Chemical Practicum Learning Project-Based Instrument Analysis to Develop Students' New Literacy Skills

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Abstract. The era of globalization has required universities to prepare graduates who are ready to work according to the competence of the 21st century, namely graduates who not only master skills according to their fields but are required to have new literacy such as technology literacy, data literacy, and human literacy in the context of problem solving in their fields of expertise. According to his qualifications, chemistry graduates must be able to solve chemical problems according to their field through procedural approaches using chemical instruments. Through the study of chemical practicum project-based instrument analysis associated with daily life can provide the ability of instrumental analysis correctly and can improve new literacy which is the main key of the competence of chemical graduates. Through project-based learning, students are required to be able to draft practicum, run projects and report project results. The results obtained that students' ability to access, complete, and upload assignments online include the ability to upload a list of borrowing tools online (96%), able to describe how to create a working solution (90%), as well as being able to upload reports well (97%). Achievement of students' skills in conducting instrumentation analysis with a minimum high category include pH-meter tools (94%), conductometers (85%), and spectrophotometers (83%). The ability of students in designing projects with minimal categories both in detail include design systematics (71%), goal formulation (62%), variable identification (73%), variable control (72%), hypotheses (45%), library foundation systematics (47%), inter-concept relationships (65%), use of formulas (50%), tool determination (65%), conducting experimental steps (65%), and time allocation (100%). The achievements of students' ability to communicate project results in detail include discussing results (58%), presenting (77%), reporting in writing (63%), charting (60%). The achievement of students' skills in processing data of high category minimum project results includes valid data collection (83%), systematic reports (67%), report quality (68%), data analysis and discussion (62%), drawing clear conclusions (55%). From this study obtained the learning model of chemical practicum project-based instrumentation analysis can improve data literacy in low, medium, high categories (5, 63, 32%), technology literacy (2, 20, 78%), and HR literacy (0.75, 25%) so as to improve the competence of chemistry graduates. It is necessary to provide a lot of training so that the low literacy skills can be improved again.

Keywords:project-based learning, data literacy, technology literacy, human literacy, instrument analysis chemistry practicum

I. INTRODUCTION

Globalization has resulted in a change in the overall life of society, not least the education and employment sectors. Universities are required to reform the education system in order to better prepare graduates to become a workforce in accordance withthe21st century ompetensi k (Cavinato, 2017). One of the competencies of graduates in the field of analytical chemistry is the ability to perform chemical analysis conventionally and instrumentally. This is reflected in the learning achievements of the Instrument Analysis Chemistry (KAI) practicum course, namely mampu mengaplikasikan the principle of instrumentation analysis carefully, accurately, and responsibly using spectrophotometry, chromatography and electrochemical methods.

The results of analysis of various teaching materials, research reports, and observations in analytical chemistry practicum are known to still be dominated by conventional analytical methods rather than instrumental analysis methods. The practicum model given is still mostly verific using a practicum manual like a recipe book. In the implementation of practicum, students often encounter practicum indiscriminately which is unwittingly obtained data of poor observation results. They ultimately have difficulty in compiling discussions, interpreting and explaining practical data to draw conclusions. They end up often looking for shortcuts in arranging discussions by exemplifying from practicum reports that have been compiled by other practicum participants or from previous year's practicum report without trying to understand how to analyze and interpret observation data in preparing discussions and drawing conclusions. Exemplary behavior in making practicum reports, in addition to being evidence of weak mastery of the concept of instrumentation analysis is also a proof of low motivation in students in studying analytical chemistry and illustrates that kai's verificative practicum model has not been able to improve new literacy in the global era such as technology literacy, data literacy, and human literacy which is the main key of the competence of chemical graduates(Frederick, 2013).

The lack of new literacy owned by students is thought to be one of them occurs because the practical learning model conducted by lecturers is still largely verificative. Scientific learning model is seen as an appropriate learning model to meet the needs of the workforce in the era of globalization because it can direct students to improve chemical literacy. The active learning model that is widely applied in the chemical learning of instrument analysis in the laboratory is the *project-based learning* model (Baş & Beyhan, 2010; Erdem, 2012; Bagheri *et al.* , 2013; Chun *et*al., 2015; Cavinato, 2017).

PjBL model can provide authentic experience for students in developing problem solving skills in daily life (real world) through scientific approaches including critical thinking for problem solving, cooperating and communicating in teams, as well as interpreting data, predicting results, drawing conclusions (Jollands *et*al., 2012; Bagheri *et*al., 2013; Frederick, 2013; Wurdinger & Qureshi, 2015; Cavinato, 2017). This authentic experience is what chemistry graduates need to be able to compete in the world of work. This statement is supported by the results of research that reveals pjbl model can prepare graduates who are ready to enter the world of work compared to the verificative learning model (Baumgartner & Zabin, 2008; Jollands *et*al., 2012; Wurdinger & Qureshi, 2015).

Robinson (2013), has recommended authentic assessment guidelines to see performance improvements in instrumentation analysis practicum which include: 1) the use of analytical balance sheets, pipettes, measuring flask in making raw solutions or in dilution, 2) understanding of components and instrumentation designs used for chemical analysis, 3) understanding of the basic principles of measurement and variables that can be controlled to influence absorption, detection limits, and linearity, 4) how to analyze data from various measurements using statistical methods, 5) literature searches to conduct analysis with a high degree of accuracy and precision, 6) reports of work results containing experimental methods, procedures, and results including validation reports.

The summary of the description above is clear that if we teach science (chemical instrument analysis) can be done with various models that all rely on *student active learning.* The competence of chemical graduates can be improved through the development of new literacy i.e. technology, data, and human literacy that can be done by providing authentic experiences through project-based active learning models (Carbó *et al.,*2010; Frederick, 2013; Robinson, 2013; Fakayode, 2014; Cavinato, 2017). The first scenario is done by increasing the composition of the learning material using instrumental analysis method compared to conventional analysis method (Bowden etal., 2012), secondly, applying the principles of Good *Laboratory Practice* during practicum which include problem identification, hypothesis submission, determination of analysis methods, data collection and analysis as well as conclusion drawing by applying testing quality procedures like an accredited laboratory to ensure the quality of test results, traceability of measurements, quality of testing methods through validation tests of analytical methods as stipulated in SNI ISO/IEC 17025:2017 (KAN, 2008; Merck, 2014; Taylor etal., 2015). Improved composition between the instrumentental analysis method and the conventional analysis method will directly provide opportunities for students to use modern instruments for longer, so that students get a longer opportunity to learn the principles and functions of modern instrumentation. In addition, in order for the authentic experience obtained by students during practicum to be more in-depth, it must be accompanied by the application of testing quality procedures like accredited laboratories that always prioritize the reliability of test results as reflected in the technical requirements for an accredited laboratory that is the need to validate analytical methods that include testing accuracy, precision, limit detection, quantization limits, and linearity ranges.

II. METHOD

1.1 Instruments for retrieving data

This research is *a mixed-method* research with *concurrent embedded design* model. The implementation of project-based practicum learning model was conducted using the design of one *group pretest-posttest design* in a class of 65 students. In practicum, authentic assessment is used to measure the level of technology literacy, data literacy, and human literacy.

1.2 Data analysis

The final product of the research is a proven *blended learning-based* Instrument Analysis Chemistry practicum model that can measure the level of competence of graduates. Data analysis is used to determine the level of technology literacy, data literacy, and human literacy.

III. RESULTS AND DISCUSSION

In the era of industrial revolution 4.0 universities need to develop new literacy, namely technology, data, and human literacy. Students should be able to utilize, process data, and apply technology and understand how to use the technology. Human literacy is important to survive in the global era, so that it can function well in the human environment and can understand interactions with fellow human beings. Therefore universities need to find methods to develop students' cognitive capacities such as critical thinking skills and communication that are indispensable to survive in the era of industrial revolution 4.0. Technology, data, and human literacy from students can be developed in the learning process. During the implementation of the project- based KAI practicum model, in addition to being able to be used to develop instrumentation analysis skills, it can also be used to measure new levels of literacy in the era of industrial revolution 4.0. The parameters of each new literacy component can be measured in the project-based KAI practicum as presented in Figure 1.

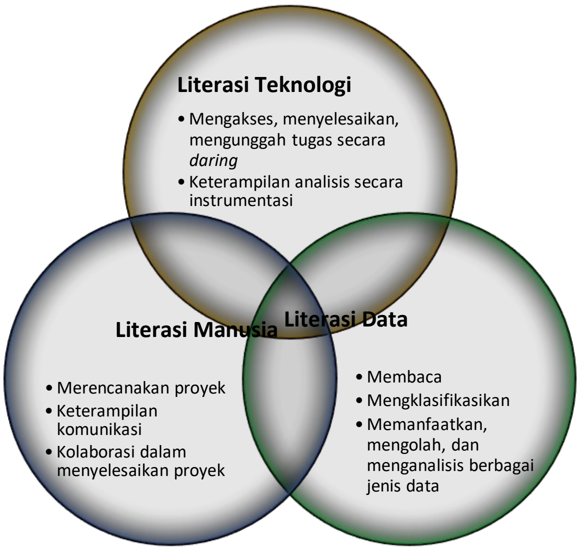

Figure 1. New literacy measurement parameters in project-based KAI Practicum

The project-based learning model begins with the provision of open and complex problems related to real life and requires students to think a high level in solving them. This problem solving ability is very important for students to master in meeting the demands of future careers. In the project-based KAIpracticum learningmodel, students are required to have initial knowledge and skills as the basic capital for completing projects collaboratively. Without adequate initial knowledge and skills, project-based practicum learning will not proceed as expected (Frederick, 2013). In the study of chemical practicum analysis instruments need to be combined between verification-based practicum with project-based practicum as has been done by Cavinato (2017). In this study, the combination of verification-based practicum and project was associated with the application of laboratory quality procedures in order to obtain valid instrumentation measurement/analysis results through the development of a deeper understanding in the search for scientific literature, translating into experimental steps, instrumentation operations to collect data, data calculation and analysis, validation, and conclusion (Frederick, 2013; Taylor etal., 2015).

The project-based KAI Practicum Model is designed in 3 stages, namely the preparation stage, the verification-based practicum stage, and the project-based practicum stage. In practice the preparation stage is intended to know the basic skill level of the laboratory that can be observed in describing how to make a working solution, observation in the practice of making a working solution and its standardization, as well as assessment of reports in the manufacture of work solutions. The practice of verification stage is intended to introduce various instrumentation equipment to students. The project-based practicum stage is used to measure high levels of thinking ability in solving problems related to daily life through instrumentation analysis (Cavinato, 2017; Frederick, 2013; Robinson, 2013; Wurdinger & Qureshi, 2015).

a. Level of technology literacy

1. Ability to access, complete, upload tasks online

The measurement results of students in accessing and uploading a list of borrowing tools by 96%, and in uploading reports by 97%. The ability of students in describing how to make a working solution by 90%. The practical design begins with the assignment of making a working solution used in the verification practicum stage. Students are given the task of meeting the needs of the working solution and seeking specification information from the concentrated solution / solids to make a working solution, drafting a description of how to make a working solution, and ending the process of making a working solution and standardization. Students of each achievement group have mostly had good knowledge in compiling descriptions of the making of work solutions, although there are still some mistakes made. Errors in describing the creation of the work solution encountered include:

a) Miscalculation. Calculation errors occur a lot in the manufacture of a working solution derived from its concentrated solution. This error occurs because students only memorize how to make a working solution from the concentrated solution by using a formula without accompanied by correct understanding. Miscalculation in describing the creation of the observed work solution by 9%.

b) Fault of purity. The error of ignoring the purity of the substance in describing the manufacture of the work solution is observed by 18%.

c) Volume error. This error occurs not because of an error in the calculation or because of the purity factor. Volume error in describing the creation of the work solution is observed by 6%.

d) Molecular formula errors in describing the manufacture of working solutions by 32%.

This proves that some students still have knowledge and understanding of analytical chemistry concepts in low solution content especially the context of working solution making as well as mathematical technical application (Dalgarno, Bishop, Adlong, & Bedgood Jr., 2009; Karataş, 2016).

2. Instrumentation analysis skills

In accordance with the practicum material that has been prepared in the verification practicum stage, which includes the determination of the price of weak acid ka with pH-meter, conductometric titration, as well as the determination of the concentration of analyte with UV-Vis spectrophotometer. In measuring instrumentation analysis skills, the assessment is not only centered on the skills of operating instrumentation, but includes the stage of practicum design, the stage of practicum implementation, as well as the reporting stage of practicum. Through authentic assessment obtained results there are 58 students have a high level of instrumentation analysis skills and very high categories, 7 students in the category is sufficient, and does not exist in the category less. The level of instrumentation analysis skills spread evenly across all achievement groups and did not differ significantly.

If the level of instrumentation analysis skills observed in each instrument obtained the following data: 1) the level of analytical skills using pH-meters with high criteria and very high there are 61 people, 2) the level of analytical skills using the conductometer with high criteria and very high there are 55 people, as well as 2 students in the criteria less, 3) the level of analytical skills using the conductometer with high criteria and very high there are 54 people , as well as 1 student in less criteria. From this fact it appears that instrumentation analysis skills in using UV-Vis spectrophotometers are most difficult to master by students then sequentially conductometer and pH-meter instruments.

b. Data literacy level

Student data literacy can be observed from students' ability to read, classify, process, and analyze test result data, and test method validation results.

1. Read data

Individual data reading skills are assessed through valid data *collection*activities. This dimension has an average achievement rate of 83%. This level of achievement is measured by skill observation using simple equipment and instrumentation. Students have no difficulty in using simple laboratory equipment such as in the process of bulking solids, taking liquids, dissolving, and dilution, as well as weighing processes.

2. Classify data

The skills of filing data individually are assessed through activities.

a) Systematically compile report materials
This dimension has an average achievement rate of 67%. This level of achievement is measured through the assessment of the report format and the references used. The format of the student project report is in accordance with the guidelines used, but the shortcomings seen only in referrals that access is still too minimal.

b) Quality of appearance in reporting results This dimension has an average achievement rate of 68%. This level of achievement is measured through the assessment of the quality of reporting as well as the systematics of project reports. The quality and systematics of the project report prepared by students is in accordance with existing guidelines.

3. Utilizing, processing, and analyzing data

Skills to utilize, process, and analyze data individually are assessed through the following activities.

a) Analyze data and discuss results in depth
This dimension has an average achievement rate of 62%. This level of achievement is measured through the assessment of project reports related to the results of the manufacture of working solutions, the creation of calibration curves, as well as the results of method validation tests covering linearity range, LoD, LoQ, accuracy and precision.

b) Draw conclusions clearly according to the formulation of the problem
This dimension has an average achievement rate of 55%. This level of achievement is measured by assessment in concluding the project report. There are some groups still unsuitable in drawing conclusions. The conclusion should answer the existing problem and contain information on whether the analysis method used as well as the data obtained is valid. The information of the method validation test has not been utilized to make conclusions.

During the introductory practice, students have gained experience in accessing assignments, completing and uploading assignments *online* through *elena.unnes.ac.id* pages and operating various instrumentations for analysis. During the implementation of project work in the project-based KAI practicum model, students have been trained in reading, classifying, utilizing and analyzing data based on their level of validity. Data obtained during the implementation of the project include absorbance data, linearity range, calibration curve correlation coefficient, LoD and LoQ magnitude, and precision and accuracy test result data. Experience in utilizing information and communication technology and instrumentation shown by students during practicum has proven that students are able to apply, understand, and use technology in their learning. This proves that students already have technology literacy as one of the new literacy in the era of industrial revolution 4.0.

c. Level of human literacy

Students' authentic experience in completing projects is used to measure the level of human literacy.

1. Ability to design projects

The design of the project in the form of instrumentation analysis methods that can be obtained from the standard method, modification of the standard method, or the development of analytical methods from the source of scientific articles must be made in detail. The details of the process include how to take samples, the manufacture of working solutions, the preparation of samples, the creation of calibration curves, the measurement of samples, the calculation and analysis of data. Method validation or confirmation tests are also included including linearity tests, LoD and LoQ calculations, precision and accuracy tests. The purpose of method validation test is to assess students' ability to perform instrumentation analysis and test whether modified analysis methods still produce valid data. Similar research has also been conducted by Carbó *et al.* (2010), Fakayode (2014), Jiang (2005), and Taylor *et al.* (2015). The ability to design individual projects is assessed through activities as presented in Table 1.

Table 1. Dimensions Of Project Designing Capabilities

No	Activities	Target (%)
1	Menyusun design according to systematics	71
2	Formulating specific experiment objectives	62
3	Identify variables	73
4	Controlling variables	72
5	Berhipotesis	45
6	Write the foundation of the library systematically and sequentially	47
7	Seamlessly connect concepts in a bibliography	65
8	Explain the right formulas and equations	50
9	Precisely determine experimental tools and materials	65
10	Perform experiment steps correctly	65
11	Allocate time	100

2. Communication skills

Communication skills are measured at the time of presentation of the project results and from the quality of the articles compiled. The results of the measurement of communication skills are mostly in the high category. The level of communication skills achievement has been relatively high with a spread of *high* categories there are 53 students (82%) and the rest in the category is *enough*. Students from *the top* and *middle* achievement groups were in the *high* category as much as 82%, while from the *lower* achievement group only 62%.

Individual communication skills are assessed through the following activities.

a) Discuss

This dimension has an average achievement rate of 58%. This level of achievement is measured through observation including the skills to convey the results of discussions in front of the class, cooperation in groups, questioning skills, answers, and attitudes towards ideas / inputs.

b) Serves

This dimension has an average achievement rate of 77%. This level of achievement is measured through observation including presentation skills, time utilization during presentation, as well as confidence.

c) Report in writing

This dimension has an average achievement rate of 63%. This level of achievement is measured by the assessment of the format of scientific articles made. Deficiencies observed in the writing of methods, results and discussions, as well as references used. The content of the method is still the same as the project report and has not been summarized following the rules that apply in the writing of scientific articles.

d) Create a graph/table

This dimension has an average achievement rate of 60%. This level of achievement is measured through the quality assessment of the graph/table as well as the information displayed. Students have been skilled in creating charts, although not complete.

The average level of achievement of each indicator of verbal communication skills is higher than that of non-verbal communication skills indicators. The average achievement of verbal communication skills from *the*upper, *middle,* and *lower* achievement groups was 77, 77, and 71%, while non-verbal communication skills were 68, 63, and 67% respectively. From the observations in the presentation and assessment of scientific articles obtained the results that the communication skills of students have classically met the target of 82% in the *high*category. The level of communication skills achievement can still be developed through scientific writing training and scientific articles as well as preparation and timing in presentations/discussions. Project-based practicum learning can also be used to improve communication skills, both presentation delivery and scientific report writing as stated by Henderson (2010), Fakayode (2014), and Sojka & Che (2008).

3. Collaboration in completing projects

Collaboration in completing projects is observed through observation in each activity before practicum and activity after completion of practicum. Pre-practicum activities include preparing equipment and chemicals used during practicum, after practicum

activities include participation in cleaning practicum equipment, restoring equipment and chemicals used during practicum.

Assessment of attitude of responsibility is measured by the criteria of student participation in

preparing tools and materials used for practicum, concern in cleaning waste / waste waste practicum, practicum equipment and returning it in a clean state.

The observations showed the level of student responsibility achievement is still high despite the decrease compared to the level of disciplinary achievement. Individual student participation in preparing practicum equipment is still low, this is the cause of the decrease in the level of achievement of attitudes of responsibility. One of the causes of low student participation is due to the delay of students in following the practicum. Project-based learning applied in chemical practicum can increase the sense of responsibility of students and give freedom in exploring their practicum responsibly. The same result has been proven by Bagheri *et al.* (2013), Cavinato (2017), Doppelt (2003), Frederick (2013), and Wurdinger & Qureshi (2015) in his research.

In the preliminary practice, the benchmark of technology literacy skills of students is assessed from accuracy in completing and uploading tasks through *the elena.unnes.ac.id* page as well as skills in performing instrumentation analysis. Students will have a high level of technology literacy if they can access the assignment, complete and re-upload the assignment in a timely manner according to the agreed provisions and skilled in conducting instrumentation analysis. From the assessment of the level of technology literacy obtained information that 78% of students have a level of technology literacy in the high category, 20% in the moderate category, and 2% in the low category.

In the work of the project, in addition to measured critical thinking skills, communication, and scientific work skills, measured also the level of data and human literacy. Data literacy benchmarks are seen from students' ability to classify and process data, as well as the ability to decide the quality of test method validation results. From the assessment of literacy data obtained information that 32% of students have a level of data literacy in the high category, 63% in the moderate category, and 5% in the low category. The benchmark of human literacy is seen from the ability of students in drafting projects, communication skills in delivering project results, as well as collaboration in completing projects. From the assessment of human literacy obtained information that 25% of students have a high level of human literacy in the category, and 75% in the moderate category. The results of evaluation of data literacy, technology, and human level from students who follow the practice of Chemical Instrument Analysis using project-based KAI practicum model are presented in Figure 2.

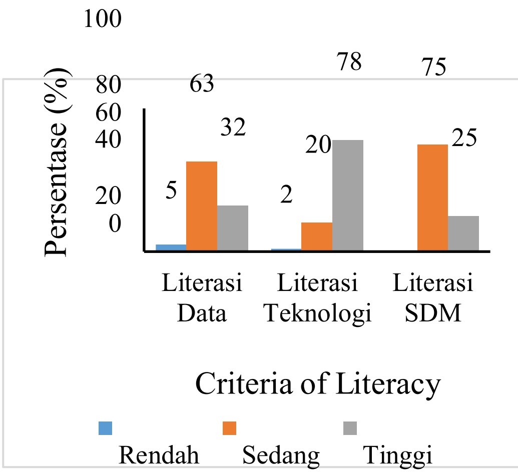

Figure 2. New level of literacy in the era of student disruption after application project-based KAI Practicum model

IV. CONCLUSION

The project-based practicum learning model developed has characteristics: emphasizing on the development of skills membaca, classifying, utilizing, processing, analyzing various types of data, kperformance analysis instrumentation, kcommunication skills,as well as planning and kolaboration in completing the project. The new literacy rates of students in the low, medium, high categories in a row are data literacy: 5, 63, 32%, technology literacy 2, 20, 78%, and HR literacy 0,75,25%.

REFERENCES

[1] Bagheri, M., Ali, W. Z. W., Chong, M. B. A., & Daud, S. M. (2013). Effects of Project-Based Learning Strategy on Self-Directed Learning Skills of Educational Technology Students. *Contemporary Educational Technology*, *4*(1), 15–29.

[2] Baş, G., & Beyhan, Ö. (2010). Effects of Multiple Intelligences Supported Project-Based Learning on Students' Achievement Levels and Attitudes towards English Lesson. *International Electronic Journal of Elementary Education*, *2*(3), 365–385.

[3] Baumgartner, E., & Zabin, C. J. (2008). A Case Study of Project-Based Instruction in the Ninth Grade: A Semester-Long Study of Intertidal Biodiversity. *Environmental Education Research*, *14*(2), 97–114.

[4] Bowden, J. A., Nocito, B. A., Lowers, R. H., Guillette, L. J., Williams, K. R., & Young, V. Y. (2012). Environmental Indicators of Metal Pollution and Emission: An Experiment for the Instrumental Analysis Laboratory. *Journal of Chemical Education*, *89*, 1057–1060.

[5] Carbó, A. D., Adelantado, V. J. G., & Reig, F. B. (2010). Black Boxes in Analytical Chemistry: University Students Misconceptions of Instrumental Analysis. *US-China Education Review*, *7*(7), 15–29.

[6] Cavinato, A. G. (2017). Challenges and Successes in Implementing Active Learning Laboratory Experiments for an Undergraduate Analytical Chemistry Course. *Analytical and Bioanalytical Chemistry*, *409*(6), 1465–1470.

[7] Chun, M.-S., Kang, K. Il, Kim, Y. H. M., & Kim, Y. H. M. (2015). Theme-Based Project Learning: Design and Application of Convergent Science Experiments. *Universal Journal of Educational Research*, *3*(11), 937–942.

[8] Dalgarno, B., Bishop, A. G., Adlong, W., & Bedgood Jr, D. R. (2009). Effectiveness of a Virtual Laboratory as a Preparatory Resource for Distance Education Chemistry Students. *Computers and Education*, *53*, 853–865.

[9] Doppelt, Y. (2003). Implementation and Assessment of Project-Based Learning in a Flexible Environment. *International Journal of Technology and Design Education*, *13*(3), 255–272.

[10] Erdem, E. (2012). Examination of the Effects of Project Based Learning Approach on Students' Attitudes Towards Chemistry and Test Anxiety. *World Applied Science Journal*, *17*(6), 764–769.

[11] Fakayode, S. O. (2014). Guided-Inquiry Laboratory Experiments in the Analytical Chemistry Laboratory Curriculum. *Analytical and Bioanalytical Chemistry*, *406*(5), 1267–1271.

[12] Frederick, K. A. (2013). Using Forensic Science to Teach Method Development in the Undergraduate Analytical Laboratory. *Analytical and Bioanalytical Chemistry*, *405*(17), 5623–5626.

[13] Henderson, D. E. (2010). A Chemical Instrumentation Game for Teaching Critical Thinking and Information Literacy in Instrumental Analysis Courses. *Journal of Chemical Education*, *87*(4), 412–415.

[14] Jiang, W. (2005). Good Laboratory Practice in Analytical Laboratory. *The Journal of American Science*, *1*(2), 93–94.

[15] Jollands, M., Jolly, L., & Molyneaux, T. (2012). *Project Based Learning as a Contributing Factor to Graduates' Work Readiness*.

[16] Kan. (2008). SNI ISO/IEC 17025: 2008 concerning General Requirements of Competency of Testing Laboratories and Laboratories.

[17] Karataş, F. (2016). Pre-service Chemistry Teachers' Competencies in the Laboratory: A Cross-Grade Study in Solution Preparation. *Chemistry Education Research and Practice*, *17*(1), 100–110. https://doi.org/10.1039/c5rp00147a

[18] Merck. (2014). Your Reliable Partner for Accredited Lab.

[19] Robinson, J. K. (2013). Project-Based Learning: Improving Student Engagement and Performance in the Laboratory. *Analytical and Bioanalytical Chemistry*, *405*(1), 7–13.

[20] Sojka, Z., & Che, M. (2008). Presentation and Impact of Experimental Techniques in Chemistry. *Journal of Chemical Education*, *85*(7), 934–940. https://doi.org/10.1021/ed085p934

[21] Taylor, P. D. P., Barałkiewicz, D., Bettencourt Da Silva, R., Brodnjak Vončina, D., Bulska, E., Camoes, M. F., … Perämäki, P. (2015). A Summer School where Master Students Learn the Skills Needed to Work in an Accredited Analytical Laboratory. *Analytical and Bioanalytical Chemistry*, *407*(23), 6899–6907.

[22] Wurdinger, S., & Qureshi, M. (2015). Enhancing College Students' Life Skills through Project Based Learning. *Innovative Higher Education*, *40*(3), 279–286.