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Approaching Experiential Learning in STEM Lessons and Applying in Teaching Biology

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Abstract:
Experiential learning is a learning model that is correlated with STEM education and when it is applied appropriately, it will increase the effectiveness of the organizing teaching STEM lessons. Theoretical research on experiential learning models and STEM education has clarified the theoretical basis for the correlation of implementing experiential learning models in Biological STEM lessons. At the same time, the pedagogical experiment has organized three Biological STEM lessons, with participating of 143 students grade 11. Through the survey, the majority of students showed that they have an increase in learning motivation, confidence in science and interest in careers after participating in STEM lessons. The suggestions in the article help teachers orientate to use a modern approach in STEM education to form and develop students' competencies.

Key Word*: Experience; Experiential learning; STEM education; STEM lesson; teaching Biology.*

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I. Introduction

Experiential learning has emerged since ancient times, until the twentieth century, it became an educational ideology and developed into a teaching model that emphasizes the formation of learners' competencies through real-world experiences. The experiential learning is determined to be common, present in human activities anytime, anywhere (Kolb et al, 2017), according to appropriate learning styles will develop the curriculum (Kolb et al, 2005). Kobl's experiential learning model is applied in teaching in many fields: in technical education, verbal instruction has been compared with learners' self-organization, thereby determining the effectiveness of the environment and structure of the experiential learning process (Patil et al, 2018); in mechanical engineering education, experiential learning assisted learners in understanding difficult mathematical concepts (Widiastuti et al, 2018); in civil engineering and construction management, it created an integrated innovation framework suitable when making projects (Zhang et al, 2019); in guiding pedagogical students to organize experiential learning activities in schools (Nguyen et al, 2020), etc.

In recent years, emphasis has been drawn to the significance of STEM education for a nation's future (Oh et al, 2013) and it has become a major topic of research on a global scale (Takeuchi et al, 2020), has exceptional potential to satisfy all criteria for raising the standard of general education (Hanif et al, 2019). In schools, STEM education is flexibly organized with the form of STEM lessons, STEM experiential activities, or scientific and technical research projects. In which, STEM lessons have content that is linked to real-world problems of social, scientific, and technological existence, and students are asked to solve problems, acquire knowledge, and respond to meet the requirements of the lesson. STEM lessons use a variety of teaching methods to guide students in integrating knowledge from STEM fields into practical problem solving. For example, a project approach to STEM improves student achievement in high-level cognitive tasks as scientific processes (Diana Laboy-Rush, 2015) or the potential of problem-based learning on topics as enhancing students' attitudes and interest in STEM and future STEM careers (Melanie LaForce et al, 2017), or designing experiential tasks in the engineering process that are effective to improve knowledge, create intrinsic motivation and student satisfaction, stimulate students' interest in STEM fields (Nguyen Tien Long et al, 2020), or organize experiential learning activities according to the orientation of STEM education (Hang Thi Nguyen et al, 2021), etc. Participating in the activities of a STEM lesson, students need to use the design and build solutions model to solve problems according to technical processes and conduct scientific methods to test hypotheses. The application of a number of teaching methods with a modern approach will help successfully implement STEM lesson activities. However, research on approaches to teaching methods, including experiential learning to organize STEM lessons has not been mentioned. Therefore, the questions that needs to be clarified in the article are: Why approach experiential learning in STEM lessons? How are the results of the experiential learning approach in STEM lessons shown when applied inteaching biology?

II. Methodology

The Theoretical Research Method

The theoretical research method is used to refer to the literature on experiential learning and STEM education, thereby clarifying the correlation of implementing experiential learning in STEM lessons and orienting the design of STEM lesson plans to be applied in teaching biology.

The Pedagogical Experimental Method

The Research Design

Use the designed STEM lesson plans into Biological teaching activities in school. Survey students' opinions and attitudes regarding their motivation for studying, their confidence in their ability to understand science concepts, and their interest in STEM careers both before and after implementing STEM lessons.

Research Participants

The participating students were selected through a deliberate sampling method. The study was conducted on 143 students grade 11 from two high schools whose educational activities are interested by administrators and teachers. Students have relatively equal qualifications and participate actively in learning activities.

Research Instrument

The Biological STEM lessons plan demonstrates the link between experiential learning and STEM education.

A survey form of students' perceptions and attitudes towards learning motivation, belief in learning science subjects and interest in STEM careers.

Data collection and analysis

Find the connections between the STEM learning activities and Kobl's experiential learning cycle in order to create effective STEM lesson plans and make sound teaching recommendations for biology. Data obtained from the survey of students' opinions and attitudes is processed, analyzed, compared, and evaluated on statistical software to draw meaningful conclusions

III. Result and discussion

1. Correlation between experiential learning and STEM education and orientation in STEM lessons

This means that learners know how to analyze, reflect on, and evaluate their own experiences in combination with different types of learning, learning spaces, and background knowledge in science, technology, engineering, and mathematics (Nadelson & Seifert, 2017). STEM education provides students with interdisciplinary knowledge and necessary skills, which is one of the activities of experiential education. Therefore, STEM education is hidden in the scope of concepts, connotations, and frameworks of experiential activities. Experiential learning in STEM lessons is a new educational orientation with many advantages, but the schools can not consider STEM and experiential learning as all-but-ignoring other effective teaching methods.

Based on four stages and four different learning styles, Kolb's experiential learning theory has determined that the quality of reflection that students provide through experience is more important than learning outcomes (McLeo, 2017). These stages - learning styles are: (1) Concrete experiences - doing/having and experience; (2) Reflective observation - reviewing/reflecting on the experience; (3) Abstract conceptualisation -concluding/learning from the experience; (4) Active experimentation -planning/trying out what you have learned. New experiences then start to emerge, serving as inputs for subsequent learning cycles until the learning objective is reached. In that process, learners perform activities such as learning to explore the framework of scientific knowledge; doing to design and form the concepts of engineering processes; and creating to build and use processes, tools, and technical materials to create products. So, Kolb's cycle guides the development of activities that integrate science, technology, engineering, and mathematics in each task of the engineering design process. Performing experiential tasks requires students to work together to conceive new ideas that apply scientific and mathematical knowledge, test prototypes, and continually improve products.

STEM lessons are the mains form of STEM education in schools, implemented right into the process of teaching subjects. Student-related factors affecting achievement in STEM subjects are identified to addresse and appropriate interventions to improve achievement in these subjects (Judah M. Ndiku & Veronica Kaluyu, 2020). A STEM lesson demonstrates the following characteristics: focuses on real-world problems; Be guided by the engineering design process; Engage students in hands-on and exploration activities; Enable students to work effectively in groups; Scientific, mathematical, engineering, and technological knowledge are connected and integrated in appropriate ways to create products; Allow for multiple answers and correct errors as part of the learning

process for creative solutions. Participating in the activities of a STEM lesson, students need to use model design and build solutions to solve problems according to technical processes and conduct scientific methods to test hypotheses. Therefore, applying experiential learning methods will help successfully implement STEM lessons.

Buiding STEM lessons are based on active learning through the scientific method or the engineering design process. Using teaching methods in STEM lessons to engage students in activities such as inquiry, discovery, orientation for creative action, and product creation. Scientific STEM lessons are designed based on the scientific process and including activities: Identifying scientific problems, proposing scientific hypotheses → Experimental design to verify → Selection of experimental options → Organize experiments, discuss results → Report, evaluate and adjust. Technical STEM lessons focus on design, manufacturing, product orientation that solve problems, and can perform learning activities: Identify problems, design, manufacturing → Research background knowledge and proposal design solution → Select design solution → Prototyping, test and evaluate → Share, discuss and perfecting.

In the framework of this paper, the correlations between experiential learning and STEM education are introduced through technical STEM lessons. When applying experiential learning, students have specific experiences through watching videos about real-life phenomena, and observing, answering questions to reflect what they have initially experienced. This activity corresponds to the activity of defining the problem. Next, students state the concepts and scientific basis of the proposed solution; that is, they have formed the concept. In subsequent learning activities, students are tested in new situations (Table 1). Thus, students can discover scientific knowledge on their own and apply them to design and manufacture products to solve problems. The design thinking and problem-solving and creativity competences of students are developed.

Table 1: Correlation between experiential learning cycle and activities in STEM lessons

Kolb's experiential learning cycle	Learning activities in STEM lessons	Characteristics
Concrete experience	Activity 1. Identify the problem/requirement to create an application product associated with the lesson content	Students mobilize their prior experience (knowledge, skills) and create a state of mind in which they are ready to receive new knowledge and skills through their feelings about things and phenomena.
Reflective observation		Students observe, detect signs of things and phenomena, find relationships between them to raise problems and make judgments about the problem to be learned; solution development and prototype design of the product.
Abstract conceptualisation	Activity 2. Research background knowledge and propose design solutions	Based on the judgments about the problems, teachers guide the students to propose options and solutions for the problems. Students can perform document research, and investigation, or an experiment to solve the problem or design a completed product.
	Activity 3. Present and discuss design options, use background knowledge to explain and choose options	Students compare and analyze the obtained results with the original judgment to draw conclusions for the research problem, which is also scientific knowledge to learn; Teachers organize for students to present and defend the design before manufacturing and testing.
Active experimentation	Activity 4. Manufacturing products accordance with the selected design plan, testing and evaluating them	Students create samples in accordance with the design that was done in activity 3, and at the same time, conduct testing and evaluation to develop the knowledge and skills that have been formed and applied to similar or new situations.
	Activity 5. Present and discuss the manufactured product; Adjust and finalize the original design	Students arrange the data and results obtained from the above activities to write and present reports and products in front of the class; exchange, discuss, and evaluate them for further adjustment and improvement.

2. Applying experiential learning in Biological STEM lessons

Biology is a branch of natural science that focuses on life and living things, including the structure of matter, chemical processes, molecular interactions, physiological mechanisms, and the development and evolution of organisms. Biology helps students learn biological concepts, laws and processes as a scientific basis for the application of biotechnology advances in practice. Biology serves as the scientific basis for STEM lessons involving biological objects. Through the lessons, students deepen understanding of core biological knowledge, biological research methods and applications, and the principles and processes of biotechnology, from which they form and develop competencies and identify appropriate professions. The products of STEM

lessons in biology are mostly technological processes. Therefore, the lessons are designed to be general and spend a lot of time to organize learning activities that help students explore science, develop scientific process skills, and develop resources, in which attention is paid to organizing activities to experience, practice, and learn about related professions. Science process skills require students to engage in active learning to collect and consider various information about natural phenomena in everyday life (Nurdeli Lasniroha Sagala et al, 2017). Organizing experiential learning in STEM lessons needs to meet the following principles: ensuring the required requirements for the quality and competiencies of students; clearly defining students' learning tasks; designing appropriate experiential activities derived from real-life situations and associated with local problems to be solved; providing time and space to conduct diverse experiential learning activities; and providing students with the opportunity to create learning products under the guidance and support of teachers. These are the basis for designing and organizing STEM lessons.

2.1. Design the STEM lessons plans

The design of a STEM lesson plan is made based on the analysis of the content circuit, the requirements to be achieved in the program, and the context and practical problems of different areas of life, in which pay attention to the fields of climate change, environmental protection, sustainable development, renewable energy, health, smart manufacturing, etc. The lesson plan designed should pay attention to allowing students to ask questions about various issues in society (Herbert et al., 2018). Based on a 4-step STEM lesson plan design process: Step 1: Select content; Step 2: Identify the problem to be solved. Step 3: Create criteria for your product or solution. Step 4: Designing the process of organizing teaching activities, we created STEM lessons such as: Production of biological products (making coconut oil, making sticky rice wine, making yogurt, pickling vegetables, tubers, and fruit, creating bio-pesticide, creating organic fertilizer, and so on); Create teaching models (models of the circulatory system, models of the respiratory system, models of the cells, models of the ecosystem, etc.); Design models related to biological processes (growing sprouts, growing hydroponic vegetables, growing vegetables in geoponics, creating tools to kill harmful insects, and so on), etc. Here is an illustrating example the general plan of the STEM lesson on "Designing traps to capture insects and animals that damage plants and human life":

Step 1. Select content: Growth and development characteristics in animals: stages, influencing factors; Using materials, manufacturing process and calculating and measuring the size of trap design materials.

Step 2. Identify practical problems to be solved: Insects and animals that damage plants and human life often have a short growth and development time; but their growth rate, fertility is fast; Their life cycle goes through many stages with different growth and development characteristics and has the power to destroy plants and affect human health quite strongly. So, how can it be both simple, economical, and effective to destroy them quickly, without harming the environment and other biological populations?

Step 3. Create the criteria for products/solutions: The criterias to evaluate products include: Being designed according to the technical process; Being practical; Being scientific; Being aesthetics, Being creativity (internal advantages); The criterias to evaluate report products include: Report form; Being scientific and practicality of the report's content; Presentational style; Integrated content; Ask and answer questions from other groups.

Step 4. Design the process of organizing teaching activities: Referring to Table 1, the activities are identified:

Activity 1. Identify the problem/requirement to create an application product associated with the lesson content: Students experience of plants and human life being destroyed by insects and harmful animals by observing and watching videos or pictures, asking questions and raising concerns, giving problem statements about observed images. The products that students gain from this activity are to raise the problem of how to destroy insects and harmful animals simply, economically, and without harming the environment and other organisms.

Activity 2. Research background knowledge and propose design solutions: Students work in groups to learn about the stages, forms and factors that affect growth and development in animals; discuss and report on knowledge research results; at the same time looking for measures to capture or destroy insects and harmful animals. The product of the activity is the group's system of knowledge and ideas on how to capture or destroy insects and pests.

Activity 3. Present and discuss design options, use background knowledge to explain and choose options: Based on the ideas stated, each group selects the right idea, designs a plan and draws a product model; The group agreed on a plan to make the product.

Activity 4. Manufacturing products according to the selected design plan, tested and evaluated: Students make the product according to the designed plan, conduct product testing, record the results, and prepare the report.

Activity 5. Present and discuss the manufactured product; Adjust and finalize the original design: Teacher use the art gallery technique to organize the groups to report their products. The groups' report and product are

evaluated by teacher and students in accordance with the criterias already established in step 2, after which the groups discuss how to finalize the product design.

2.2. Organizing teaching STEM lessons

STEM lessons are implemented in and outside the classroom, through the following steps:

Step 1. Disseminate the plan. It is implemented in the classroom before the lesson 1 week so that students know the STEM lesson plan and the work to be done.

Step 2. Finalize the in-classwork preparation for completing activities 1, 2, and 3 in order.

Step 3. The student groups implement the product manufacturing outside the classroom to complete activity 4.

Step 4. Write a report about group's activities outside the classroom, then introduce the product, discuss in the classroom, thereby perfecting the group's product – this is the activity 5 implementation.

2.3. Evaluate the organizing teaching STEM lessons

STEM lesson assessment methods and tools are quite diverse, used to assess students' competencies and qualities. They are the methods of writing, observation, answering questions and the assessment tools as tests, questions, exercises, student products, checklists, rubrics, assessment boards, rating scales, etc..

Three STEM lesson plans based on the design orientation that are related to experiential learning methods were implemented and organizing teaching in two high schools that educational activities are interested by administrators and teachers. Three STEM lesson plans are "Designing traps to capture insects and animals that damage plants and human life", "Planting bean sprouts" and "Building a nutrient pyramid". The lessons were attended by 143 students grade 11 that have relatively equal qualifications and participate actively in learning activities. Students were surveyed at the pre-experiment and post-experiment stages to help determine the increase in levels of awareness and attitudes toward learning motivation (a), confidence in learning science subjects (b), and interest in the STEM professions (c). Specifically, (a) includes criterias as the desire to participate in learning activities, performing proactive tasks, trusting in the students' ability to complete themselves learning tasks, feel comfortable participating in activities, curious about the results of product testing; (b) includes criterias as be able to solve scientific questions and exercises, learn science subjects very interesting, feeling better at scientific subjects, wanting to learn more about science, have skills to learn about science; (c) includes criterias as identifying some STEM careers, wanting to learn more STEM careers. With the expression of attitudes such as "agree" (1), "no opinion" (2) and "disagree" (3); of the cognitive level as "often" (1), "sometimes" (2) and "never" (3). Assign a weighted score for (1) from 8 to 10; for (2) from 5 to 7; for (3) from 1 to 4 and the percentage of students answering for the criteria and performance is calculated on the average value and then compared post-experiment with pre-experiment. The results are summarized in Table 2.

Table 2:Perception and attitude results of students before and after participating in STEM lessons

Kết quả	n	$\overline{X}$	Level of awareness and attitude (%)			Comparative test
			(1)	(2)	(3)	
pre-experiment	143	6.42	30.07	52.45	17.48	t = 5.71; p = 0.018
post-experiment	143	7.59	60.84	29.37	9.79	

The average results of students' awareness and attitudes after participating in STEM lessons (7.59) were different from those before participating (6.42) with statistical significance ($t = 5.71$; $p = 0.018$), in which the levels of awareness and attitude have increased at level (1) and decreased at levels (2) and (3) of post-experiment compared with per-experiment. With a 95% probability ($\alpha = 0.05$), this difference was initially determined to be statistically significant. This shows that students have an increased awareness and attitude about learning motivation, belief in scientific subjects, and interest in STEM careers after being involved in STEM lessons; that is, when designing and organizing STEM lessons in teaching Biology, teachers need to be interested in approaching experiential learning methods in relation to students' learning activities.

IV. Conclusion

Experiential learning and STEM education are the effective educational orientations for teaching natural science subjects in order to implement an educational program that forms and develops students' competencies. In the relationship between experiential learning and STEM education, the article has provided the applicable orientation of designing and organizing teaching biological STEM lessons. Five STEM lesson activities, which correspond to the four stages of Kolb's experiential learning cycle, are implemented when organizing three STEM lessons for students grade 11, demonstrating that effective teaching is related to students' perceptions and attitudes toward learning motivation, confidence in learning scientific subjects, and

interest in STEM careers. These suggestions will aid teachers in the process of designing and organizing STEM lessons in order to achieve the teaching goal of forming and developing students' competencies. However, more research on the relationship between experiential learning and other forms of STEM education is required, with a focus on the competencies that the subject has the advantage of forming and developing for students. Simultaneously, expanding research on the relationship of other active teaching methods to STEM education in order to provide appropriate choices in teachers' specific teaching contexts. The following research direction is to supplement the method of assessing students' competencies through experiential learning in STEM lessons and conducting experiments to evaluate the proposal's effectiveness.

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