Implementing finite element method in aerodynamics course to foster experiential learning

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Abstract. The study in Aerodynamics has shifted from large theoretical curriculum into authentic learning experiences in response to the industry requirement. In addition, the development of computational methods has revolutionized the design cycle in aerodynamics. This work describes an integrated approach in an undergraduate Aerodynamics course using the Kolb’s Learning cycle. Experiential learning is incorporated in the class to provide more opportunities for students to understand the theoretical concept through experiencing the applications and impact of the concept in real life. The Finite Element Method (FEM) which is widely used in analyzing many engineering problems was integrated into the Aerodynamics theory and application to visualize changes of parameter in the design phase. The main learning objective of the developed learning module is to apply appropriate aerodynamics models to predict the forces on and performance of a vehicle design. The module is assessed by instructor before being applied for the students in the classroom. It is considered to be an effective method for learning when lectures and computation works are integrated in a meaningful manner. This development research is expected to be able to produce graduates who are competent in the field of design.

1. Introduction
Aerodynamics in technical education requires more attention. This field studies the movement of an object in the air so that it becomes something abstract in nature because of the invisible form of air [1]. While the concept of learning that is applied is often centered on educators, this problem will make it difficult for students to understand aerodynamic concepts [1]. Besides that, the limitations of space and practice tools also become obstacles in the process of aerodynamic course [2]. For this reason, we need simulation software to know the real results of the design of aerodynamic design [2].

Based on the survey the results of aerodynamic course are still not well achieved. For that we need an appropriate learning innovation.

This study used the experiential learning model by combining with finite element methods. Experiential learning will change the concept of learning that was previously centered on educators to be student-centered [3-5]. Experiential learning will guide the achievement of understanding through the four Kolb’s cycles including Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualization (AC), Active Experimentation (AE) [6]. On the other hand, the Finite Element Method (FEM) is a numerical method that can solve problems in technical education. The Finite Element Method (FEM) can visualize abstract of aerodynamic calculations with the help of ANSYS R15 simulation software [7].
2. Methods

This research develops learning on aerodynamics courses using the experiential learning model and combined with finite element methods to improve students’ understanding in aerodynamic phenomena. In developing learning this study used the ADDIE research model (Analysis, Design, Development, Implementation, and Evaluation). However, due to limited research time, this research is limited to the third stage, namely Development. Data retrieval uses interviews with users. The results of this development stage are in the form of Learning Implementation Plans. The development research stages are as follows:

2.1. Analysis

This stage of analysis is conducted to determine the needs in the learning process in terms of the results of interviews with lecturers of aerodynamics courses at Mechanical Engineering Education, Sebelas Maret University. The results of the interview will provide information on developing appropriate learning using the experiential model and finite element method in the aerodynamics course.

2.2. Design

This design phase will arrange the design of the implementation of learning. This arrangement refers to the Experiential Learning Kolb’s, where students get knowledge through their own experience so that the design of student center learning-based learning needs to be made. The drafting of the implementation of this learning focuses on core learning activities, where the Kolb’s cycle (Figure 1) will be applied starting from Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation [8].

![Figure 1. Kolb’s Cycle](image)

2.3. Development

After the design of the learning model has been determined according to the Kolb’s cycle [8], the aerodynamic learning material was developed. This material will be visualized in ANSYS R15 simulation software. The topic of this material discussion is lift force in sedans, in the development of variations used is how the influence of the presence and absence of spoilers (Figure 2 and Figure 3) on the drag and lift force produced[9,10].
3. Results and Discussion

3.1. Analysis Results

After the learning style questionnaire is given and filled in by students then proceed to analyse the questionnaire and get the following results as the interview, here are some points from the interview with the lecturer in aerodynamics courses: (1) Learning methods that have been applied in the learning process in the form of lectures, discussions, visualization of simulation results, and experimental in the lab; (2) Abstract concepts are explained through visualization of existing simulation results; (3) Visualization related to abstract concepts is very important to be used to facilitate students in the lecture process; (4) The use of the finite element method has not been applied because in the learning process students only see the results of the simulation in the form of visualization; (5) The learning process has not applied the experiential learning model and the finite element method, but the model and method allow it to be applied to this course; (6) The experiential learning cycle can be applied to aerodynamics courses from the concrete experience to active experimentation. But according to the lecturer the most distinguishing stage with learning is usually in active experimentation where students are given assignments to carry out simulations; (7) The finite element method can be applied to almost all chapters. But in this study, sub-material was proposed regarding the drag and lift forces acting on the car. This proposal is because there is no such sub-material in the aerodynamics course and students who take part in this study concentrate in the automotive field. This proposal is approved by lecturer lecturers and will be included in the semester learning design if this research has been completed; (8) Application of experiential learning models and finite element methods will make it easier for students to get their own experience related to aerodynamic phenomena; (9) In the process of visualizing students need to be deployed in a simulation. This simulation is hampered by the existing laboratory facilities for it to be carried out by group division of tasks; (10) The application of this model and method will make it easier to achieve the objectives of the semester learning design.

Based on the description of the interview analysis above, it can be concluded that an important point in the process of developing this learning is that students still do not use their own experience in studying aerodynamic phenomena. In this case students need to do their own simulation. The conclusion of the analysis of the needs of users is as follows; (1) The ongoing learning has not applied the Kolb's cycle; (2) Students do not have their own learning experience; (3) Help with ANSYS R15 simulation software can improve students' understanding; (3) The combination of experiential learning models and finite element methods is believed to be able to achieve learning goals.

3.2. The Design Results of the Learning Implementation Plant

This stage is an Experiential Learning model combined with the Finite Element Method to solve aerodynamic problems as well as to visualize abstract aerodynamic problems. This learning is designed based on the Kolb’s cycle [11]: (1) Concrete Experience. In this cycle the basic knowledge of students about aerodynamics is explored and developed. A new thing can be obtained by students
concretely. For this reason, a solution is needed such as the use of broadcast media to accelerate the ability of students to experience real aerodynamic problems. In this topic, the problem of aerodynamics is highlighted about the drag and lift forces that occur in a vehicle. At this stage FEM has been used to produce broadcast media; (2) Reflective Observation. Students begin to reflect on what they have observed, then curiosity about something they observe increases; (3) Abstract Conceptualization. Students are asked to link what has been observed with the theory being studied. Students will use assignments to complete calculations in aerodynamics and then asked to analyse; (4) Active Experimentation. Students are actively involved in solving aerodynamic problems as well as students can develop what has been obtained previously. At this stage FEM as a tool that can publish the active experience of students.

3.3. Development Results
This module is divided into two sections. The first section, improves student understanding of the drag and lift in the car. At the Concrete Experience stage, small groups are formed and then asked to discuss the drag and lift force on the vehicle. Students are given the freedom to access information from the internet. Then students are asked to explain the results of their discussion by showing what the drag and lift is going to happen to the vehicle. As a tool the lecturer prepares a vehicle design display and students are asked to illustrate how the drag and lift are happened. After that to improve student understanding, the lecturer displays the FEM simulation results about the drag and lift that occur in a vehicle. Reflective Observation, Students are asked to reflect on what factors influence the drag and lift on a vehicle that can occur. In the Abstract Conceptualization stage, students are provided with the results of the calculation process from the MEH related to the CD and CL, then students are asked to analyze the drag and lift force analytically. The drag calculation equation is as follows:

\[ F_D = \frac{1}{2} C_D \rho V^2 A \]  

(1)

The lift calculation equation is as follows:

\[ F_L = \frac{1}{2} C_L \rho V^2 A \]  

(2)

Then the analytic analysis is compared with the analysis of FEM. Here students are introduced to FEM as a numerical solution to solving aerodynamic problems. At the end of the first part students are asked to make a vehicle model that will be analyzed for drag and lift as an Active Experimentation. Making this model can use Solid Work software, because before taking an aerodynamics course student have taken a design course with software. So that students are given the freedom to make their own models.

The second section, analyzes the differences in vehicles not and by using spoilers. In the first stage students are asked to present any factors that can affect the drag and lift as a Concrete Experience. Reflective Observation stage students are asked to observe impressions from the lecturer about a vehicle, but this vehicle has several additional components that are useful for improving the aerodynamic performance of a vehicle. After that, students are asked to identify what components are the difference with the general vehicle. In the Abstract Conceptualization stage students are asked to focus on spoiler components. After that students are asked to do calculations related to the drag and lift force on the vehicle with spoilers, the lecturer presents the results of the calculation process related to CD and CL from the spoiler vehicle. Then students are asked to look for the effect of adding spoilers to the vehicle. At Active Experimentation students are asked to carry out a simulation process of their own designs and added to make a vehicle design with spoilers and then simulate a spoiled vehicle. At this stage students are given a tutorial on simulating drag and lift using ANSYS R15 simulation software. Tutorial in the form of writing and video is shown. The simulation process was carried out using a laboratory computer.
The result of the development of drag force material in streamlined pattern cars using ANSYS R15 software simulation is presented in Figure 4 and Figure 5.

![Figure 4. Streamline Car Image Pattern without Spoiler](image)

![Figure 5. Streamline Car Flow Pattern with Spoiler 1](image)

With the visualization as shown above, it is expected to be able to increase understanding of drag and lift. A spoiler-free car has a direct flow of fluid down just behind the car so that the vortex is formed right behind the car resulting in high drag. Cars with one-level spoilers have fluid flow following the spoiler cross section so that some of the fluid moves straight and some are down but some distance behind the car so that vortex is formed slightly behind the car which results in smaller drag values compared to cars without spoilers. The Coefficient of Drag (CD) and Coefficient of Lift can be determined through this simulation. So the calculation of the Drag Force and Lift Force can also be determined.
4. Conclusion
This research uses the four basic cycles of Kolb’s in achieving learning objectives and to accelerate it then combined with the Finite Element Method which is useful for solving aerodynamic problems as well as to visualize abstract aerodynamic concepts. No formal assessment of this module has been made although initial faculty reaction has been positive. Research on learning development is expected to improve the quality of college graduates, especially in the field of design and analysis of aerodynamic products. So that graduates have skills that compete with other college graduates.

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