Developing chemical equilibrium practicum module based on guided inquiry to explore students' abilities in designing experiments

To cite this article: F D N Pamenang *et al* 2020 *J. Phys.: Conf. Ser.* **1470** 012097

Developing chemical equilibrium practicum module based on guided inquiry to explore students' abilities in designing experiments

F D N Pamenang[1], J Harta[1], R V Listyarini[1], L W Wijayanti[1], M C Ratri[1,2], N D Hapsari[1,2], M Asy'ari[1] and W Lee[2]

[1]Chemistry Education Study Program, Sanata Dharma University, Indonesia
[2]Department of Chemistry, Sogang University, South Korea

Email: fransiscadita@usd.ac.id

Abstract. In welcoming chemistry learning that emphasizes the quality of students, the teacher's role is very important. As a prospective chemistry teacher, students must be prepared critically, both in terms of mastery of teaching materials and the development of learning models that are implemented. One of the alternatives offered is guided inquiry-based learning, which aims to develop students' abilities so that exploration can continue. This study aims to develop valid dan practical product of chemical equilibrium practicum module based on guided inquiry to be used by chemistry education students in the experiment, so that students are able to think critically and reflectively. This research is a design thinking through the framework of Empathize, Define, Ideate, Prototype, and Test (EDIPT), with chemistry education students. Supporting instruments of this research include consultation sheets, observation sheets, and student response questionnaires. Data analysis was conducted in quantitative descriptive. The results of the study show that the practicum module developed can help developing the flow of students' thinking carefully, analyse practical needs, design varied practicum topics, and reflect on experience during designing and implementing experiments. The average of students responds well to the development of the practicum module.

1. Introduction

Chemistry involves two important inseparable things, namely chemistry as a product and process. Chemistry as a product can be in the form of concepts, principles, facts, and theories, while chemistry is a process in the form of scientific action, namely studying how students discover concepts, design scientific processes, and develop scientific processes themselves [1]. Chemical learning at this time emphasizes the product and learning process. Good products are produced through a good learning process. Mastery of the process in learning requires scientific skills that are included in science process skills.

Chemical learning based on the 2013 curriculum applies a scientific approach and authentic assessment that uses the principles of assessment as part of learning. A scientific approach to learning needs to be done by applying a learning model based on discovery or inquiry learning through practical learning. The benefits obtained in involving students through guided inquiry practice activities include increasing the meaningfulness of learning, conceptual understanding and understanding of the nature of science [2]. One way to develop student scientific skills is through the practicum. Hofstein and Luneta stated science laboratory activities/practicum as “experiences of learning in which students interact with materials to observe and understand the natural phenomena”.

Students learn by performing concrete activities, by comparing experimental data to a model, and by designing an investigation [3]. When doing a practicum, of course, a guide or lab module is needed. This practicum guide has benefits, among others, being supporting learning during experiments, increasing students' interest in practicum, and knowing how to do lab work. Also, it can train how to design, provide experiments and prove hypotheses with problem-solving associated with the real world [4].

Chemical labs in the laboratory up to now still use the "cookbook-type" practicum guide, which in the first stage is to test the practical skills and the second stage to prove the theory [5]. The practicum guide type by presenting procedures or step-by-step instructions like this might still be suitable to be applied in practicum-based chemistry learning. However, providing this type of guidebook can narrow the freedom of students to plan and design experiments and procedures in studying the phenomena that exist. Based on the data analysis from researcher, students' achievement of chemistry by using guided inquiry-based module is higher than students' achievement of chemistry by using "cookbook-type" manual book [6].

One of the lessons that provide a direct learning experience through the use and development of science process skills includes guided inquiry learning [7]. Guided inquiry learning is an instructional approach, providing a framework, planning and implementation of thinking by developing students' skills and accessing information resources to effectively build knowledge [8]. Suharyadi defined that the learning process that connects and relates a concept with an example in life will survive longer in students' memory [9]. In general, the inquiry learning process includes five steps such as formulating the problem, proposing hypotheses, gathering data, testing hypotheses, and drawing conclusions [10]. The developed guided inquiry-based learning material is effective to be used in teaching and learning in order to improve students' science literacy skills [11]. This learning is carefully planned, instructionally controlled by the teacher to guide students through in-depth material [12]. Guided inquiry learning is one of the learning-oriented constructivist theories that gives students the ability to search for concepts and meanings and build knowledge individually based on experience in their environment [13][14]. According to Gialamas, Cherif, Keller, and Hansen, the guided inquiry method of teaching promotes students' active participation in the learning process [15].

The combination of practicum modules with guided inquiry learning is expected to provide students the freedom to choose problems and phenomena and solutions to problem solving [16]. Practicum module based on Guided Inquiry proved to be stimulating for students' motivation, students' application of research skills, construction of meaning and acquiring scientific knowledge [17].

The development of this guided inquiry-based practicum module refers to five processes in the framework of EDIPT thinking design, namely empathize, define, ideate, prototype, and test [18]. The development of practicum modules begins with growing empathy for the need for developing practicum modules. Empathy that has been obtained before, then defined by the designer or developer of the module to think about and determine the creativity that can be created by utilizing empathy that arises over these problems. The next stage, ideation, began to provide a challenge for the designer or developer of the module to determine what practicum modules would be made. Furthermore, the creativity of a well-designed practicum module needs to be realized in a concrete form (prototype) and finally tested. In this testing phase, an evaluation of whether the creative idea of the designer or developer of the practicum module can be accommodated properly or not [19]. This study explains how the students develop Chemical Equilibrium Practicum Module based on the guided inquiry.

2. Method

This research was a survey study set which conducted in Chemistry Education Study Program, a department within the Faculty of Education and Teachers Training at Sanata Dharma University, Yogyakarta, Indonesia. This research employed an analysis of a closed and open questionnaire to answer four problem formulation; (1) self-motivation, (2) understanding of material, (3) designing practicum, and (4) motivation to develop practicum. The survey was conducted on 4th semester 2019 to 35 respondents from Chemistry Equilibrium Course. This course is an obligatory course for fourth-year student and preparing students for understanding Chemistry Equilibrium in daily life. Respondents were students of class 2017. The supporting instruments of this research include consultation sheets, observation sheets, and student response questionnaires.

3. Result and Discussion

3.1. Guided Inquiry-Based Practicum Module

This lab module is different from traditional practicum modules. The traditional practicum module presents a series of instructions that must be carried out by students to improve practical skills and prove existing theories. Guided inquiry-based practicum modules allow students to design and experiment with certain phenomena.

Guided inquiry-based practicum modules are used in chemical equilibrium labs. Chemical equilibrium practice is a practicum subject that must be taken by students in semester 4 of Chemistry Education Study Program. Table 1 shows a list of experiments in guided inquiry based chemical equilibrium practicum. Each experiment contained in this guided inquiry-based practicum module consists of: Purpose, Context, and Exploration.

The initial part in the lab module is in the form of experimental objectives. The purpose of the experiment was given to guide students in compiling a series of experiments and summarizing what would be done in the laboratory to fit the objectives to be achieved. The next part is the context, the context of presenting facts in everyday life related to the specific title of the experiment. For example, in experiment 1). Application of Phase Diagrams in daily life. The context given in this experiment is related to the application of phase diagrams, namely the use of dry ice in keeping the ice cream from melting. Dry ice will sublime and will prevent the ice cream from melting. In this context, the question is asked about what will happen to ice cream and dry ice at other temperatures and pressures. 2). Colligative Properties of Solution. The context that emerged in this experiment was the use of ethylene glycol as an anti-freezing agent on the vehicle radiator. Ethylene glycol prevents freezing of water on the radiator. Ethylene glycol protects the engine from freezing and prevents radiator water from boiling when vehicle temperature increases.

Table 1. List of experiments in guided inquiry based chemical equilibrium practicum.

1.	Colligative Properties of Solutions
2.	Application of Phase Diagrams in Daily Life
3.	Equilibrium and Reaction Kinetics: Relationship of Reaction Kinetics and Equilibrium Constants
4.	Determination of Equilibrium Constants and Le Chatelier's Principles
5.	Homogeneous and Heterogeneous Equilibrium
6.	Electrochemistry: Nernst Equation

The next part is exploration. In this section, students are given general direction on how to achieve the experimental goals. Several questions are presented in this section to guide students in designing appropriate trial procedures. For example, in experiment 1) the application of phase diagrams. The questions given can help students make good and correct experimental designs, so that by understanding these exploration students can propose ways to achieve the expected results, for example, students are asked to look for phase diagrams making up ice and dry ice. In addition, the question that arises is about the position of the triple point, sublimation, standard temperature and pressure in the phase diagram of the dry ice constituent. In experiment 2) namely, the colligative properties of the solution, there are several questions that lead students to design appropriate experimental procedures, for example why salt water evaporates more slowly than fresh water, and why salt addition can affect the freezing water content. It should be noted that the prerequisite courses of chemical equilibrium courses are the basics of chemistry course. In this course, students have been provided with ways to prepare the right tools and materials to be safe. Students need a proactive attitude in asking the teacher about the most appropriate experimental design for a particular topic because detailed instructions are not given in the lab module.

This preliminary question is given to direct students in developing good trial procedures so that students become aware and aware of what they will do in the laboratory. The practicum module is given 2 weeks before laboratory activities are carried out and allows the teacher to assess the design or procedure proposed by students before practicing in the laboratory.

3.2. Guided Inquiry Practicum Laboratory Session

The session on chemical equilibrium practicum is divided into 2 components: (1) discussion, with the teacher and (2) experiment. Discussions with the teacher are conducted 1 week before practicum. This is the first stage of EDIPT, namely Empathize. This activity is indeed quite time-consuming and laborious when compared to traditional experiments (cookbook-type). But with this component in place, the teacher can ensure students understand the objectives and experimental procedures they have designed themselves. Students are really looking for information and references that support the experimental preparation process. This stage is the second part of EDIPT, namely, define.

When discussions with teachers take place, students provide a variety of experimental design ideas and creativity. This activity is the third stage of the EDIPT, namely Ideate. Students explore tools and materials that can be used to achieve experimental goals. Each group has a different experimental design and sample use. If the experimental design is not in accordance with the objectives to be achieved, students make improvements to the design. When the experiment took place, students became more confident in conducting experiments, because the experiments carried out were the results of their own designs. They followed the steps they had arranged and certainly differed from one another. This is the fourth stage, namely the Prototype stage. The last stage of EDIPT, namely Test, is done by testing the experimental design through practice directly and then the experimental results are assessed by the teacher (Test Phase).

3.3. Student Response

To obtain student responses, students are asked to fill out a questionnaire. In the aspect of self-motivation, most of the respondents felt motivated and interested in learning where respondents were asked to compile their own research designs for lab work.

> *R12: This is a new challenge for me, where I have to be independent in groups to make a practicum design and do it myself in each group. I love being able to learn and add to my experience in learning chemistry.*
>
> *R18: At first, I was having a hard time because this was my first experience, but slowly I got used to it and was able to design a practicum.*
>
> *R27: The experience that I got was that I could design my own lab. Guidance from the Teacher really helped me.*

This result is in line with the opinion of researchers that guided-inquiry activities can raise students' motivation because they give the freedom in making their choice [20].

In the aspect of understanding the material, as many as 61.5% of respondents agreed that the preparation of a practicum design adds understanding and insight into chemistry, especially chemical equilibrium material. However, as many as 53.8% of respondents felt that they understood the basic concepts of practicum because they had to design my own practicum procedures compared to if the practicum procedure had been arranged from the beginning. Students' responses to aspects of designing a practicum showed that as many as 53.8% of respondents felt that there were enough difficulties in preparing a practicum design for each topic of practicum. This is evidenced by the response of the following students:

R3: Yes, because this is the first experience and is still confused about how to design good and correct practice.

R7: Yes, the difficulty in determining how much material to use and determining the right procedure.

R8: My difficulty is finding an easy and effective design.

R19: Yes, the difficulty is because some material is still confused and doesn't know whether it will succeed or not. Requires a lot of time to design so that other activities are sometimes overlooked.

The interesting thing is that as many as 53.8% of respondents are interested in developing work procedures for wise and efficient practicum in terms of the use of tools and materials.

R10: While making a practicum design, I feel happy because here I can learn how to design a simple and wise practice in terms of material used.

When viewed from the aspect of motivation to develop a practicum, as many as 38.5% of respondents were motivated enough to design and develop new practicums regarding chemical equilibrium. Fortunately, as many as 65.4% of respondents were motivated to implement a practicum plan that they compiled themselves at the school where they were teaching later. And 61.5% of respondents realized that guided inquiry-based chemistry practicum could be a provision to teach at school later.

R14: In this inquiry-based practice, please maintain so that students are able to improve soft skills and critical thinking skills.

In addition to responses from students, the assessment of the supervisor on the design of student experiments was also given. For example, in experiment 1 regarding the colligative properties of the solution, the assessment for the design is quite good, but it is necessary to pay attention to aspects of the use of chemicals to conform to the principle of green chemistry, namely preventing excessive waste through the use of small amounts of chemicals. In experiment 2, regarding the application of phase diagrams in daily life, the assessment of the teacher on the experimental design was considered good, but it was necessary to add an explanation of the relationship between the diagram and the dry ice properties. Observations by supervisors were also carried out during the experiment. Most students have very good grades because they have various creative ideas about practicum design and are very varied. The experimental design that was made by the students was successfully done well.

4. Conclusion

Chemical Equilibrium Practicum Module based on guided inquiry shows how students are given the freedom to make and compile their own experimental procedures. Through these practicum module students are not only trained in skills and dexterity in conducting experimental procedures but are looking for concepts and meanings and building individual knowledge based on experience in their environment. The results of the study indicate that the practicum module developed can help develop students' thought carefully, analyze practical needs, design various practical topics, and implementing experiments. The average student responds well to the effectiveness of using a lab module. The chemical equilibrium practicum module based on guided inquiry is highly suitable to be implemented in learning process. However, the practicum module still needed to be further investigated regarding the dissemination.

References

[1] Mulyasa E 2006 *Kurikulum Tingkat Satuan Pendidikan* (Bandung: PT. Remaja Rosda Karya)
[2] Shwartz Y, Ben-Zvi R and Hofstein A 2006 The use of scientific literacy taxonomy for assessing the development of chemical literacy among high-school students *Chem. Educ. Res. Pract.* **7** 203-25
[3] Hofstein A and Lunetta V N 2003 The laboratory in science education: foundations for the twenty-first century *Sci. Edu.* **88** 28–54
[4] Puspasari, Astuti I and Suratman D 2018 The development of problem-based practicum module to learn reaction rate and base-acid solution *J. Edu. Teach. Learn.* **3** 206-18
[5] Laredo T 2013 Changing the first-year chemistry laboratory manual to implement a problem-based approach that improves student engagement *J. Chem. Educ.*, **90** 1151-4 dx.doi.org/10.1021/ed300313m
[6] Juniar A, Manalu L and Masteriana D 2017 Development of guided inquiry – based module on the topic of solubility and solubility product (Ksp) in senior high school *Adv. Soc. Sci. Educ. and Hum Res* **104** 70-3
[7] Llewellyn D 2005 *Teaching High School Science Through Inquiry* (Amerika: Corwin Press)
[8] Widyaningrum D A and Wijayanti T 2018 Developing of guided inquiry-based biochemistry practicum guidebook *Indonesian Journal of Biology Education* **4** 209-14
[9] Suharyadi, Anna P and Hernan 2013 Pengembangan buku ajar berbasis kontekstual pada pokok bahasan asam dan basa *Jurnal Riset dan Praktik Pendidikan Kimia* **1** 60
[10] Wardani S, Kadarohman A, Buchari, and Permanasari A 2013 Learning based inquiry laboratory activities to increase inter-intrapersonal intelligence *Inter. J. Sci and Res* **2** 417-21
[11] Aulia E V, Poedjiastoeti S and Agustini R 2018 The effectiveness of guided inquiry-based learning material on students' science literacy skills *J. Phys.: Conf. Ser* **947** 012049
[12] Minner D D, Levy A J and Century J 2010 Inquiry-based science instruction-what is it and does it matter? results from a research synthesis years 1984 to 2002 *J. Res. Sci. Teach*. **47** 74-496
[13] Sanjaya W 2014 *Strategi Pembelajaran Berorientasi Standar Proses Pendidikan* (Jakarta: Kencana Prenadamedia Group)
[14] Bada and Olusegun S 2017 Constructivism learning theory: a paradigm for teaching and learning *J. Res. Method in Edu.* **5** 66-70
[15] Gialamas S, Cherif A, Keller S, and Hansen A 2001 Using guided inquiry in teaching mathematical subjects *Humanistic Mathematics Network Journal* **25** 23-30
[16] Alake-Tuenter E, Biemans H J, Tobi H, Wals A E, Oosterheert I and Mulder M 2012 Inquiry-based science education competencies of primary school teachers: a literature study and critical review of the american national science education standards *Inter. J. of Sci. Educ.* **34** 2609-40
[17] Suduc A, Bizoi M and Gorghiu G 2015 Inquiry based science learning in primary education *Procedia Social and Behavioral Sciences* **205** 474-9
[18] Anand A, Mishra S, Deep A and Alse K 2015 Generation of educational technology research problems using design thinking framework *2015 IEEE Seventh International Conference on Technology for Education (T4E).* doi:10.1109/t4e.2015.28
[19] Rusdi M 2018 *Penelitian Desain dan Pengembangan Kependidikan: Konsep, Prosedur, dan Sintesis Pengetahuan Baru* (Depok: Rajawali Press)
[20] Bayram Z, Oskay Ö Ö, Erdem E, Özgür S D and Şen Ş 2013 Effect of inquiry-based learning method on students' motivation *Procedia-Social and Behavioral Sciences* **106** 988-96