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Students' Construction of a Simple Steam Distillation Apparatusand Developmentof Creative Thinking Skills: A Project-Based Learning

Chansyanah Diawati[1,a)], Liliasari[2,b)], Agus Setiabudi[2] and Buchari[3]

[1]*Chemistry Education Program, FPMIPA Universitas Lampung, Jl. Prof. Dr.SoemantriBrodjonegoro No. 1, Bandar Lampung 35145, Indonesia*
[2]*Chemistry Education Program, UniversitasPendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia*
[3]*Departmen of Chemistry, InstitutTeknologi Bandung, Jl. Ganesha No.10, Bandung 40132, Indonesia*
[a)]Corresponding author: chansyanah.diawati@fkip.unila.ac.id
[b)]liliasari@upi.edu

Abstract. This project-based learning combined the chemistry of separation process using steam distillation with engineering design process in an undergraduate chemistry course. Students built upon their knowledge of phase changes, immiscible mixture, and the relationship between vapor pressure and boiling point to complete a project of modifications steam distillation apparatus. The research method is a qualitative case study, which aims to describe how (1) the creative thinking skills of students emerged during six weeks of theproject, (2) students built steam distillation apparatus characteristics as the project product and (3) students response to the project-based learning model. The results showed that the students had successfully constructed a steam distillation apparatus using plastic kettle as steam generator and distillation flask. A Plastic tubewas used to drain water vapor from steam generator to distillation flask and to drain steam containing essential oil to the condenser. A biscuit tin filled with ice was used as a condenser. The time required until resulting distillate was fifteen minutes. The production of essential was conductive qualitatively by a very strong smell typical of essential oil and two phases of distillate. Throughout the project, students formulated the relevant and varied problem, formulated the goals, proposed the ideas of the apparatus and materials, draw apparatus design, constructed apparatus, tested apparatus, evaluated, and reported the project. Student response was generally positive. They were pleased, interested, more understanding the concepts and work apparatus principles, also implemented new ideas. These results indicate that project-based learning can develop students' creative thinking skills. Based on these results, it is necessary to conduct research and implemented project-based learning to other concepts.

INTRODUCTION

The desire to produce school and college graduated who can think creatively reflected in national curriculum documents throughout the world. The purpose of these documents refers to problem solving, creativity, entrepreneurship and innovative thinking; because "our future is now closely tied to human creativity" [1]. School graduates who think critically and respond creatively will more likely be able to face the challenges of the 21st century. Such graduates will contribute positively to the personal, social, technological and economic worlds that they will inhabit as adults [2-4].

Although the content knowledge and creative thinking are important for education and professional achievement, classrooms often provide few opportunities for students to think creatively. However, creative thinking and problem solving can be built in teaching in many ways. If the ability to be creative is important for students' success in the future, teachers should explicitly encourage and teach creativity in schools [5]. Therefore, the teaching of creative thinking skills should be key components in education from the primary to the undergraduate level. Thus, stimulation and support for the development of divergent thinking and creativity throughout education process should be pursued. In teaching, there should be a good balance between the acquisition of knowledge and skills, on

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the one hand, and promoting and providing freedom to innovate, created and proposed, on the other. Educators should strive to integrate into chemistry teaching the connection between knowledge and everyday life, its industrial, technological, economic, social and other aspects. The emphasis of the integration was in the knowledge assimilation process that requires and favors higher level of cognitive thinking, and analytical critical and creative approaches, through problem solving [6].

Creative thinking is a skill to develop; find; or create new constructive combinations based on the data, information, or elements that already exist, with a different perspective, that appears as a manifestation of their perceived problems, so as to produce the useful solution [7,8]. Like the other thinking skills, creative thinking can be trained. Many researchers believed –and in some cases demonstrate empirically– that every individual has the ability to think creatively, at least in certain contexts [5,9]. Furthermore, researchhas shown that creative thinking is influenced by various of circumstances, including whether collaborative work and the extent which individuals are motivated to solve problems [10-14]. At the same line, most research suggested that there are differences in creativity and gain student achievement, when the classroom environment manipulated [5,15-17].

Project-based learning grows out of the progressive education movement and constructivist science education reform since 1908. Dewey and other progressive educators laid the curricular and psychological foundation for project-based learning, which the core values are "child-centered learning," "learning by doing," and "applying school teaching in the home." This model was further strengthened by the work of constructivists as Piaget and Vygotsky [18].From the literature review, the definition of project-based learning is curriculum-based contextual instruction, which organizes learning based on questions or problems challenging; involving students in choosing a topic, consider the approach, designing, solving problems, making decisions, providing the opportunity to work relatively independently for extended time; and produce tangible product related to the problem [19-24].

Project-based learning has fundamental features, namely content and authentic assessment; facilitation instead of the instruction; cooperative learning and reflection; merging the skills of adults; use of authentic questions ("directives") which serves to regulated and guided instruction; community of inquiry among students and teachers; collaboration of members of the public on questions or problems; community service; multidisciplinary theme; the use of cognitive apparatus; produce artifacts or products that enable students to learn, apply the concept, representing knowledge, and receive continuous feedback [20,25,26]. Research shows that this model has been shown to significantly enhance the high order thinking skills, including creative thinking skills [11,13,27-30].

Steam distillation is one of the topics of practicum in the chemistry of separation course on Program StudiPendidikan Kimia in Provinsi Lampung. Based on the study of practicum guide document, the style of separation chemistry practice is expository, where the apparatus, materials, experimental procedures and how to assembled the apparatus has been provided in detail. Based on field studies, the practice of steam distillation has not done in 2014, because some components of the apparatus have been broken, and replacement apparatus are not yet available. As a result, students do not acquire a deep understanding of experimental design, working principles of apparatus, and the relationship between the concepts and observation result, and its application in everyday life.

It was known that steam distillation apparatus components more common in chemical laboratories consists of apparatus of fragile glass. Assembly of steam distillation apparatus was also quite complicated. Students had been familiar with expository lab model and used apparatus that has been provided. Laboratory work on this model is more emphasis on the process of manipulating the apparatus rather than ideas [31]. Such model is also placing very little emphasis on thinking, being an ineffective means of conceptual change, and being unrealistic in its portrayal of scientific experimentation [32].

If there are components of the apparatus broken or not working, students are not able to find an alternative replacement apparatus, therefore the practical work cannot be implemented. Students are not challenged to think creatively to solve the problem if it occurs. In fact, laboratory practices should be training students to think creatively in designing, analyzing, synthesizing, and develop awareness and respect the integrity of data at the measurement uncertainty [32]. Based on these limitations, it is necessary conducted of steam distillation practicum project using simple apparatus and does not easily break through modification by the students.

Several studies have been conducted to develop learning creative thinking skills improvement oriented. These studies namely through laboratory application based on creative and critical thinking [33]; the application of technology in learning [34];projects of creative design process [13]; teachers professional development [29]; project-based blended learning; and inquiry-based science education [4]. Based on literature review, the research that develops creative thinking skills through project-based learning of steam distillation apparatus modification to separate the essential oils of plants hasn't been found.

Project-based learning advocates for the creation of a learning context in which students can actively participate and discuss, using the directive question to elicit the various learning activities. Although it has been used at the

undergraduate level, however, project-based learning which modifies the lab apparatus in the context of chemical separation has never been done. Therefore, the purpose of this study is to describe (1) the creative thinking skills that emerged during the six weeks the students carry out the project, (2) the characteristics of student-built steam distillation apparatus, and (3) the students' response to the project-based learning models.

RESEARCH METHODOLOGY

The research has been conducted in chemical separation course at Program StudiPendidikan Kimia in Provinsi Lampung. A subject is a group of six members of undergraduate pre-service chemistry teacher students in 2015 that contracts chemical separation course. They work in a group on a self-selected project related to the theme 'separation of essentials oil from plants through steam distillation,' related challenging problems.

This research method is a qualitative case study. Yin states that case study is best used when " how" questions are being asked about a contemporary set of events over which the researcher has little or not control [35]. We, therefore, employed a case study methodology to describe how creative thinking skills emerged during the six weeks the students carry out the project; what characteristics of student-built steam distillation apparatus, and the manifestation of students' creative thinking skills; and students response to the project-based learning model.

Project-based learning applied in this study refers to Colley [18].This model consists of six stages of the cycle. In this project, students were given the challenge to conduct the steam distillation practice to separate essential oils from plants. During the project, students consult regularly outside of class, related to the project plan, the progress and project constraints. The lecturer's role is to facilitate, advise, guide, monitor, and mentor students, not just to conduct lecture and laboratory work [18]. Students are supported by discussion relate to their design, encouraged to construct and testing the apparatus. Students must report the results of testing and evaluating. At the end, the students prepare a report and present the findings of the project in class.

The data collection techniques used was performance assessment, interviews, and field notes. The performance assessmentinstrument arranged by highest grading rubric score 3 and lowest 1. Data from multiple sources was content-analyzed in relation to each other. This triangulation process helped to enhance the credibility of the findings and the assertions made about students' experiences.

RESULTS

The students' creative thinking skills performance isshown in Table 1.

TABLE 1. Students' creative thinking skillsperformance score

Task	Score
Product performance of planning the project	
Based on the problem, the students formulate relevant problem.	3
Based on the problem, the students formulate varies problem.	3
Based on the problem, the students formulate the relevant idea of the project purpose.	2
Based on the problem, the students formulate the relevant idea of the importance of project.	3
Students described the procedure of apparatus modification; the concept is correct and relevant.	2
Students detailing a list of apparatus and materials with an adequate amount, relevant, and unique.	3
Students write relevant ideas about how the project will be evaluated.	1
Students draw a design apparatus, the correct concepts and using materials that are much cheaper than commercial apparatus.	3
Students describe the function of each component of apparatus in detail.	2
Students describe the working principle of each component of apparatus in detail.	2
Students describe the workingprocess of apparatus on the design in detail.	3
The process performance of implementing the project	
Students replace steam generator which much cheaper than commercial apparatus and practice.	3
Students replace distillation flask which much cheaper than commercial apparatus and practice.	3
Students replace condenser which much cheaper than commercial apparatus and practice.	3
Assemblingapparatus with a compact and appeal.	2
Test to prove that apparatuscan be modified to function relatively the same as a commercial apparatus.	3
Test to prove that the apparatusis modified easily in the assembled and use.	3
Average	2.6

Scoring of the creative thinking skills is based on performance assessment rubric which the highest score is 3 and the lowest score is 1. As shown in Table 1 the average students' creative thinking skills scores are 2.6 from the maximum score 3. It indicates that project-based learning of steam distillation apparatus modification was effective to develop students' creative thinking skills.

Steam distillation apparatus which has been built by the students shown in Figure 1.

(a) (b)

Figure1. Student-built steam distillation apparatus; (a) from the front (b) from behind

As shown in Figure 1, the steam distillation apparatus constructed by students consists of two plastic kettles, heat-resistant plastic hose, biscuits tins and bottle container distillate. Each plastic kettle serves as a steam generator and a container of distilled compound. In this project, students determine their own plants sampled, namely orange peel. Plastic hose used to drain water vapor from steam generator to distillation flask and to drain steam containing essential oil to the condenser. As condenser used a biscuit tin filled with ice. Based on testing, the time required until resulting distillate was fifteen minutes. Test to ensure that essential oil has been produced is conducted qualitatively by a very strong smell typical of D-limonene essential oil and distillate separated into two phases.

The Open-ended comments from students on project-based learning experience were obtained from the audiotape interviews. In response to the difference between project-based learning with that has been applied previously, the following quote is representative: "I have read and look for more information to be able to complete this project." However, this makes them better understand the concept, such as the statement of all the students: "the implementation of this practice model makes us more understanding of the concept of steam distillation, either about the working principle and function of each component. One of the students liked the challenging nature of the problem, she said: "These practice models to make learning activities are not boring and made us think the facts of life by implementing new ideas." Student response to how they felt during the study, the following is a quote that represents: "The practice model is a new experience and very interesting. I'm really excited to do it. When I successfully assembled of apparatus, try and get distillate, it was making me very happy."

DISCUSSIONS

According to Krajcik, Czerniak, and berger opinion [28], the first feature project-based learning was driving question or problems serve to organized and guide instruction. Accordingly, in the class, the students read a discourse on a challenging problem given on the worksheet on the essential oils separation plants through steam distillation practices. They ask questions individually. They brought their problem home and wrote down their questions, then formulate the problem as a group throughout the first week. Based on the interviews, in order to formulate the problem, the students read more and seek information from various sources [36]. Outside the classroom in this week, group members came together to report the problem formulation to the lecturer for feedback. The lecturer provides direction of how to formulate the problems that lead to solving the problem. As a result, they have been able to formulate the problem well.

Then, the students designed their own project based on their identified problem for one week. The students were assign title and purpose project. Students developed procedures to modify the steam distillation apparatus, list of tools, proposed plant sample to be distilled, and draw a design of apparatus, then consult the lecturers. Students used two plastic kettles to replace the steam generators flask and distillation flask, and orange peel as a sample. Students used materials in everyday life. Based on field notes, during consulted, they said: "A major problem was the steam distillation apparatus fragile and complicated. This plastic kettle used to boil water, based on the principle of steam distillation, the boiling point of a mixture of water and essential oils of orange peel will not exceed 100^{o}C."Related

with the used of electricity as a heating source, students giving a reason: "in order to practice the steam distillation more practical and effective." They then construct the apparatus once approved, tested, and evaluated. In project-based learning students acquire and apply concepts and principles in their investigation, they formulate plans, track progress, evaluate the solution, and produce artifacts related to the problem [20].

In this study, based on performance assessment, students have been successfully built a steam distillation apparatus as a product of the project. Students applied new ideas to replace the component which much cheaper than commercial apparatus, more practice, and the same function relatively. Interestingly, the students used plastic material, whereas the distillation process involves the heating process. In this case, students combined the chemistry of separation via steam distillation with engineering design process to solve the problem. Students built upon their knowledge of phase changes, immiscible mixture, and the relationship between vapor pressure and boiling point.

According to Taylor, one of the products of creative thinking is a physical object. The creative product can ultimately be judged by four level of creative thinking, which range from elementary to complex [37]. The creative thinking as a product, that produced by the students, classified into third levels, namely inventive creative thinking, which couples efficiency and ingenuity with available materials and ideas.

Students response were generally positive, that they were pleased, interested, more understanding the concepts and principles of work apparatus, also implementing new ideas. Overall, since the problem formulation until generated the product, depict the student creative thinking skills shown during the project.

CONCLUSIONS

Throughout the project, students formulate the relevant and varied problem, formulate the goals, propose the idea of the apparatus and materials, drawing apparatus design, constructing apparatus, testing apparatus, evaluating, and reporting the project. Students had successfully constructed a steam distillation apparatus using materials that are cheaper than commercial apparatus. Students also practiced the separation of essential oils of orange peel using their steam distillation apparatus modified. Student response was generally positive, that they were pleased, interested, more understanding the concepts and principles of work apparatus, also implementing new ideas. These results indicate that through project-based learning can develop creative thinking skills of students. Based on these results, it is necessary to do the research on project-based learning to other concepts.

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