average for communicating was 80%. Next, another character built on stage four was democratic, respecting friends' opinions, and other people's achievement. While students are performing their presentation on their experimental results, they practiced receiving inputs from other groups. During discussion of paper or power point making, students learned democracy and respect their friends' opinion in their groups. Respecting friends' achievement also happened especially in products produced by other groups by granting more score. The total average for democratic characteristic, respecting friends' opinion, and respecting other people's achievement was 80%, 40%, and 60% respectively.

The improvement of conceptual mastery for this research was followed by problem solving skills with high scores and at least 16 characteristics were built through PBL steps. This learning success in cognitive domain and psychomotoric were influenced by scientific attitudes from the students as well as were determining someone's success in learning (Popham, 1995). Next, Popham stated that according to some expertise, someone's shifted attitudes or characteristics could be predicted if he/she had already had high cognitive mastery. This research result was in accordance with the results of some researches (Kelly & Finlayson, 2009), in that PBL besides improving conceptual mastery, it was also improving the social skills such as teamwork, confidence, and interactive manner with other people, and communication. Besides that, problem-based lab work learning also improved the students' skills in being careful with chemicals, doing careful observation, and trying to find information related with lab work conducted. Generally, students' responses toward learning implementation was very positive, they are: (a) improving their involvement; (b) giving direct experience through modeling; (c) practicing on doing great experiments; and (d) expecting that it could be applied on other lab work.

## CONCLUSION

Based on research results and discussion, it could be concluded as follows. First, instrumental analysis of chemistry lab work learning model which was developed adapted problem-based learning steps, possessed these characteristics: (a) open-ended problems related spectrophotometry and potentiometry materials; (b) kit from problem solving was produced using 7 local materials; (c) characters were observed and interview was conducted on every problem-based learning step; (d) problem solving was measured through reports of problem solving, presentation of problem solving results, and products of problem solving results. Second, the implementation of problem-based IACLLM model using local material could both improve conceptual mastery and increase the skills of problem solving for pre service teachers in a very good category. Third, the characteristics developed in problem-based IACLLM using local material were: religious, discipline, curious, creative, critical cooperative, respectful for other people's opinions and achievements, democratic, throrough, careful, and hardworking. Students gave positive response toward the implementation of IACLLM.

Based on the results achieved in this research, these recommendations can be made. The implementation enlargement of problem-based lab work learning for other lab work subjects needed to be done, remembering that around 50% of Skill Subjects were followed by lab work; so that it would have a good potency to give academic atmosphere in order to achieve the competency of pre service chemistry teacher through lab work. The lecturer for lab work subject must always innovate to change the verification-based lab work paradigm to be problem-based lab work, by digging more ideas with students in finding open-ended and contextual problems hoping that it could color students' characteristics both as a person and as a teacher as his duty.

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