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Applying an Experiential Learning Cycle with the Aid of Finite Element Analysis in Engineering Education

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ABSTRACT

To enhance student's understanding of basic engineering concepts, engineering education should include more active learning in its curricula. This article purposed to develop an active learning module for mechanical engineering students through a commercial finite element package. Kolb Learning Cycle was employed as the fundamental pedagogic of the module. This paper outlined how Kolb's theory of the experiential learning was used to improve a learning module for 'Heat Transfer' course in mechanical engineering education. This model, which covered three topics (steady state heat conduction, transient heat conduction and thermal stress), briefly summarized, and reviewed Kolb's stages of the experiential learning. A commercial finite element software was choosen to facilitate students' understanding of difficult mathematical concepts. Each stage of the learning module was highlighted. Recommendations were made for future evaluation and research.

Keywords: engineering education, experiential learning, Kolb's cycle, learning module

INTRODUCTION

Sustainable improvements in engineering education curricula significantly require to fulfill the demands of professional engineers in the current industry era. Increases in industry competitiveness and the massive use of new technology are the major factors forcing the transformation of engineering practice(s). Teaching engineering plays a crucial role in providing relevant knowledge and skills to meet any change in the industrial requirements. Basically, engineering education aims to equip students with specific knowledge and skills of science and engineering principles as well as general understanding of the product, process and system that constitute the society (Andersson & Andersson, 2010). Recent studies have revealed that the lecture-centreted instruction is less suitable for educating future engineers and meeting the current instruial demands. There have been a wide gap in such industrial

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requirements as a lack of communication and teamwork skills, inability to a broader societal perspective and good knowledge of fundamental engineering science (Li, Ǒchsner, & Hall, 2017).

Therefore,engineering education needs to create an active learning environment engaging students in learning process, and focus problems, design challenges and collaborative works on completing assignments and/or tasks (Pinder-Grover, 2013). Hence, such an approach not only enables students to retain their knowledge in long-term memory but also challenges to teach difficult engineering concepts/topics. For example; Clark, Thompson, and Mountcastle (2014) found that their students, who engaged in active-learning activities and spent more time to apply a mathematical definition on the real-life problems, successfully overcame their difficulties of a specific subject in a parcular basic engineering course. Learning, which creates knowledge through the transformation of experience, is a continous reconstruction of experience.

Learning from experience is the essence of experiential learning, which is a holistic model firstly introduced by Kolb (Kolb & Kolb, 2008). It consists of four elements: concrete experience, observation and reflection, the formation of abstract concepts and testing in a new situation. Abdulwahed and Nagy (2013) considered the Kolb’s experiential learning framework as a suitable pedagogical model for engineering education. They also purposed a new approach for laboratory-based learning given the Kolb’s theory. Jaksic (2010), who implemented the Kolb’s cyle to teach Programmable Logic Control within a Computer Integrated Manufacturing course, reported that the students’ design skills improved after implementing four quadrant learning activities. Several engineering courses have been developed in regard to the Kolb’s cycle and Finite Element Analysis (FEA) commercial software (Brown et al., 2015; Brown et al., 2014; Watson, Brown, & Liu, 2015), such as machine design, mechanical vibration, structural analysis and biometrics. These courses have aimed not only to improve the students’ understanding of the engineering concepts but also train them with the basic knowledge of the FEA theory. The Finite Element Analysis, which is a numerical method to find approximate solutions for complex engineering problems, usually represents the complicated mathemathical form(s) of differential and integral equations (Widiastuti, 2014).

This article presents how to integrate experiential learning into engineering courses, which have no hands-on laboratory components. An experiential learning module for the students in *Heat Transfer* course was designed to incorporate a finite element analysis software. The module aimed to promote conceptual change for the students, which would serve as vocational teachers in engineering. This is unique to develop technical expertise of fundamental engineering concepts and encourage them to build their teaching/pedagogical identities.

METHODOLOGY

This article embraced the Kolb’s constructivist model as a pedagogical basis to design the learning module for a *Heat Transfer* course. This course was part of the first-year curriculum of the Mechanical Engineering Education program at Sebelas Maret University. The module consisted of three sections, i.e, steady state heat transfer, transient heat transfer and thermal stress.

The experiential learning theory (ELT) model in this study depicted two related modes of grasping experience (Concrete Experince and Abstract Conceptualization) and two related models of transforming experience (Reflective Observation and Active Experimentation) (see Figure 1).

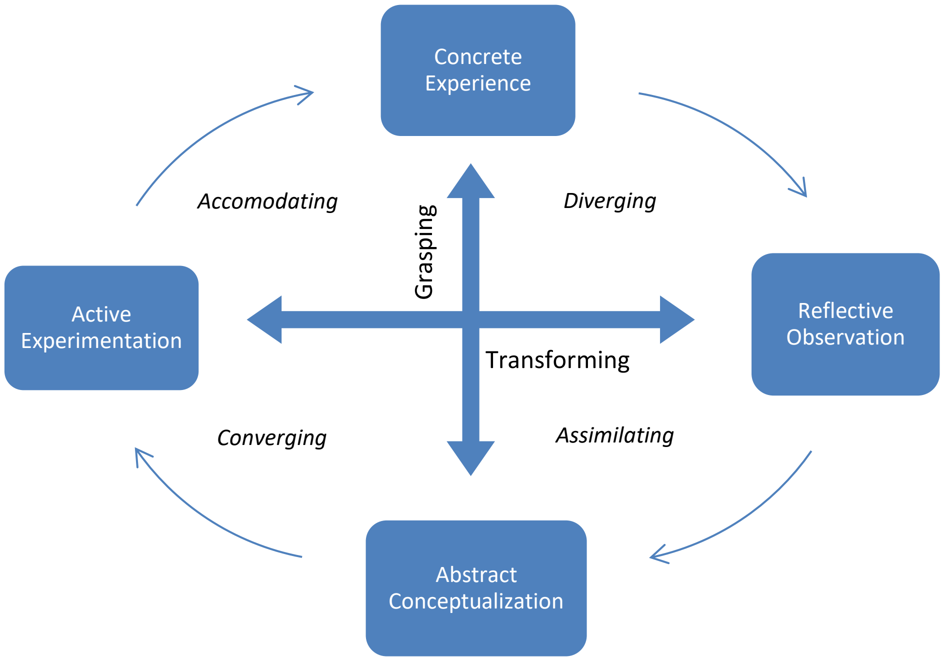

Figure 1. Experiential learning cycle (Kolb & Kolb, 2008)

As presented in Figure 1, the Kolb's cycle begins with a concrete experience whereas the learning process starts with doing something in an assigned task. In view of the Kolb's cycle, students cannot learn by simply watching or reading something, but they achieve to learn through active engagement.

The reflective observation, the second stage of the cycle, enables students to take time-out from "doing" and review previously grasped informations . At this stage, verbalization and discussion are required for teacher-student and student-student discourses.

The third stage engages students in making sense of the events, interpreting on what has happened, and understanding the relationship(s) between entities. This stage, called Abstract Conceptualisation, involves to compare *what has been done* with *what has already been known*.

The final stage, Active Experiment, affords students to transfer their generated knowledge into practicum. They are encouraged to plan what to dofor a new understanding and to predict what happens in the next.

a) Implementation Of Elt For Heat Transfer Course

In *Heat Transfer* course, students are expected to improve their knowledge about heat conduction in solids for steady state and transient condition. This course, which has large enrollments with around 70 students, includes lectures and tutorials without a laboratory facility. The four-quadrant activities representing the ELT cycle were applied to three major topics with the aid of commercial finite element analysis software. By fully completing this cycle, the students were expected to have a stronger grasp of difficult concept(s) in *Heat Transfer*. Unlike previous works (Brown et al., 2014)introducing the FEA theory within the main topics, this module emphasized the use of the FEA software to illustrate the mathematical form and understanding of the basic engineering concepts. Pre-service vocational school teachers need strong mathematics and science knowledge to deliver the engineering concepts to their students (Asunda & Hill, 2008). The FEA theory, which includes intensive mathematics, requests students to possess more rigorous maths education (Watson et al., 2015).

As can be seen from Figure 1, the development of FEA-based learning module is pedagogically rooted in an experiential learning of the Kolb's cycle. Each section of the module presented the following sub-sections:

- Educational objective
- Problem description and objective analysis
- Mathematical equation
- General steps of the FE analysis
- Comparison of analytical and numerical analysis
- Summary and discussion

ANSYS® Workbench, a commercial FEA software, was linked with the module.

A module of heat transfer analysis using ANSYS Workbench was developed to be the supplement material for the heat transfer course. Section #1 focused on the steady state heat transfer, which aimed to assist students in visually verifying temperature distribution of an object under specified boundary conditions. During the introductory lecture of the Heat Transfer subject, the mathematical form of one-dimensional heat conduction was provided. In the first quadrant acitivities, group problem solving was chosen as a learning method to develop the FEA model of heat conduction in a plane wall. A problem was adopted from an example in Chapter 2 of a textbook of Heat Transfer (Cengel, 2003). This problem could easily be solved via hand calculations allowing a verification of the FEA solutions. The students were encouraged to precisely identify the boundary conditions of the problem following the tutorial provided in the module.

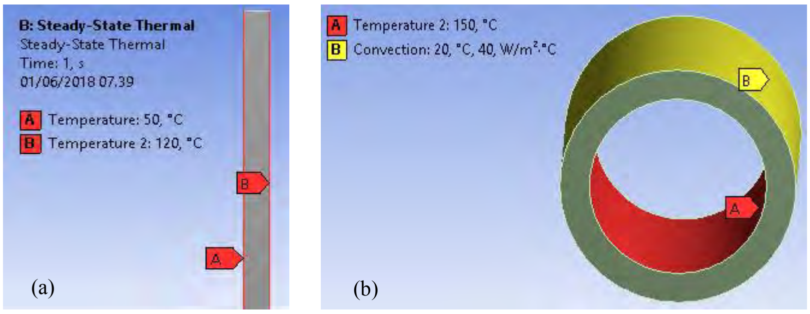

Figure 2. Heat conduction problem for (a) Section#1 and (b) Section#2

For the 'reflective observation' stage, the students were required to identify temperature distribution along the wall thickness from the ANSYS solution as well as compare the results with the analytical solution. In this stage, students were introduced to the use of the FEA as a numerical method to approximately obtain the solution in heat transfer. The teacher created a discussion environment about the effect of thermal conductivity on the rate of heat conduction under steady state. This led to the 'abstract conceptualisation' stage facilitating the students to understand the concepts of heat conductivity and heat flux. The problem of heat loss through a steam pipe was provided to engage the students in an active experiment to learn the heat conduction in a cylinder.

The learning outcome for Section#2 equipped the students with knowledge of thermal resistance relations and convection conditions at the boundaries. In the 'concrete experience' stage, the students presented their solutions of the problem provided in the previous section. After analysing the system's performance, the boundary in the outer surface of the cyclinder was changed to a convection condition. The students had an observation on the variation of heat flux through the cylinder pipe as well as the effect of the convection on the heat flow. They were, then, be able to conceptualize the analysis of heat transfer in a medium consisting two or more layers. In introducing the importance of insulator material and the effect of insulator radius on the rate of heat transfer within a cylinder shape, a case study of heat loss from steam pipe with insulator was provided for the active experiment in Section#2. The case study was adapted from Kreith, Manglik, and Bohn (2011).

The last section of the heat transfer learning module in this article handled the variation of temperature with time as well as the position in one-dimensional system. The one-dimensional transient heat conduction problem could be solved exactly for three basic geometries: plane wall, cylinder and sphere (Kreith et al., 2011). However, the solution involved infinites series that students found difficult. The general heat conduction equation in an infinite slab was described as

$$\frac{1}{\propto}\frac{dT}{dt} = \frac{d^2T}{dx^2} \qquad 0 \leq x \leq L (1)$$

In the 'concrete experience' stage, the students discussed the heat flux of the steam pipe with different insulator radius and types of material under steady state condition. Following the provided tutorial, they identified transient temperature profiles within the pipe during the 'reflective observation' stageThe students were expected to understand how to identify the difference(s) between steady state and transient modes of the heat transfer. The bimetallic strip problem derived from Boley and Weiner (1988) was selected for the project as the active experiment. This problem aimed to introduce the concept of thermal stress in advanced level of heat transfer subject.Table 1 summarizes all learning activities implemented during the heat transfer course with the aid of commercial FEA software.

Table 1. *Learning activities of each stage in the ELT'*

Stage	Section 1	Section 2	Section 3
Concrete experience	Enabled the students to developed a FEA model of heat conduction in plane wall	Afforded them to discuss the solution of heat transfer in a pipe and modify the boundary conditions with convection in outer surface of the pipe	Helped them brainstorm the heat flux in the pipe with different insulator parameters and follow the tutorial provided to develop the transient model of that problem
Reflective observation	Provided them to discuss the temperature distribution within the wall and make a prediction of the result for different thermal conductivity	Requested them to write a short report on the analysis of pipe problem with convection condition at the boundaries	Engaged them in making an observation on the temperature profile as a function of time and position
Abstract conceptualization	Enabled them to compare the numerical result(s) with analytical solution and lecture on the concept of thermal conductivity	Asked them to identify the differences between heat flux within a plane wall and a pipe and understand the concept of thermal resistance	Afforded them to discuss the elapsed time after the heat transfer was initiated and before the steady state conditions were reached

Active experimentation	Enabled them to develop and analyse heat loss in a steam pipe analytically and numerically	Required them to calculate thermal resistance in a steam pipe with different insulator diameters and materials	Helped them develop bimetallic strip problem via the FEA software by combining thermal and structural analysis

CONCLUSIONS

This article implemented the Kolb's experiential learning cycle, as a teaching method, to the *Heat Transfer* in the pre-service vocational teacher education of mechanical engineering. It developed a series of learning activities in four quadrants representing the process of grasping and transforming the informations. The current study has not employed a formal assessment of this module; although the faculties' initial reactions were positive. Future studies should evaluate and assess the applicability of the Kolb's cycle. A long-term study implementing the experiential learning cycle will not only enhance student learning but also empower pre-service teachers' pedagogical skills.

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REFERENCES

Abdulwahed, M., & Nagy, Z. K. (2013). Applying Kolb's experiential learning cycle for laboratory education. *Journal of Engineering Education, 98*(3), 283-294.

Andersson, N., & Andersson, P. H. (2010). *Teaching Professional Engineering Skills: Industry Participation in Realistic Role Play Simulation.* Paper presented at the The 6th International CDIO Conference, Montréal, Canada.

Asunda, P. A., & Hill, R. B. (2008). Preparing Technology Teachers to Teach Engineering Design. *Journal of STEM Teacher Education, 45*(1), 26-52.

Boley, B. A., & Weiner, J. H. (1988). *Theory of Thermal Stresses*. Mineola, New York: Dover Publications, Inc.

Brown, A. O., Jensen, D. D., Schimpf, P. H., Crawford, R. H., Orabi, I. I., Watson, K. A., . . . Jackson, K. S. (2015). *Active Engineering Education Modules: A Summary of Recent Research Findings*. Paper presented at the 122nd ASEE Annual Conference & Exposition, Seattle, WA.

Brown, A. O., Watson, K. A., Liu, J., Orabi, I. I., Rencis, J. J., Chen, C.-C., ... Jensen, D. D. (2014). *Assessment of Active Learning Modules: An Update in Research Findings*. Paper presented at the 121st ASEE Annual Conference & Exposition, Indianapolis, IN.

Cengel, Y. A. (2003). *Heat Transfer: a Practical Approach* (2nd ed.): Mc-Graw Hill, Inc.

Clark, J. W., Thompson, J. R., & Mountcastle, D. B. (2014). *Investigating Student Conceptual Difficulties in Thermodynamics Across Multiple Disciplines: The First Law and P-V Diagrams*. Paper presented at the 121st ASEE Annual Conference & Exposition, Indianapolis, IN.

Jaksic, N. (2010). *Teaching PLCs Using the Kolb Learning Cycle*.

Kolb, A. Y., & Kolb, D. A. (2008). Experiential Learning Theory: A Dynamic, Holistic Approach to Management Learning, Education and Development. In S. J. Armstrong &

C. Fukami (Eds.), *Handbook of Management Learning, Education and Development*. London: Sage Publication.

Kreith, F., Manglik, R. M., & Bohn, M. S. (2011). *Principles of Heat Transfer*. Stamford, CT, USA: Cengage Learning.

Li, H., Öchsner, A., & Hall, W. (2017). Application of experiential learning to improve student engagement and experience in a mechanical engineering course. *European Journal of Engineering Education*, 1-11. doi:http://dx.doi.org/10.1080/03043797.2017.1402864

Pinder-Grover, T. A. (2013). *Active Learning in Engineering: Perspectives from Graduate Student In- structors*. Paper presented at the 120th ASEE Annual Conference and Exposition.

Watson, K. A., Brown, A. O., & Liu, J. (2015). *Finite Element Analysis Active Learning Modules Embedded Throughout A Curriculum: Implementation and Assessment of Results Based on Student GPA*. Paper presented at the 122nd ASEE Annual Conference & Exposition, Seattle, WA.

Widiastuti, I. (2014). *Mechanical Performance of a PLA- based Biodegradable Plastic for Liquid Packaging Application.* (Doctor of Philosophy), Swinburne University of Technology, Melbourne, Australia.