TEACHER CANDIDATE'S GENERIC SCIENCE SKILLS ON ORGANIC CHEMISTRY REACTIONS THROUGH PROBLEM-BASED LEARNING MODEL

Ratu Evina Dibyantini[1*], Retno Dwi Suyanti[2], Ramlan Silaban[3]

[1*]Chemistry Education Study Program Postgraduate School, Universitas Negeri Medan, Indonesia; [2,3]Chemistry Education Study Program, Universitas Negeri Medan, Indonesia.
Email: [1*]ratuevina1962@gmail.com; [2]dwi_hanna@yahoo.com

Abstract

Purpose of the study: This study was aimed at obtaining information about teacher candidates' generic science skills on organic chemistry reaction, namely addition, substitution, and elimination.

Methodology: This study was one group pretest-postest design with the quasi-experimental method. The subject was done to teacher candidate students which consist of the experimental group taught by using the problem-based learning model (PBL) and control group taught by using the direct instruction model. The data were obtained through generic science skills tests in the form of multiple choices test and calculated by using SPSS version 20 as well as the practicum observation results.

Main Findings: The result showed that generic science skills of an experimental class taught on addition and substitution material were at the high level and for elimination, the material was at the medium level, meanwhile for control class on addition and substitution material were at medium level and for elimination, the material was at a low level. The results of the logical inference practicum were at the high category. The practicum result of direct observation was at a high level.

Applications of this study: The findings of this study are expected to give contribution to the organic chemistry learning model in order to develop students' generic science skills to improve the quality of the chemistry education students.

Novelty/Originality of this study: This study is recommended to improve students' generic science skills on addition, substitution, and elimination materials by using the PBL model in the classroom or laboratory in the future.

Keywords: Generic Skills, Problem Based Learning, Organic Chemistry Reactions, Addition, Substitution, Elimination.

INTRODUCTION

Generic science skills are skills that can support the learning in every discipline, and potentially can be transferred to every context at the higher education level or workplace (Jackson, 2013) In learning science, generic skills are called as generic sciences skills (GSS). The importance of GSS for university students is stated by (Cropanzano & Mitchell, 2014) that these skills are integrated into the chemistry curriculum. (Taber, 2016) stated that in chemistry education, generic skills are highly needed for the success of the students. Generally, there are ten generic skills namely direct observation, un-direct observation, scale understanding, symbolical language, logical frame, logical consistency, the law of cause and effect, modelling, logical inference, and abstraction (Urious, 2015). To improve the material concept that has been taught, the students as chemistry teacher candidates are needed to be provided with generic science skills, such as thinking and acting skills based on their prior knowledge in science (Liliasari, 2007).

Organic chemistry is a branch of chemistry in which its origin is from a living creature but develops into compounds of carbon since every organic compound consists of a carbon atom (Fessenden, 1982). Chemistry reaction is a change from one compound or molecule into another compound or molecule. In organic chemistry reactions, it is signaled by the covalent disconnection and creating a new covalent connection. The process of covalent disconnection may be gradually or simultaneously. A gradual reaction to produce a product is known as (Riswiyanto 2009). The basics of organic chemistry reactions varieties are addition, substitution, and elimination reactions (Taber, 2016) and (Solomon, 1997).

Based on the observation of chemistry lecturing on organic chemistry 1 and 2 subjects in the last three years, the result showed that there were many students could not understand the concept of organic chemistry. It was found from the students' average score that was 70 and it showed that only 15 % of the students got A and so did the practicum, especially on organic chemistry reactions which was below the expectation as well as some materials couldn't be conducted caused by the limited times and facilities in the laboratory. The reality showed that chemistry teacher in several high schools stated that organic chemistry subject which learned by teacher candidate in teacher training center these days were less provide them with how to teach senior high school students the organic chemistry subject. It is supported by the interview and questionnaire results from several teachers who stated that it is quite hard to determine types of organic chemistry reactions found in senior high school Olympics questions. The concepts of organic chemistry were considered as hard to understand particularly on the types of reactions, reaction mechanisms, and organic synthetic. The students considered it as an abstract object which is hard to understand. Thus, the problem-based learning model is highly needed to improve the concepts of organic chemistry reactions.

(Selcuk, Sezgin, Serap Çaliskan, 2013) stated that PBL is a learning method in which the students develop their critical thinking and problem-solving skills in their group to develop the understanding of a basic concept through real-life problem analysis. In problem-based learning, the small group consists of 6 or 8 students is created. They are guided by a tutor. They are given an authentic and complex problem to help them making a theory of application and real-life relationships (Tasoglu & Bakaç, 2014) and (Sada & Mohd, 2016). In addition, Nagarajan & Overton (2019) explained that the use of a problem-based learning model can motivate students to learn continuously and improve any applied skills. Sadiah, Bahrom, and Balaachandran (2013) stated that the problem-based learning model can support learning and achieve any skills, such as problem-solving, critical thinking, communication, teamwork, and individual. (Cropanzano & Mitchell, 2014)claimed that learning with a problem-based learning model can help students to achieve a higher score. Thus, this study was aimed at gaining information about teacher candidates' generic science skills on organic chemistry reactions subject, namely addition, substitution, and elimination.

LITERATURE REVIEW

Problem Based Learning Model

In PBL, group discussions as well as group workforce students to interact with their friends. PBL approach helps students to create interdisciplinary connections and provides them direct engagement with the methodology. As (Strollo, Davis, & Avenue, 2017)claimed that PBL can improve students' engagement in learning. The findings showed that PBL is an efficient instructional method to reinforce college students' critical thinking disposition and skills regardless of the instruments wont to measure the outcomes (Jamiat, 2018). According to (Nagarajan & Overton, 2019), Project and problem-based learning are student-centered learning approaches that supply educators the chance to interact learners in solving complex real-world problems. (Silaban, 2018) stated that Problem Based Learning by using PowerPoint with the scientific approach is the most effective in improving students' learning outcomes.

Furthermore, (Gao, Wang, Jiang, & Fu, 2018) explained that the problem and goals of learning should be designed according to the following rule: the problem must be clear and the results predictable. The difficulty of solving the problem should correspond to the abilities of the students. To perform the task, students must seek additional resources and interact with others. A suitable environment should be provided by teachers to assist students actively participate in learning activities and check out to propose possible solutions. After grouping, students should discuss and analyze the problem and explicitly state the task and evaluation criteria. The key to PBL was to style an appropriate problem scenario, which was best associated with the important lives of scholars.

(Jansson, Andersson, & Nording, 2015) defined problem-based learning (PBL) as a style of student-centered learning which facilitates the integration of multiple subjects, was investigated to determine if it would be a more appropriate instructional method for teaching Environmental Chemistry than traditional teacher-centered education model. PBL is known to be an efficient methodology not only for learning but also for acquiring an in-depth understanding of Environmental Chemistry. Problem-based uses complex, learning problem-based learning (PBL) is an academic approach based on real-world problems that may motivate students to spot and research the concepts and principles that they have to understand to devise a solution to the problem. Therefore, (Flynn & Biggs, 2012) developed and applied PBL to organic and medicinal chemistry laboratory courses.

(Rubiyanto, Anugrahwati, & Prakoso, 2018) also conducted a study that used PBL as a method to synchronize the chromatographic course and the lab work. Students were guided to extract some problems from the experiment performed within the lab especially those associated with the analysis and interpretation of the info resulted followed by a conference. After completing the task, on each schedule of sophistication activity material associated with the lab work material, a number of the groups who had obtained the related topic within the lab work explained the issues they addressed also because the solutions they obtained to interpret the results of their analysis. At the top of the category activity, the lecturer confirmed what the presenters in each group were delivered. Afterward, the lecturer should explain the chromatographic material following the course outline.

Meanwhile (Costantino & Barlocco, 2019) used the PBL method in learning organic chemistry materials particularly for laboratory courses to synthesize and extracting medicine to provide students with critical-thinking skills. Problem-based learning methods support student learning of content as well as scientific skills. Furthermore, (Shultz & Li, 2016) acknowledged that within the course of problem-based learning, students seek outside information associated with the matter, and thus, information literacy skills are practiced when problem-based learning is used. Their work used a mixed-methods approach to investigate the information-seeking behavior of students in a problem- based organic chemistry laboratory course. Thus, the PBL method can develop students' information literacy skills.

Generic Science Skills

Generic science skill is a cognitive strategy related to cognitive, affective, and psychomotoric aspects that are both naturally innate and can be explored. Therefore, generic science skills can be applied to many areas of studies. It is also can be used as skills and attribute in daily life as well as work-life since it covers basic competence and core competence including cognitive, personal, and interpersonal skills related to the carrier. Generic skill is highly needed to pursue higher education and a successful carrier (Tawil and Liliasari, 2014). Furthermore, Dacre, Renang, and Sewell in

(Cameron, Brimble, Knutsen, & Freudenberg, 2014) argued that working is not a skill naturally innate, however, it is a combination of carrier development learning, working life and life experience, technical knowledge, generic science, and emotional skills. According to Bennett, Dunne, and Carre (Cameron et al., 2014), generic science is a skill to support every discipline of studies and is potentially transferred to every context of higher education and the workplace. Not only transferring generic skills but also is important to enable students to apply their knowledge or disciplinary in every context (Jackson, 2013). Specifically, Moewrani et al. (2001) proposed that there are 10 generic skills needed in learning chemistry at University level, they are direct observation, indirect observation, scale understanding, symbolical language, logical frame, logical consistency, the law of cause and effect, modeling, logical inference dan abstraction. Generic skills in chemistry are skills to be utilized to study a higher chemistry material or another disciplined independently (Moewrani et al., 2001). It is in line with what has been stated by Brotosiswoyo (2000) that generic skill is a basic skill that benefits to be used in many work environments. (Suyanti, 2017) stated that the differences between high and low of students' generic skills in chemistry who were taught by using teaching strategy can improve their thinking skills as well as direct interaction.

According to (Khabibah, 2017) stated that by using a module based on discovery learning in the learning process is effective to increase generic science skills. Through practicum ability student are expected to be able to memorize, organize and construct their knowledge correctly at their brain (Suyanti & Sugiyarto, 2013) and (Ni Made Pujani, 2014) also developed a learning material based generic science skill to improve students' laboratorium skill as well as generic science skill in astronomy. She has successfully designed the draft of learning media based generic skill for science which consists of syllabus and practicum module, practicum skill test, and generic science skill test content-based, as well as manual for learning organization completed with assessment and scoring rubric which can improve students' laboratorium skill as well as generic science skill in the science subject. (Siswanto, Saefan, Suparmi, & Cari, 2016) shows that learning by using E-Lab to improve students' generic science skills positively affect students' understanding concept.

Addition, Substitution, Elimination

In this study, the materials discussed were addition, substitution, and elimination. Addition reaction is a reaction of adding an atom or atomic group in a molecule, in which a transformation of the unsaturated molecule would be saturated. In the addition reaction of an alkene, the pi bond is broken and the electron pair is used to form two new sigma bonds. Unprotected pi electrons in carbon-carbon bonds attract electrophiles (E +) like H +, so this reaction begins with an electrophilic attack and results in a carbocation. The carbocation is then attacked by a nucleophile producing the product. The addition is divided into two, namely electrophilic addition and nucleophilic addition. Electrophilic addition reactions are addition reactions that occur when the group that first attacks a double bond is an electrophile reagent. A nucleophilic addition reaction is an addition reaction that occurs when the group that first attacks a double bond is a nucleophile reagent. This reaction is found in carbon compounds that contain a double bond between two carbon atoms with another atom. Like compounds containing carbonyl groups and compounds that have cyanide groups (Fessenden, 1982).

Substitution reactions are chemical reactions, where an atom in a chemical compound is replaced by another atom. Substitution reactions in organic chemistry are grouped into two namely nucleophilic substitutions consisting of SN1 and SN2 and electrophilic substitution depending on the reagent used. SN2 reaction only has one reaction stage. The reagent attack and the release of the group go together. Whereas in the SN1 reaction goes through a carbocation, the away group must be attached to either tertiary or secondary carbon to stabilize. A methyl or primary leaving group will not form carbonium. Electrophilic substitution reactions occur in aromatic compounds including hetero aromatic. The electrophilic substitution reaction mechanism consists of the first stage of the formation of electrophile E + (fast), E + attack on the benzene ring (slow as a step to determine the rate of reaction) and taking H + from the benzene ring (fast) (Solomon, 1997).

Elimination reaction is a type of organic reaction where two substituents are released from a molecule in either one or two mechanism steps. In this reaction, a single bonded compound turns into a double bond. The elimination reaction is divided into two, namely unimolecular (E1) elimination and bimolecular (E2) elimination and alcohol dehydration. The E1 reaction is an elimination reaction in which a carbocation (an unstable and high-energy intermediate, which immediately reacts further) can give a proton to a base and produce an alkene. E2 reaction does not go through a carbocation as an intermediate but in the form of concurrent reactions (concerted reactions) that occur at one stage. In secondary and tertiary alcohol dehydration follows the E1 pathway. The hydroxyl group is protonated, a carbocation is formed by the release of a water molecule and then a proton is removed to produce alkene (Fessenden, 1982).

METHODOLOGY

This study used Educational Research and Development Design. Generally, it was conducted through four steps; they were (1) introduction (2) designing learning model, (3) material testing (4) implementation of the learning model, and learning materials. This study was "one group pretest-postest design" with a quasi-experimental method. The subject was teacher candidates' students in their fourth semester of chemistry education program who took organic chemistry subject in the academic year of 2017-2018 Universitas Negeri Medan, on addition, substitution and elimination materials.

The students consisted of 2 classes which randomly taken, a namely experimental class with 21 students taught by using organic chemistry reactions textbook equipped with Problem based Learning model as well as the generic science skills while the control class with 27 students taught by using direct instruction model. This study was conducted for 10 meetings in the classroom and 3 lab meetings in 1 semester. At the first meeting, the pre-test, as well as the post-test at the final meeting were given to both experimental and control groups. The technique of data collection was done by using multiple choices test consisted of 25 questions to measure students' generic science skills which consist of indicator of logical consistency, abstraction, symbolical language, models, logical inference, cause-effect, and scale comprehension which are valid and reliable. The questions were validated by expert validators.

The data were the experiment and control group students' pre-test scores which were calculated by using N-gain formula through SPSS version 20. To find out the generic skills, direct observation on the addition, substitution, and elimination practicum were conducted in the laboratory by using an observation sheet while essay tests to find out indirect generic skills. According to (Arends, 2012) there are five phases needed to implement problem-based learning (PBL), they are:

Step 1   Orientation of the Problem

In this step, the tutor introduces problems or brainstorm students to the material by giving some illustrations.

Step 2   Organization in Learning.

In this step, the tutor constructs the material being taught. In the development material, materials are constructed to some comparing structure and examples in real life.

Step 3   Individual or Group Investigation.

In this step, the tutor gives problems like an assignment for individual or group discussion to solve a problem.

Step 4   Developing and Presenting Works.

Tutor asks students to explain the results of their work in written, report, or any.

Step 5   Evaluation.

Tutor evaluates students' works and appreciates them by giving appreciation or applause.

RESULTS

The data of this study was the score of students' generic science skills on addition, substitution, and elimination materials which consist of logical consistency, abstraction, symbolical language, models, logical inference, cause-effect, and scale comprehension. The data were taken from the experimental group which was taught by using Problem Based Learning model and the control group by using the Direct Instruction model. The total number of students as the sample of this study was 48, those were 21 for experimental and 27 for the control group.

The requirement test of normality and homogeneity test was done previously before the hypothesis test was conducted by using the program of SPSS 20 f*or windows*. The improvement of generic science skills is shown in table 1 which consists of the average score of pre-test, post-test, N –gain of addition, substitution, and elimination materials of chemistry teacher's candidate.

Table 1: The average score of pre-test, post-test, N –gain of addition, substitution and elimination materials

	Materials	Control Class			Experimental Class		
		Pretest	Posttest	N-gain	Pretest	Posttest	N-gain
1	Addition	6,66	21,77	0,395	10,28	36,57	0,776
2	Substitution	12	29,03	0,521	14,09	43,23	0,930
3	Elimination	2,07	3,85	0,148	2,09	8	0,579

Table 1 indicates students' generic skills on addition, substitution and elimination in experimental and control class has improved generally. The highest average pre-test score is 14.09 in the experimental group and is 12 in the control group. Meanwhile, the highest average post-test score is 43.23 in the experimental group, and t is 29,03 in the control group. Based on the table above, it can be seen that the N-gain of the experimental group is 0.93 which indicates a high achievement level while the control group is 0.52 indicating a medium achievement level. Therefore, it is found that the Problems based Learning model can improve generic science skills of chemistry teacher candidates on substitution material, both classes had the highest N-gain score (93 % and 52%). It was caused by the substitution material is easier to be understood than addition and elimination materials. The presentation of the average scores of pre-test, post-test, N–gain on addition, substitution, and elimination materials in experimental and control class is shown in the figure 1 & 2.

Generic Science Skills on Organic Chemistry Reaction Practicum

In the practicum session, generic skills of direct observation and logical inference were developed. Direct observation is collecting data related to phenomenon through human senses or sensory aids. Direct observation can be done in everyday life. The generic skill of logical inference was obtained through discovering observation patterns which are the principle of making (Sudarmin & Haryani, 2015). The generic skill of direct observation was obtained from the observation's score on the observation sheet meanwhile the logical inference was from the score of ability to answer concept questions and analyze data and draw conclusions through the problem-based learning model on the essay test sheet.

In addition reactions practicum, teachers candidate learn addition reactions based on the determination of iodine numbers from various fats/oils which are principally excess I_2 titrated with $Na_2S_2O_3$ thiosulfate so that teacher candidate can deduce the size of the unsaturation of a fat/oil. In the electrophilic substitution experiment, students study electrophilic substitution reactions based on the production of benzene nitro from benzene compounds plus concentrated nitric acid with a sulfuric acid catalyst. Teacher elimination experiments prospective students study elimination through dehydration alcohol of 3-methyl 3-penthanol into alkene compounds with the concentrated sulfuric acid dehydrator. Below is presented in table 2 the practicum score of logic inference generic science skills, in addition, substitution and elimination essay tests.
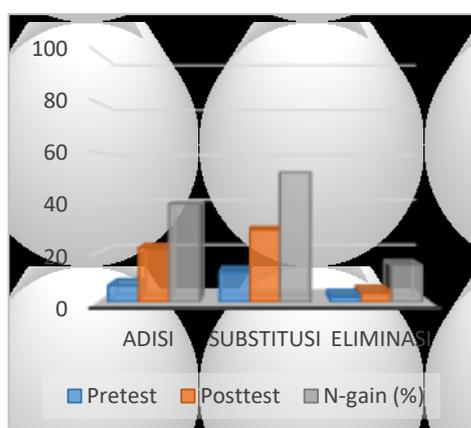

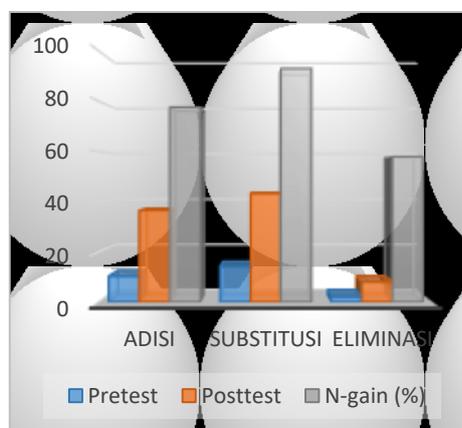| **Figure 1:** The average score of pre-test, post-test post-test, N –gain of addition, substitution experimental class | **Figure 2.** The average score of pre-test, post-test N –gain of addition, substitution, and elimination materials in materials in the control class |

Table 2: Practicum of addition, Substitution dan Elimination

Practicum	Pretest Average Score	Posttest Average Score	N-gain (%)	Achievement Standard
Addition	68,413	91,048	72,33	High
Substitution	54,761	86,809	70,88	High
Elimination	56,428	87,714	71,23	High

Table 2 shows an increase in the generic ability of science, in addition, substitution and elimination practicums with a value of 72.33, 70.88, and 71.23. N-gain achieved in this study includes a high level of achievement (Meltzer, 2002). This shows that problem-based learning can increase positive skills and confidence in problem-solving so as to increase the ability to think creatively, self-learning skills, and self-evaluation (Yoon, 2012) and (Zakiyah, 2014) also stated that the generic ability of science can be improved by problem-based learning models. From the table above it can be seen that the N-gain in addition, additions is higher than the substitution and elimination practices. It can be seen in the figures 3 & 4.

Generic Science Skill Direct Observation of Addition Practicum

In the direct observation, addition practicum can be seen from the observation sheet which consists of seven abilities. On direct observation of addition practicum, there were 5 observed skills, they were: stringing titration tools, creating and standardizing sodium thiosulfate, determining the iodine value of fats, titration using sodium thiosulfate, reading burette scale, determining the endpoint of titration and determining iodine value of oil can be seen in the following Table 3.
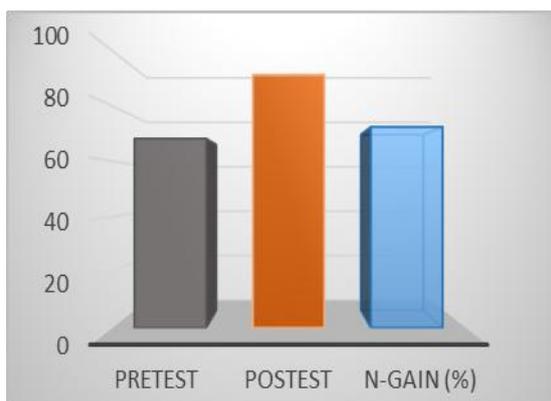
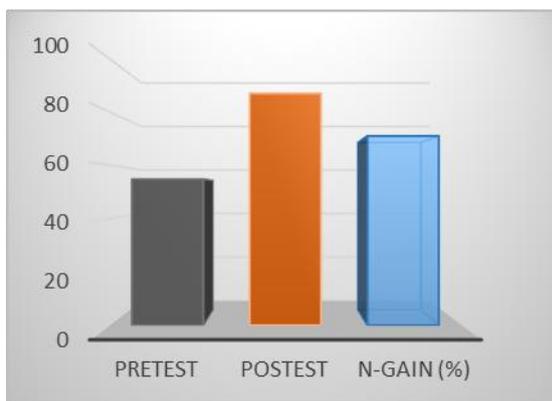**Figure 3:** The graph of pre-test, post-test dan N-gain material

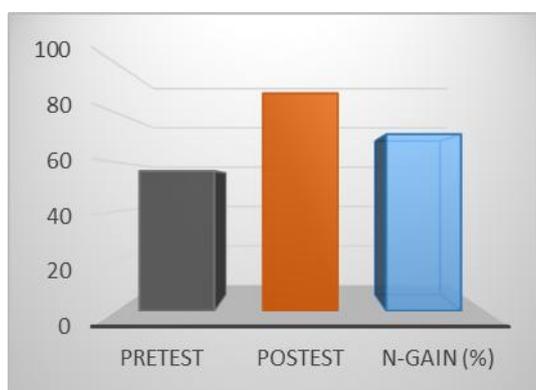**Figure 4:** The graph of pre-test, post-test dan N-gain on addition on substitution material

Figure 5: The graph of pre-test, post-test dan N-gain on elimination material

Table 3: Observation results of addition practicum

No	Activity	Score (%)	Information
1	Stringing titration tools	100	Very Good
2	Creating and standardizing sodium thiosulfate	77,381	Good
3	Determining the iodine value of fats	83,333	Very Good
4	Titration using sodium thiosulfate	86,904	Very Good
5	Reading burette scale,	97,619	Very Good
6	Determining the endpoint of the titration	98,809	Very Good
7	Determining the iodine value of oil	95,238	Very Good

Based on table 3 the observation results show that students have been skilled and very good at carrying out the addition practice especially in arranging titration tools, but in making and standardizing sodium thiosulfate needs to be improved. From the description above it can be described Generic Science Ability observations on the student addiction practicum below.
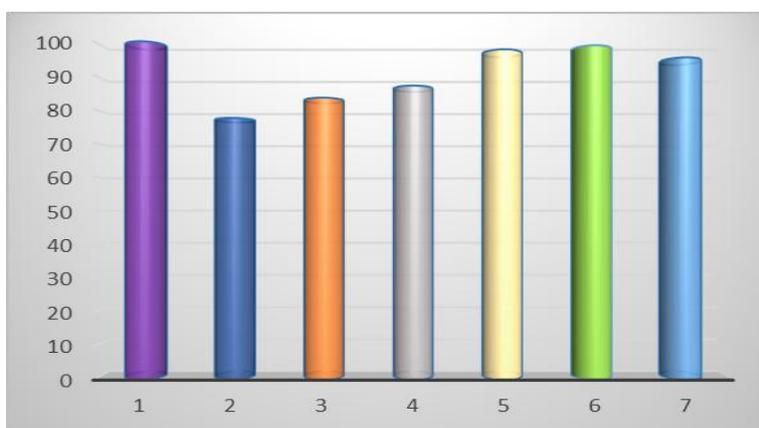

Figure 6: The students' generic science skills on observation of addition practicum

Information:

1. Stringing titration tools
2. Creating and standardizing sodium thiosulfate
3. Determining the iodine value of fats
4. Titration using sodium thiosulfate
5. Reading burette scale,
6. Determining the endpoint of the titration
7. Determining the iodine value of oil

Generic Science Skill Direct Observation of Substitution Practicum

On direct observation of substitution practicum, there were 4 observed skills, they were: setting up the reflux apparatus, preparing reflux solutions, refluxing and analyzing refluxing results can be seen in the following table:

Table 4: Observation results of substitution practicum

No	Activity	Score (%)	Information
1	Setting up the reflux apparatus	98,81	Very Good
2	Preparing a reflux solutions	83,33	Very Good
3	Refluxing	88,09	Very Good
4	analyzing refluxing results	71,43	Good

Based on table 4 the observation results show that students have been skilled and very good at practicing substitution practicums especially in arranging reflux devices, but in analyzing the results of reflux it needs to be improved. From the description above can be described Generic Science Ability observations on student substitution practicum below.
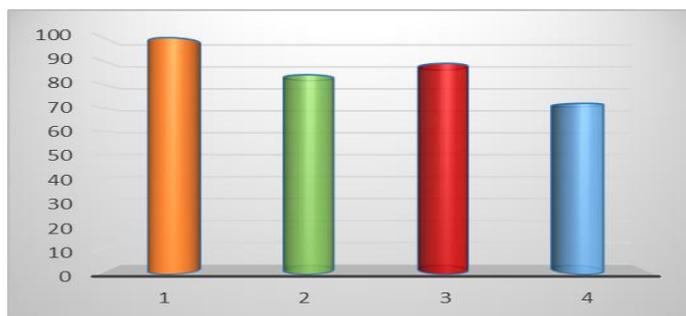

Figure 7: The students' generic science skills on observation of substitution practicum

Information:

1. Setting up the reflux apparatus
2. Preparing a reflux solutions
3. Refluxing
4. Analyzing refluxing results

Generic Skill Direct Observation of Elimination Practicum

On direct observation of elimination practicum, there were 7 observed skills, they were: setting up the reflux apparatus, preparing reflux solutions, refluxing, setting up the distillation apparatus, doing fractional distillation, analyzing distillate, and testing elimination product can be seen in the following table:

Table 5: Observation results of elimination practicum

No	Activity	Score (%)	Information
1	Setting up the reflux apparatus	84,52	Very Good
2	Preparing a reflux solutions	75	Good
3	Refluxing	78,57	Good
4	Setting up the distillation apparatus	69,05	Fair
5	Doing fractional distillation	78,57	Good
6	Analyzing distillate	77,38	Good

No	Activity	Score (%)	Information
7	Testing elimination product	75	Good

Based on table 5, the observation results show that the students have done the elimination practicum very well, especially in arranging reflux devices, but in arranging the fractionation distillation apparatus it still needs to be greatly improved. From the description above, it can be described as Generic Science Ability observations on the elimination of student practice below.
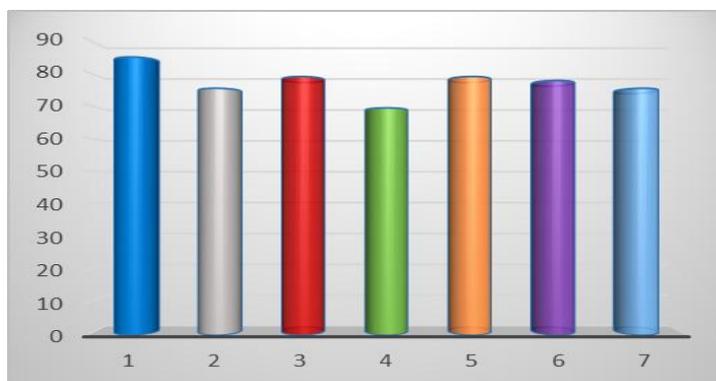

Figure 8: The students' generic science skills on observation of elimination practicum

Information:

1. Setting up the reflux apparatus

2. Preparing a reflux solutions

3. Refluxing

4. Setting up the distillation apparatus

5. Doing fractional distillation

6. Analyzing distillate

7. Testing elimination product

CONCLUSION AND SUGGESTIONS

Based on the results of data analysis and discussion of research results it can be concluded that problem-based learning can improve students' learning outcomes, it can be seen from the generic science skills of the experimental group taught by using the problem-based learning model is higher than the control group on addition, substitution, and elimination materials. (Abubakar & Arshad, 2015) their research found that problem-based learning has improved students' problem-solving skills and high order thinking skills. It is also in line with what has been found by (Zakiyah, 2014) that the application of PBL model can improve students' generic science skills by using some indicators, such as direct observation, indirect observation, the law of cause and effect, logical inference and logical framework.

In the practicum of organic chemistry reactions by using a problem-based learning model, the generic science skill of logical inference and direct observation on the addition, substitution, and elimination practicums in the experimental group were categorized at a high level. While the previous study on the experiment of organic chemistry distillation, solubility, recrystallize and hydrocarbon experiment which was conducted by Sudarmin & Haryani (2015) showed that generic skills of observation and logical inference of chemistry teachers' candidate was at the average level, therefore it can be developed in order to improve the quality of organic chemistry learning.

This study is recommended to improve students' generic science skills on addition, substitution, and elimination materials by using a Problem-based Learning model in the classroom or laboratory in the future, as well as to apply PBL and generic science skills to another similar type of materials.

LIMITATION

This study was conducted in the classroom and laboratory discourse In the future, it is expected that in the industrial revolutionary 4.0 era, lecturing can be conducted everywhere by implementing a problem-based learning model as well as generic science skills.

ACKNOWLEDGMENT

AUTHORS CONTRIBUTION

Ratu Evina Dibyantini, Retno Dwi Suyanti, Ramlan Silaban

RS gave an idea about the learning model which contained active students, collaborative, and students centered and developed problem solving and independent learning skills that is problem-based learning (PBL) as well as reviewed the literature. **RDS** gave an idea about generic skills needed by students as a future teacher which can be applied in many aspects, can be used to learn about many concepts and science's problems (KGS). From both ideas, **RED** was interested in planning, designing; analyzing the data with RDS, making a conclusion as well as writing about Generic Science Skills on Organic Chemistry Reaction through Problem based Learning Model. **RED, RDS, RS** together created the final manuscript.

REFERENCES

1. Abubakar, A. B., & Arshad, M. Y. (2015). Self-Directed Learning and Skills of Problem-Based Learning : A Case of Nigerian Secondary Schools Chemistry Students. *International Education Studies*, *8*(12), 70–78. https://doi.org/10.5539/ies.v8n12p70
2. Arends, R. (2012). *Learning to Teach* (9th ed.). New York: McGraw-Hill.
3. Brotosiswoyo, B.S. (2000). Hakekat Pembelajaran Fisika di Perguruan Tinggi. Dalam Hakekat Pembelajaran MIPA & Kiat Pembelajaran Fisika di Perguruan Tinggi. Disusun oleh Tim Penulis Pekerti Bidang MIPA. Depdiknas, Proyek Pengembangan Universitas Terbuka Jakarta.
4. Cameron, C., Brimble, M., Knutsen, J., & Freudenberg, B. (2014). The What, Why and How of Generic Skills : A Financial Planning Case Study. Journal of Australasian Accounting, Business and Finance, *8*(4), 63–82. https://doi.org/10.14453/aabfj.v8i4.5
5. Costantino, L., & Barlocco, D. (2019). Teaching an Undergraduate Organic Chemistry Laboratory Course with a Tailored Problem-Based Learning Approach. *Journal of Chemical Education*. https://doi.org/10.1021/acs.jchemed.8b01027
6. Cropanzano, R., & Mitchell, M. S. (2014). Social Exchange Theory : An Interdisciplinary Review Social Exchange Theory : An Interdisciplinary Review, *Journal Of Management* (April). https://doi.org/10.1177/0149206305279602
7. Fessenden & Fessenden alih bahasa Aloysius Hadyana P.,(1982), *Kimia Organik*,edisi ke-3, Erlangga, Jakarta.
8. Flynn, A. B., & Biggs, R. (2012). The Development and Implementation of a Problem-Based Learning Format in a Fourth-Year Undergraduate Synthetic Organic and Medicinal Chemistry Laboratory Course. *Journal of Chemical Education*, 52–57. https://doi.org/10.1021/ed101041n
9. Gao, S., Wang, Y., Jiang, B., & Fu, Y. (2018). Application of problem-based learning in instrumental analysis teaching at Northeast Agricultural University. *Analytical and Bioanalytical Chemistry*. https://doi.org/10.1007/s00216-018-1025-7
10. Jackson, D. (2013) The contribution of work-integrated learning to undergraduate employability skill outcomes. *Asia-Pacific Journal of Cooperative Education*.
11. Jamiat, N. (2018). The Design of Problem Based Learning and Effects on College Students ' Critical Thinking : A Preliminary Review. *ICEEL*, 176–180. https://doi.org/10.1145/3291078.3291081
12. Jansson, S., Andersson, P. L., & Nording, M. L. (2015). Implementation of Problem-Based Learning in Environmental Chemistry. *Journal of Chemical Education*. https://doi.org/10.1021/ed500970y
13. Khabibah, E. N. (2017). The Effectiveness of Module Based on Discovery Learning to Increase Generic Science Skills. *Journal of Education and Learning*. https://doi.org/10.11591/edulearn.v11i2.6076
14. Liliasari (2007).Scientific Concepts And Generic Science Skills Relationship in the 21st Century Science Education. *Proceeding of The First International Seminar on Science Education* Bandung: Indonesia University of Education (UPI).
15. Meltzer, D. E. (2002). The relationship between mathematics preparation and conceptual learning gains in physics : A possible "' hidden variable '" in diagnostic pretest scores, 1259–1268. https://doi.org/10.1119/1.1514215
16. Moewarni, P., & et al. (2001). Kiat Pembelajaran Kimia di Perguruan tingggi.In T.P.MIPA, *Hakikat Pembelajaran MIPA* dan *Kiat Pembelajaran Kimia di Perguruan tingggi*. PAU-PPAT Dikti , Depdiknas.
17. Nagarajan, S., & Overton, T. (2019). Promoting Systems Thinking Using Project- and Problem-Based Learning. *Journal of Chemical Education*. https://doi.org/10.1021/acs.jchemed.9b00358
18. Pujani, N. M. (2014). Perangkat, Pengembangan Ilmu, Praktikum Fisika, Jurusan Pendidikan Matematika, Fakultas Alam. *Jurnal Pendidikan Indonesia*, *3*(2), 471–484. https://doi.org/10.23887/jpi-undiksha.v3i2.4463
19. Riswiyanto(2009). *Kimia Organik*,Erlangga, Gelora Aksara Pratama.
20. Rubiyanto, D., Anugrahwati, M., & Prakoso, N. I. (2018). Problem Based Learning (PBL) Method as a Synchronization Approach of Chromatography Course and Chromatography Laboratory Work. *2nd International Conference on Chemistry, Chemical Process and Engineering (IC3PE)*, 20090. https://doi.org/10.1063/1.5065050
21. Sada, A., Mohd, Z. A. Y. (2016). Prospects of Problem-Based Learning in Building Critical Thinking Skills among Technical College Students in Nigeria. *Mediterranean Journal of Social Sciences*, *7*(3), 356–365.

https://doi.org/10.5901/mjss.2016.v7n3p356

22. Sadiah, Bahrom, and Balaachandran (2013). Problem Based Learning: A Process for the acquisition of learning and Generic skill, *The4th International Research Symposium.*

23. Selcuk, Sezgin, G., Serap Çaliskan, M. S. (2013). A Comparison Of Achievement In Problem-Based, Strategic And Traditional Learning Classes In Physics. *International Journal on New Trends in Education and Their Implications*, (January), 154–164.

24. Shultz, G. V, & Li, Y. (2016). Student Development of Information Literacy Skills during Problem- Based Organic Chemistry Laboratory Experiments. *Journal of Chemical Education.* https://doi.org/10.1021/acs.jchemed.5b00523

25. Silaban, R., 2018. Analisis Hasil Belajar Kimia Siswa yang dibelajarkan Menggunakan Model Problem Based Learning Bermedia PowerPoint Melalui Pendekatan Saintifik pada Pokok Bahasan Redoks.*Jurnal Ilmu Pendidikan Indonesia*.Vol 6,No.3,110-119. https://doi.org/10.31957/jipi.v6i3.608

26. Siswanto, J., Saefan, J., Suparmi, & Cari (2016). The Effectiveness Of E-Lab To Improve Generic Science Skills And Understanding The Concept Of Physics Keefektifan E-Lab Untuk Meningkatkan. *Jurnal Pendidikan Fisika Indonesia*, *12*(1), 33–40.

27. Solomon (1997). Fundamentals of Organic Chemistry.

28. Strollo, C., Davis, K. L., & Avenue, E. C. (2017). Incorporating Problem-Based Learning (PBL) Into the Chemistry Curriculum : Two Practitioners' Experiences. *Journal of the American Chemical Society.* https://doi.org/10.1021/bk-2017-1266.ch008

29. Sudarmin, & Haryani, S. (2015). The Ability of Generic Science at Observation and Inference Logic Prospective Chemistry Teacher in Organic Chemistry Experiment. *International Journal of Science and Research*, *4*(5), 2975–2980. https://doi.org/10.11591/ijere.v5i4.5961

30. Suyanti, R. D., & Sugiyarto, H. K. (2013). Keefektifan Praktikum Multimedia Ikatan Kimia Dalam Usaha Meningkatan Prestasi Belajar Kimia Mahasiswa. *Cakrawala Pendidikan*, (3), 461–469.

31. Suyanti, R. D.(2017). Analisis Keterampilan Generik Kimia Melalui Penerapan Model Strategi Pembelajaran Peningkatan Kemampuan Berfikir (SPPKB) Dengan Media EXE Learning pada Redoks.*Prosiding Seminar Nasional Kimia UNY 2017.*

32. Taber, K. S. (2016). Learning generic skills through chemistry education. *Chem. Educ. Res. Pract.*, *17*(2), 225–228. https://doi.org/10.1039/C6RP90003H

33. Tasoglu, K. A., & Bakaç, M. (2014). The Effect of Problem Based Learning Approach on Conceptual Understanding in Teaching of Magnetism Topics. *Eurasian J. Phys. & Chem. Edu*, *6*(September 2013), 110–122.

34. Tawil, M., & Liliasari(2014).Keterampilan-keterampilan Sains dan Implementasinya Dalam Pembelajaran IPA.Makassar. Badan Penerbit Universitas Negeri Makasar.

35. Urious, E. R. R. (2015). Generic Skills Development and learning/ Assessment Process : Use of Rubrics and Student Validation. *Journal of Technology and Science Education*, *5*(2), 107–121. https://doi.org/10.3926/jotse.147

36. Yoon, H. (2012). The Efficacy of Problem-based Learning in an Analytical Laboratory Course for Pre-service Chemistry Teachers. *International Journal of Science Education*, (September 2013), 37–41. https://doi.org/10.1080/09500693.2012.727041

37. Zakiyah, H. (2014). Implementasi Model Pembelajaran Berbasis Masalah pada Materi Titrasi Asam Basa untuk Meningkatkan Keterampilan Generik Sains Mahasiswa Program Studi Pendidikan Kimia. *Lantanida Journal*, *1*(1). https://doi.org/10.22373/lj.v2i1.668