PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

COMO OS PROCEDIMENTOS DE QUALIDADE DE LABORATÓRIO AFETAM A COMPETÊNCIA DOS ESTUDANTES COM GRADUAÇÃO EM QUÍMICA?

HOW LABORATORY QUALITY PROCEDURES AFFECT THE COMPETENCE OF CHEMISTRY UNDERGRADUATE STUDENTS?

PRASETYA, Agung Tri[1*]; CAHYONO, Edy[2]; SUDARMIN[3]; HARYANI, Sri[4]

[1]Graduate study of Science Education Program, Universitas Negeri Semarang, Indonesia

[2,3,4] Chemistry Department, Faculty of Mathematics and Natural Science, Universitas Negeri Semarang, Indonesia

** Correspondence author*
e-mail: agungchem@mail.unnes.ac.id

Received 05 December 2019; received in revised form 15 December 2019; accepted 08 January 2020

RESUMO

De acordo com as competências do século XXI, a reforma do sistema educacional nas universidades é necessária para melhorar a qualidade dos graduados. O objetivo deste estudo foi aprimorar a competência dos graduados em química empregando um modelo de aprendizado baseado em projetos através da aplicação de procedimentos de qualidade laboratorial (PBL-ALQP). O modelo PBL-ALQP foi utilizado no experimento de instrumentação para análise química e foi realizado em duas etapas. Na fase preliminar, foram observadas atividades dos alunos na preparação de soluções de trabalho e na análise de instrumentação para medir o nível de realização das habilidades laboratoriais necessárias e habilidades de análise de instrumentação, respectivamente. No trabalho do projeto, os alunos dos grupos receberam um projeto para resolver problemas relacionados à análise de instrumentação. Ao se referir aos artigos científicos que eles deviam procurar, os alunos tinham que ser capazes de compilar projetos de projetos, implementar projetos, relatar resultados do projeto, implementando procedimentos de qualidade de laboratório, para que os resultados das análises realizadas possam ser confiáveis e válidos. Através de uma avaliação autêntica, observou-se a atividade do aluno para medir o nível de realização de habilidades de pensamento crítico, habilidades de comunicação e habilidades de trabalho científico. O nível de realização de habilidades básicas de laboratório, habilidades de análise de instrumentação, habilidades de pensamento crítico, habilidades de comunicação e trabalho científico de estudantes de química estão em categorias altas. Os resultados indicaram que o modelo PBL-ALQP pode ser usado para melhorar a competência dos graduados em química.

Palavras-chave: *Aprendizagem Baseada em Projetos; Procedimentos de Qualidade Laboratorial; Competências de Graduação; Condutometria de Titulação Ácido-Base; Espectrofotometria UV-Vis*

ABSTRACT

Reform of the education system in universities is needed to improve the quality of graduates according to 21st-century competencies. The purpose of this study was to enhance the competence of chemistry graduates by applying a project-based learning model through the application of laboratory quality procedures (PBL-ALQP). The PBL-ALQP model has been used for the chemical analysis instrumentation experiment and was carried out in two stages. In the preliminary stage, student activities in working solutions preparation and conducting instrumentation analysis were observed to measure the achievement level of necessary laboratory skills and instrumentation analysis skills, respectively. In project work, students in groups were given a project to solve problems related to instrumentation analysis. By referring to the scientific articles that they must look for, students must collaboratively be able to compile project designs, implement projects, report project results by implementing laboratory quality procedures so that the results of the analysis carried out can be trusted and valid. Through authentic assessment, student activity was observed to measure the achievement level of critical thinking skills, communication skills, and scientific work abilities. The achievement level of basic laboratory skills, instrumentation analysis skills, critical thinking skills, communication skills, and scientific work abilities of chemistry students are in high categories. The results showed that PBL-ALQP model could be used to improve the competence of chemistry graduates.

Keyword: *Project-Based Learning; Laboratory Quality Procedures; Undergraduate Competencies; Acid-Base Titration Conductometry; UV-Vis Spectrophotometry*

DOI: 10.52571/PTQ.v17.n34.2020.28_P34_pgs_10_22.pdf

1. INTRODUCTION

Globalization has caused significant changes in the field of education. Higher education institutions are required to reform the education system to improve the quality of graduates following 21st-century competencies (Cavinato, 2017). Competencies of graduates in analytical chemistry are high order thinking skills and strong instrumentation analysis skills to accommodate the needs of the workforce according to 21st-century competencies (Prasetya, Haryani, Cahyono, & Sudarmin, 2019).

The preliminary study results of students work from the Chemistry Study program - at the Faculty of Mathematics and Natural Sciences Universitas Negeri Semarang (FMIPA UNNES) located in Central Java Indonesia - in the period 2017-2019, found that there were students who did not understand the concepts and principles of instrumentation analysis (Haryani, Liliasari, Permanasari, & Buchari, 2010). Students' instrumentation analysis skills are still low, this is indicated by the measurement results that have not yet been tested for accuracy and precision, and the validation of the test methods for the quality of measurement results has not been validated. Critical thinking skills of students are also still low, as shown by their weak ability to design proposals, implement and report research results. Efforts should be made to improve the competence of undergraduates from Chemistry study programs at the FMIPA UNNES to be equal and be able to compete with undergraduates from other tertiary institutions in the global era (Haryani, 2011; Haryani, Prasetya, & Bahron, 2017).

Project-based learning models are widely applied in chemical analysis practices to develop undergraduate competencies (Bagheri, Ali, Chong, & Daud, 2013; Bowden et al., 2012; Cavinato, 2017; Chun, Kang, Kim, & Kim, 2015; Frederick, 2013; Lee, Blackwell, Drake, & Moran, 2014). The application of project-based learning models can provide authentic experiences for students in developing critical thinking skills to solve problems through collaboration (Cesarino, Mulholland, & Francisco, 2018; Jollands, Jolly, & Molyneaux, 2012; Wurdinger & Qureshi, 2015). Utilization of project-based learning models through accredited laboratory simulations to obtain valid measurement results (Taylor et al., 2015). The forensic science model is used to increase student involvement in Experiment activities (Frederick, 2013). The results provide more enormous benefits and experience compared to traditional experiments; students are more critical and competitive. Chemical analysis instrumentation experiment utilizing environmental issues has been used to see misconceptions in modern chemical instrumentation. It was used to train instrumentation analysis skills accurately, foster motivational, collaborative, and communication attitudes (Carbó, Adelantado, & Reig, 2010; Robinson, 2013).

Classical and instrumental analysis results categorized as valid if the analysis carried out by following the principles of scientific work through the applying of laboratory quality procedures. Validation of testing methods as the applying of laboratory quality procedures needs to be trained for students so that graduate competencies can be improved. It is necessary to develop a chemical analysis instrumentation experiment model that can increase the competence of undergraduates through a project-based learning model by applying laboratory quality procedures (ALQP) (Bowden et al., 2012; Jiang, 2005; Taylor et al., 2015).

The development of the PBL-ALQP model aims to improve the mastery of instrumentation analysis concepts, basic laboratory skills, instrumentation analysis skills, critical thinking skills for problem-solving, communication skills, and scientific work abilities. The PBL-ALQP model was divided into two stages, namely the preliminary stage and project work. The preliminary stage was intended to introduce various instrumentation to students as well as to measure the level of basic laboratory skills and instrumentation analysis skills. Project work was aimed at providing authentic experiences for students in solving problem-related to daily life, developing a correct understanding of scientific processes, critical thinking skills, communication skills, and scientific work abilities (Wurdinger & Qureshi, 2015). The PBL-ALQP model that is implemented in blended learning, which combines experiment learning in the laboratory with online learning. Learning begins with giving open-ended, complex, and related problems with daily life, and is designed so that students work collaboratively, disciplined, and responsibly. New knowledge needs to be possessed by students to search for literary literature in solving problems, as well as critical thinking skills for making hypotheses, compiling and carrying out experiment procedures, conducting data analysis and making conclusions based on information collected to solve problems (Cavinato, 2017; Frederick, 2013).

2. MATERIALS AND METHODS

2.1 Data Collecting Instruments

This research is a development of the PBL-ALQP model, which is proven to improve the competence of chemistry undergraduates (Creswell, 2010). The implementation of the PBL-ALQP model was carried out using a one-group pretest-posttest design in 2 classes consisting of 65 students during 12 class meetings, as presented in Table 1. All the students are bind as a participant of the instrumentation analysis course (required course as undergraduate students in chemistry). At the initial meeting, learning agreement covers their willingness as a subject in current research without affecting their final mark. Individual assignments given online include drafting and experiment reports, discussions, and self-assessments through *elena.unnes.ac.id*. In the preliminary stage, an authentic assessment, which is a method of assessing all student activities during the experiment, is carried out by ten observers. The authentic assessment consists of evaluating the design and experiment report and observing student activities during the experiment activity. An authentic assessment in weeks 1-3 was used to measure the level of basic laboratory skills through observing the activities of students in taking, weighing, dissolving, and diluting chemicals and how to do titrations. An authentic assessment in the 4th-6th week is used to measure the level of instrumentation analysis skills through observation of student activities in stringing, calibrating, and operating pH-meter, conductometer, and UV-Vis spectrophotometer in verification practice activities.

In project work, authentic assessment is used to measure the level of critical thinking skills, communication skills, scientific work abilities, and the attitude of discipline and responsibility of students. All authentic assessment instruments used in the study have been validated by learning and evaluation experts with valid results, and have been tested to determine their reliability through interrater reliability testing.

Study material as a source of problems that are open-ended, complex, and related to daily life that must be revealed and sought for resolution by students include analysis of well water quality, analysis of tap water quality, analysis of iodine levels in table salt, analysis of essential minerals in fruit/vegetables, and analysis of heavy metals in waste. Collaborative students must be able to find literature related to one of the study materials from various sources of reference as a basis for developing project designs. Implementation of project work must be carried out by applying laboratory quality procedures, namely by using the principles of scientific work to obtain valid data. One way to apply laboratory quality procedures is to validate testing methods, which include a limit of detection (LoD) tests, a limit of quantization (LoQ), linearity ranges, and precision and accuracy tests.

2.2 Data Analysis

All the results were classified into the group of design assessment and experiment, as well as student activities and experiment observation. Furthermore, authentic assessment rubrics were used in the form of *Likert* scales that have been prepared, the achievement level of basic laboratory skills, instrumentation analysis skills, communication skills, scientific work abilities, and the attitude of discipline and responsibility of students can be measured (Hake, 2008). Students' abilities in designing, implementing, and reporting on project work are used as a basis for measuring the level of critical thinking skills.

3. RESULTS AND DISCUSSION

Basic laboratory skills and instrumentation analysis skills can be built through the active role of students in the preliminary Experiment (Lee et al., 2014). The integration of preliminary experiments and project work carried out with the application of laboratory quality procedures can also improve critical thinking skills, communication skills, and scientific work abilities (Cavinato, 2017). The PBL-ALQP model can develop critical thinking skills through the ability to search the scientific literature, translate scientific articles, compile experimental steps, operate instrumentation to collect data, perform data calculations and analyzes, validate testing methods, and draw conclusions (Frederick, 2013; Taylor et al., 2015). Students' skills in presenting and writing scientific articles as a product of project work can improve communication skills. In the end, the improvement of critical thinking skills and communication skills in completing project work affects the growth of scientific work skills.

3.1 Implementation of the PBL-ALQP Model in the Preliminary Stage

The results of the assessment and observation of student activities during the preliminary experiment obtained information that there were 64 (99%) and 58 (89%) students who had basic laboratory skills and instrumentation analysis skills with high and very high criteria. From those three achievement groups (determined based on cumulative performance index), the achievement level of basic laboratory skills and instrumentation analysis skills did not differ significantly. Detailed information is presented in Table 2.

Student activities in designing experiments include analyzing the needs of working solutions and preparing descriptions of how to make working solutions. Students can recap the needs of working solutions and describe how to make working solutions properly. The percentage of errors observed in the description of the making of working solutions due to calculation factors of 9%, the material purity (18%), solution volume (6%), and molecular formula errors (32%). The difficulty level experienced by students in describing the preparation of working solutions increases sequentially from liquid raw materials (for example, HCl), solid raw materials (for example, NaOH), and solid raw materials from polyfunctional compounds (for example oxalic acid and sodium tetraborate). Student activities in making working solutions and standardization run smoothly. Some student activities recorded during observation and not following work instructions include the process of weighing, dissolving, thinning, and titrating. Considering chemicals with an analytical balance in an open condition, the container used is not suitable, stirring carelessly, and doing titration with only one hand (Robinson, 2013). Students from each achievement group have an excellent ability to make experiment reports.

The next activity in the preliminary stage is a verification experiment to determine the ionization constant (Ka) of acetic acid with pH-meter, acid-base titration with a conductometer, and to determine the concentration of copper(II) sulfate with UV-Vis spectrophotometer. An understanding of instrumentation components, analytical techniques, data analysis, concluding the focus of observation (Robinson, 2013). The information obtained from Table 2 shows that the instruments that were mastered by students in succession were the pH-meter, conductometer, and UV-Vis spectrophotometer. The highest achievement level of instrumentation analysis skills obtained by students when operating instruments in the sequence are the pH-meter, conductometer, and UV-Vis spectrophotometer. The same sequence of two former instruments makes students ease to be mastery. However, the operation procedure of the UV-Vis spectrophotometer is still complicated. The results can be seen from the level of instrumentation analysis skill achievement with very high criteria in operating the highest pH-meter compared to the conductometer and UV-Vis spectrophotometer. There are 4, 10, and 11 students who are not yet skilled in operating the pH-meter, conductometer, and UV-Vis spectrophotometer, respectively.

There are no significant mistakes observed while observing and evaluating the experiment design. However, some little mistakes, such as the carefulness of student planning for borrowing glasswares for the experiment. In advance, the number of members in the student groups impact on collaboration skills of students, particularly in shared-tasks contribution by each person. In the experiment, the ideal number in a group consists of a maximum of 3 people (Santos, Montes, Sánchez-Coronilla, & Navas, 2014). The ability of students to operate the pH-meter and conductometer is no different, because the two instruments have similar shapes, sizes, and ways of working, even though they have different functions. The similarity between the pH-meter and the conductometer helps and facilitates students in operating. Different conditions occur at the lab reporting stage with a pH-meter compared to conductometric titration. It'd, was revealed that students had difficulty in making conductometry titration charts.

The biggest mistake occurred in the lab reporting phase using a UV-Vis spectrophotometer, which is when making the calibration curve. There are several steps students must work to be able to calculate the concentration of copper(II) sulfate. This leads the errors in making reports. Difficulties experienced by students in processing data and calculations have an impact on the decline in the achievement level of instrument analysis skills with very high criteria. This condition is very similar to the results of research conducted by Robinson (2013) and Cavinato (2017) (Cavinato, 2017; Robinson, 2013).

Authentic experience gained by students in operating the pH-meter, conductometer, and UV-Vis spectrophotometer can increase understanding of the principles and practical operational ways of the instrument (Fakayode, 2014). A thorough evaluation of the preliminary experimental findings is used as feedback at the end of the experiment. Through feedback, knowledge, and understanding of analytical chemistry concepts, especially in the context of making working solutions and standardization can be improved, and mistakes in using basic laboratory equipment can be avoided (Dalgarno, Bishop, Adlong, & Bedgood Jr, 2009; Karataş, 2016). By giving feedback, instrumentation analysis skills can be improved again, mistakes made by students during an experiment can be corrected and not repeated in project work and can increase retention (Carvalho, Fiuza, Gama, & Salema, 2015; Sharples, 2019).

3.2 Implementation of the PBL-ALQP Model in the Project Work Phase

Following the syntax of project-based learning, learning begins with giving open-ended and complex problems. Students collaboratively make project designs, determine schedules, implement, and make project reports. The project design begins with compiling issues, hypotheses, and proceed with searching scientific literature relating to the themes in the discourse. From the scientific research obtained, each student proposes an instrumentation analysis method as an alternative method of analysis that can be applied to answer the problem. Through discussion in groups, they were required to decide on one way of instrumentation analysis to be used in project design. The choice of instrumentation analysis method must pay attention to the availability and condition of the instrument, as well as the availability of supporting chemicals in the laboratory (Cavinato, 2017; Fakayode, King, Yakubu, Mohammed, & Pollard, 2011; Frederick, 2013; Henderson, 2010; Robinson, 2013; Taylor et al., 2015). Following the PBL-ALQP model developed, the project work design must apply laboratory quality procedures in the activities of taking samples, making working solutions, preparing samples, making calibration curves, measuring samples, calculating and analyzing data, and validating testing methods. The validation activities of the testing methods carried out include linearity tests, LoD and LoQ calculations, precision, and accuracy tests (Carbó et al., 2010; Fakayode, 2014; Jiang, 2005; Taylor et al., 2015).

The results of observations and assessments during project work obtained information that there were 63, 82, 74, 98, and 82% of students who possessed critical thinking skills, communication skills, and scientific work abilities, as well as discipline and responsibility with high and very high criteria. Between the upper and middle achievement groups have significantly different levels of critical thinking skills and scientific work abilities. Differences also occur in the achievement level of communication skills between the upper and lower achievement groups. Of the three achievement groups, the attainment level of discipline and responsibility did not differ significantly. Detailed information is presented in Table 3.

3.2.1 Critical thinking skills

Critical thinking skills are measured using criteria consisting of five dimensions, namely 1) elementary, 2) in-depth clarification, 3) judgment, 4) inference, and 5) strategies (Perkins & Murphy, 2006; Saripudin, Haryani, & Wardani, 2015; Sarwi & Liliasari, 2010; Sarwi, Rusilowati, & Khanafiyah, 2012; Tawil & Liliasari, 2013). Analysis of the achievement level of critical thinking skills in completing projects of each dimension is presented in Figure 1.

The elementary dimension is measured by looking at the systematic suitability of the project design and experimental objectives. There are 2 out of 19 groups that have not made hypotheses and data analysis techniques in the project design. As most references are still in the form of scientific articles, there are only two groups whose references are in the form of standard methods. The ability of students to develop hypotheses has the lowest achievement level. The assumption made by students is still not connecting between variables and has not been measured. The dimensions of in-depth clarification have the lowest performance compared to other dimensions. The systematic foundation of literature, relationships between concepts, and accuracy of the formulas use was used to measure this dimension. The ability of students to make problem formulations is still low. The formulation of a good problem must be made clearly, related to the topic in the discourse, and made in question sentences. The dimension of judgment is measured by looking at the suitability of experimental tools and materials used, the steps of the experiment, and the way data is collected. Language constraints are the main cause of students' difficulties in compiling work steps, primarily work steps for precision and accuracy tests. However, students have no difficulty in using simple laboratory equipment (taking solids, taking liquid, weighing, dissolving, and diluting), and operating instrumentation equipment. This can be understood because students have been trained in the preliminary experiment.

The dimension of inference is assessed based on depth in conducting data analysis, discussion, and conclusions. This dimension is measured through the assessment of project reports related to making working solutions, making calibration curves, as well as the results of the validation of testing methods that include linearity, LoD, LoQ, accuracy, and precision. Students were able to prepare working solutions, calibration curves, and LoD and LoQ calculations correctly. However, they still need intensive guidance from the lecturer to determine precision and accuracy. The validation results of the test method on the calibration curve (with r^2> 0.9) and LoD-LoQ calculation are 68% and 37%, respectively. In advanced, there are only 21% and 26% of students meet the requirement for precision and accuracy determination, respectively. The results indicate that students still need more practice to validate the testing method. The dimensions of strategies re-assessed through the systematic and quality of report appearance prepared by students are following existing guidelines. The lowest indicator is in the appearance of the report that is less interesting, consistency, and shallow discussion.

In the PBL-ALQP model, students are required to search literature through various sources to find instrumentation analysis techniques, so that it will require a person to think critically to be able to obtain, choose, and process the information effectively (Henderson, 2010). Through scientific articles obtained can be used to make work steps in project design (Cavinato, 2017), increase understanding of the instruments used (Fakayode, 2014), as well as to develop analytical methods (Frederick, 2013). The excellent project design will produce objective truth when it is supported by a reliable analytical method. Further, the analysis results will be then guaranteed quality, and valid data will be obtained.

The performance of the analysis method was evaluated by testing linearity, LoD, LoQ, precision, and accuracy (Jiang, 2005). Through assigning project design tasks to validate the testing method, students develop critical thinking skills. Giving open-ended, complex, and daily-related problems that must be resolved helps students hone critical thinking skills because students are required to interact directly with the real world collaboratively. Through discussion is an effective way to train and develop critical thinking skills, because in the discussion there is an exchange of opinions and in the process of exchange of opinions that students can consider, reject, or accept the opinions themselves or others to match the opinions of the group. This is what ultimately fosters students' critical thinking skills (Arfianawati, Sudarmin, & Sumarni, 2016). The achievement level of students' critical thinking skills is influenced by the ability to formulate hypotheses, formulate problems, seek reference to standard methods, translate the contents of scientific articles into work steps, perform calculations, and data analysis. The achievement level of students' critical thinking skills can still be improved through training.

3.2.2 Communication skills

The communication skills achievement level is high, with the distribution of high categories with 53 students (82%). Measurement of the achievement level of student communication skills is done through 2 methods, namely observation at the time of presentation and assessment of the quality of scientific articles that have been prepared. The average achievement level of verbal communication skills for each indicator is higher than non-verbal communication skills. The verbal communication skills result found that students: 1) already have skills in delivering presentation material in front of the class and collaboration well; 2) having confidence, being open to ideas from other groups; 3) questioning skills' need to be developed because there are still many students who are not yet involved in the discussion; 4) managing time is needed for groups who are presenting the results of the project need.

On the other hand, the assessment of non-verbal communication skills results find that 1) students are citing the references mostly from textbooks and only a small portion of recent scientific articles; 2) sub-chapter method is still the same as working procedure as it stated in the project report; 3) discussion part is still shallow, only in the form of results of the test method validation, and have not to correlate between all variables and objectives to be achieved. The results indicate that students' communication skills were still needed to be developed. Some activities, including writing scientific papers and scientific articles training, as well as preparation and timing in presentations/discussions. Project-based learning can also be used to improve communication skills, both delivering presentations and writing scientific reports (Fakayode, 2014; Gusarova, Kopytova, & Reshetnikova, 2019; Henderson, 2010; Sojka & Che, 2008).

3.2.3 Scientific work abilities

Scientific work abilities are measured through project design evaluation, observation of project implementation, and assessment of project results. Scientific work abilities are measured using criteria consisting of 5 dimensions, namely 1) observation and asking questions, 2) planning an experiment, 3) conducting an experiment, 4) communicating, and 5) applying (Cahyani, Rustaman, Arifin, & Hendriani, 2014; Luzyawati, 2014). The measurement level results of the scientific work abilities of students after participating in the experiment using a PBL-ALQP model are 48 students (74%) in the high category. Analysis of achievement level of scientific work abilities in completing projects of each dimension is presented in Figure 2.

The achievement of observation and question dimensions was measured through the quality of references used, the appropriateness of reference content, instrument condition and the availability of supporting chemicals, the background in preparing the hypothesis, the choice of analytical methods to solve the problem, as well as the formulation of the problems raised in the project design. The contents of the references obtained by students are under the problem, although the amount is very minimal. The instrument chosen was under the characteristics of the sample. The choice of instrumentation analysis method should have considered the appropriateness of the instrument's function, operational range, type of sample, ease, accuracy, selectivity, and detection limits of the instrument. The analysis techniques selection should consider the complexity of the sample, potential for interference, and the level of analytes in the sample. The results of the background assessment in preparing the hypothesis still have not paid attention to these factors carefully.

The dimensions of planning an experiment are measured through project objectives, hypotheses, completeness of tools and materials, classification of types of variables, work steps in project design, and project implementation schedules. The results obtained indicate that the chemical specifications for making working solutions are not detailed. The ability to form hypotheses is still low because it has not been able to link the relationships between variables and cannot be measured. Students also find it challenging to develop precision and accuracy test methods and how to analyze data.

The dimensions of experimenting are measured by looking at the work result data, which consists of making working solutions, sample preparation, making a calibration curve, measuring samples, testing accuracy, precision, as well as observation sheets and data analysis methods. Data from the manufacture of working solutions have used chemicals with pro analyst grade and traceable standard solutions. Students have been skilled in grouping data in tables. In making calibration curves, it is found that the standard concentration used is under the working range of the instrument. Students have been able to interpret the calibration curve obtained by looking at the correlation coefficient. There are 6 out of 19 groups whose calibration curves have a correlation coefficient (r^2) of less than 0.9. Students are not yet skilled in interpreting the results of validation of test methods, although students have been able to calculate the amount of LoD and LoQ, they cannot explain the further use of the amount. Students still cannot utilize the information obtained when validating the testing methods that have been done. The validation parameters of the test methods, which include linearity, LoD, LoQ, accuracy, and precision, can be used to assess whether the analytical method is chosen and used for analytical analysis in the sample is appropriate and appropriate. From 19 groups, there were only five groups that obtained good precision and accuracy test results (RSD < 2%, recovery 80-120%). This result shows that most students still need to practice in making calibration curves, testing precision, and accuracy.

Students' ability to discussing, presenting data, making graphics/drawings, and compiling reports are parameters for measuring the communicating dimension. The results obtained illustrate that between members in the group, there has been a division of tasks and good cooperation. Students are still not actively asking questions in discussions and tend to be passive. The presentation material that is displayed is good because it has combined information in the form of graphs, tables, and images, as well as the appropriate font size. The presentation atmosphere is less than optimal because the presenter has not been able to utilize time well and lacks confidence. Scientific articles compiled by students are good. The observed shortcomings were the method of writing, the results and discussion, and the references used.

The dimension of applying is measured by the ability of students to explain events using concepts and to apply to new situations. The results obtained indicate that the ability of students to discuss the correlation between absorbance and concentration in *Lambert-Beer* law and analysis techniques still needs to be improved. There are only a few students discussed UV-Vis spectrophotometer or atomic absorption spectrophotometer sample requirements in their report nor discussion.

The scientific work abilities of students still need to be improved, especially the dimensions of observation and asking questions. This fact shows that students have difficulty in finding and understanding the contents of scientific articles. Students need to be given the task of searching scientific articles through the internet network because supporting facilities are complete such as the availability of internet networks and computing laboratories that can be accessed by each student. The dimensions of planning an experiment need to be improved, especially the ability of students to form hypotheses, formulate problems, and arrange work steps for validation of testing methods. Students need to be stimulated in the form of assignments to translate the contents of scientific articles and present them in front of the class. Through discussion and collaboration in groups, they are asked to arrange work steps in project work based on selected scientific articles. The same step has been proven by Bramer (2001) to improve the ability of scientific work (Bramer, 2001). Project-based learning with problems related to daily life can also be used to improve life skills, develop analytical skills, and scientific work skills (Akinoglu & Tandogan, 2007; Baumgartner & Zabin, 2008; Smith & Dragojlovic, 2013; Wurdinger & Qureshi, 2015).

3.2.4 Discipline and responsibility

The level of discipline and responsibility of students in the PBL-ALQP model is very high. The disciplinary attitude of students is observed through assessment of attendance, the accuracy of completing assignments, and uploading them to *elena.unnes.ac.id*. It was observed that the time most used by students to upload assignments was in the evening before the experiment and in the morning before the experiment began. This fact shows that students are still not optimal in managing learning time, although the PBL-ALQP model, combined with blended learning, can improve discipline (Assis, Silva, & Ribeiro, 2017; Eskrootchi & Oskrochi, 2010; Medeiros, Júnior, Bender, Menegussi, & Curcher, 2017). The attitude of responsibility from students is measured by the participation of students in preparing practical tools and materials, and care in maintaining cleaning the laboratory. The PBL-ALQP model that is applied can increase the sense of responsibility of students and give freedom in exploring practically responsibly, although there are still students who have low levels of participation in preparing practical tools (Bagheri *et al*., 2013; Cavinato, 2017; Doppelt, 2003; Frederick, 2013; Wurdinger & Qureshi, 2015).

4. CONCLUSIONS

The PBL-ALQP model developed can improve graduate competencies which can be seen from the achievement level of basic laboratory skills, instrumentation analysis skills, critical thinking skills, communication skills, scientific work abilities by 99, 89, 63, 82, and 74% respectively, and attitudes discipline and responsibility of 98 and 92% in the high and very high categories. The assignment of searching scientific articles related to the problem really helped students in developing project designs and developing critical thinking skills and scientific work abilities. Presentation and writing of scientific articles from the work of the project also help communication skills of students. However, students still have difficulties in finding scientific literature, translating scientific articles, converting the contents of literature into work steps, compiling hypotheses, conducting data analysis, and drawing conclusions. Further study will then conduct to overcome the issues.

5. REFERENCES

1. Akinoglu, O., & Tandogan, R.O., *Eurasia J. Math. Sci. & Tech. Ed.*, **2007**, 3(1), 71–81.
2. Arfianawati, S., Sudarmin, & Sumarni, W., *Jurnal Pengajaran MIPA*, **2016**, 21(1), 46–51.
3. Assis, A.F., Silva, M.D., & Ribeiro, N.S., *Periódico Tchê Química*, **2017**, 14(27), 162–170.
4. Bagheri, M., Ali, W.Z.W., Chong, M.B.A., & Daud, S.M., *Contemporary Ed. Technol.*, **2013**, 4(1), 15–29.
5. Baumgartner, E., & Zabin, C.J., *Environ. Ed. Res.*, **2008**, 14(2), 97–114.
6. Bowden, J.A., Nocito, B.A., Lowers, R.H., Guillette, L.J., Williams, K.R., & Young, V.Y., *J. Chem. Ed.*, **2012**, 89, 1057–1060.
7. Bramer, S. Van., *J. Chem. Ed.*, **2001**, 78(9), 1167–1174.
8. Cahyani, R., Rustaman, N.Y., Arifin, M., & Hendriani, Y., *JPII*, **2014**, 3(1), 8–11.
9. Carbó, A.D., Adelantado, V.J.G., & Reig, F.B., *US-China Ed. Rev.*, **2010**, 7(7), 15–29.
10. Carvalho, C., Fiuza, E., Gama, P., & Salema, M., *TUSED*, **2015**, 12(2), 21–31.
11. Cavinato, A.G., *Anal. Bioanal. Chem.*, **2017**, 409(6), 1465–1470.
12. Cesarino, E.C., Mulholland, D.S., & Francisco, W., *Periódico Tchê Química*, **2018**, 15(30), 221–240.
13. Chun, M.S., Kang, K. Il, Kim, Y.H.M., & Kim, Y.H.M., *Universal J. Ed. Res.*, **2015**, 3(11), 937–942.
14. Creswell, J.W., Research Design Pendekatan Kualitatif, Kuantitatif, dan Mixed. Yogyakarta: Pustaka Pelajar, **2010**.
15. Dalgarno, B., Bishop, A.G., Adlong, W., & Bedgood Jr, D.R., *Comput. Ed.*, **2009**, 53, 853–865.
16. Doppelt, Y., *Int. J. Technol. Des. Ed.*, **2003**, 13(3), 255–272.
17. Fakayode, S.O., *Anal. Bioanal. Chem.*, **2014**, 406(5), 1267–1271.
18. Fakayode, S.O., King, A.G., Yakubu, M., Mohammed, A.K., & Pollard, D.A., *J. Chem. Ed.*, **2011**, 89, 109–113.
19. Frederick, K. A., *Anal. Bioanal. Chem.*, **2013**, 405(17), 5623–5626.
20. Gusarova, M. S., Kopytova, A. V., & Reshetnikova, I. G., *Periódico Tchê Química*, **2019**, 16(31), 903–912.
21. Hake, R.R., Handbook of Design Research Methods in Education. (A. E. Kelly, R.A. Lesh, & J.Y. Baek, Eds.). New York: Madison Ave, **2008**.
22. Haryani, S., Liliasari, Permanasari, A., & Buchari. *Jurnal Pendidikan Matematika dan Sains*, **2010**, *XV*(1), 35–42.
23. Haryani, S., Prasetya, A.T., & Bahron, H. *JPII*, **2017**, *6*(2), 229–236.
24. Henderson, D.E., *J. Chem. Ed.*, **2010**, 87(4), 412–415.
25. Jiang, W., *J. Am. Sci.*, **2005**, 1(2), 93–94.
26. Jollands, M., Jolly, L., & Molyneaux, T., Project-Based Learning as a Contributing Factor to Graduates' Work Readiness, **2012**.
27. Karataş, F., *Chem. Ed. Res. Practice*, **2016**, 17(1), 100–110.
28. Lee, J.S., Blackwell, S., Drake, J., & Moran, K.A., *Interdisciplinary J. PBL*, **2014**, 8(2), 18–34.
29. Luzyawati, L., *Wacana Didaktika*, **2014**, III(17), 21–32.
30. Medeiros, F., Júnior, P., Bender, M., Menegussi, L., & Curcher, M., A Blended Learning Experience Applying Project-Based Learning in an Interdisciplinary Classroom, ICERI2017 Proceedings, 8665–8672, **2017**.
31. Perkins, C., & Murphy, E., *Educational Technology and Society*, **2006**, 9(1),

298–307.

32. Prasetya, A.T., Haryani, S., Cahyono, E., & Sudarmin, J. *Physics: Conference Series*, **2019**, 132 (032055):1-7.

33. Robinson, J.K., *Anal. Bioanal. Chem.*, **2013**, 405(1), 7–13.

34. Santos, D.M.D.L., Montes, A., Sánchez-Coronilla, A., & Navas, J., *J. Chem. Ed.*, **2014**, 91(9), 1481–1485.

35. Saripudin, A., Haryani, S., & Wardani, S., Characterized Project Based Learning to Improve Critical Thinking Skills, ICMSE 2015, **2015**.

36. Sarwi, & Liliasari., *Forum Kependidikan*, **2010**, 30(1), 37–44.

37. Sarwi, Rusilowati, A., & Khanafiyah, S., *JPFI*, **2012**, 8(1), 41–50.

38. Sharples, M., *OEB Insights*, **2019**, 1–3.

39. Smith, O.L., & Dragojlovic, V., *J. Lab. Chem. Ed.*, ***2013***, 1(2), 25–33.

40. Sojka, Z., & Che, M., *J. Chem. Ed.*, **2008**, 85(7), 934–940.

41. Tawil, M., & Liliasari., Berpikir Kompleks dan Implementasinya dalam Pembelajaran IPA, Badan Penerbit Universitas Negeri Makassar: Makasar, **2013**.

42. Taylor, P.D.P., Barałkiewicz, D., Bettencourt Da Silva, R., Brodnjak Vončina, D., Bulska, E., Camoes, M. F., … Perämäki, P., *Anal. Bioanal. Chem.*, **2015**, 407(23), 6899–6907.

43. Wurdinger, S., & Qureshi, M., *Innovative Higher Ed.*, **2015**, 40(3), 279–286.

Table 1. *The PBL-ALQP model implementation schedule*

Meeting	Experiment event	Student activities	Observer activity
Preliminary experiment			
1st Week	Preparation	a. Reviewing chemical requirements (including the type, concentration, and volume of working solutions needed) b. Compiling a description of making working solutions	Authentic assessment to measure the level of basic laboratory skills
2nd week	Making a working solution	Making working solutions (weighing, taking, dissolving, diluting chemicals)	
3rd week	Standardize of working solutions	a. Standardization of working solutions (taking, pipetting, diluting chemicals, titration) b. Making a report	
4th week	Determination of Ka acetic acid with a pH-meter	a. Compiling a list of experimental equipment b. Practical activities (stringing, calibrating, and operating the pH-meter) c. Making a report	Authentic assessment to measure the level of instrumentation analysis skills
5th week	Acid-base titration with a conductometer	a. Compiling a list of experimental equipment b. Practical activities (stringing, calibrating, and operating the conductometer) c. Making a report	
6th week	Determination of [Cu^{2+}] by UV-Vis spectrophotometer	a. Compiling a list of experimental equipment b. Practical activities (stringing, calibrating, and operating the UV-Vis spectrophotometer) c. Making a report	
Project work			
7th week	Lab project	Designing the project, taking data with the appropriate instrumentation analysis method, validating the testing method, analyzing the data, and concluding as an answer to the problem given.	Authentic assessment to measure the level of critical thinking skills, communication skills, and scientific work abilities
8th week	Lab project		
9th week	Lab project		
10th week	Lab project		
11th week	Project reporting and presentation		
12th week	Compilation of scientific articles		

Table 2. *The achievement level of basic laboratory skills and instrumentation analysis skills*

No	Skills which was observed	Achievement score (%)			
		Less	Mid	High	Very high
1.	Basic laboratory skills	-	1	65	34
2.	Instrumentation analysis skills				
	a. pH-meter	-	6	51	43
	b. Conductometer	3	12	59	26
	c. Spectrophotometer UV-Vis	2	15	72	11

Table 3. *The achievement level of critical thinking skills, communication skills, scientific work abilities, discipline, and responsibility*

No	Skills which was observed	Achievement score (%)			
		Less	Mid	High	Very high
1.	Critical thinking skills	2	35	63	-
2.	Communication skills	-	18	82	-
3.	Scientific work abilities	-	26	74	-
4.	Discipline	-	2	6	92
5.	Responsibility	-	8	12	80

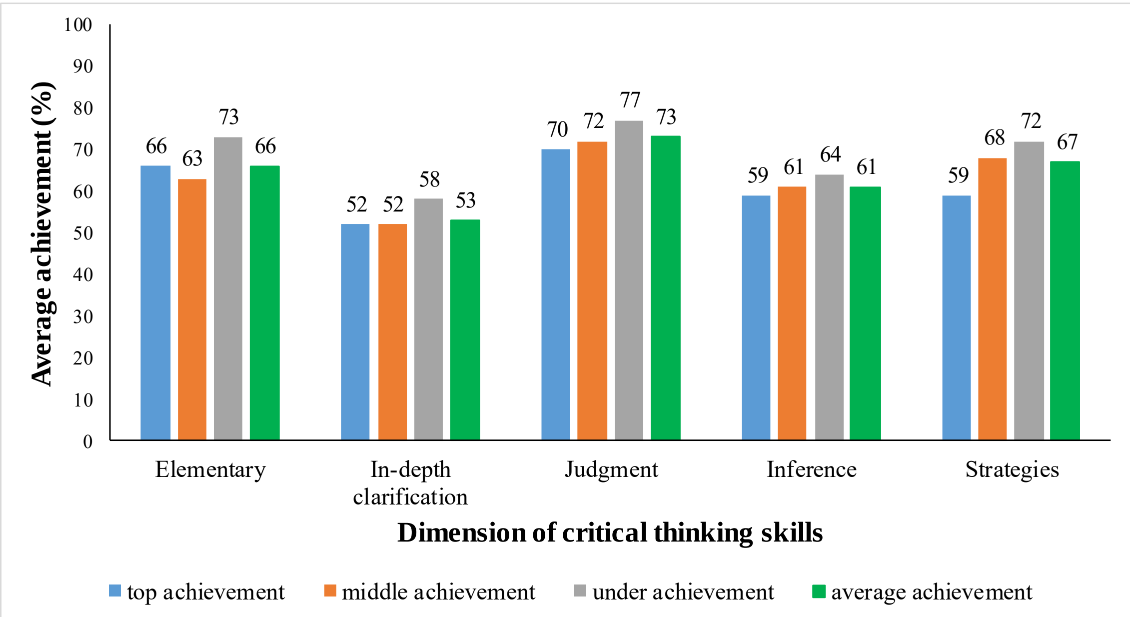

Figure 1. *Distribution of achievement level in critical thinking skills dimensions each achievement group*

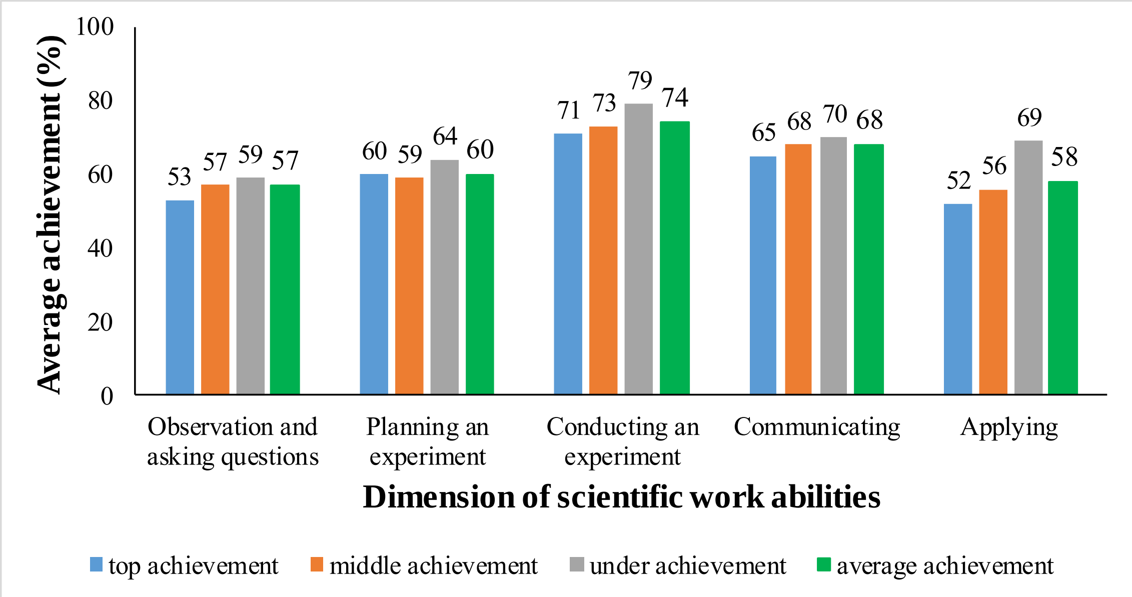

Figure 2. *The achievement level distribution of the scientific work abilities dimensions of each achievement group*