Hands on Education in Integrated Curriculum

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1. Introduction:

It has been demonstrated by numerous studies that the combination of theory and hands-on experience is a critical component of engineering education [1]. To teach engineering students how to design an experiment, preform a test, collect and analyze data, draw conclusions, etc. are critical. Hands on laboratory experiences can be delivered in various ways. They are either integrated into courses that contain both lectures and lab components or offered separately as lab courses.

Traditionally, mechanical engineering programs offer 2 or 3 mechanical lab courses in junior year, followed by one year capstone project. Some programs start from sophomore year, some extend it into senior year. There are also many programs that adopt integrated curriculum, therefore the lab components are integrated into regular courses. For example, when engineering dynamics course is offered, a 1 credit lab course is offered in conjunction with the lecture. This arrangement ties the experiments to course content very well, helps to reinforce the knowledge that students learned from lectures. It brings the real world into theoretical education.

While it is the general agreement that laboratories, hands on experience are necessary, little has been said about what they are expected to accomplish [2]. Many times course objectives of laboratories are not clear to students, sometimes to the instructors as well. For the integrated laboratory courses, instructors are likely to identify course goals than they are to specify student learning objectives. Laboratory courses are commonly used to reinforce the theory that learned from lecture. In another word, instructors are very likely to focus too much on contents then skills.

Hands-on experience should not only help students to reinforce the knowledge, but also train students towards the real world of their future job. A good and systematic training on ability to design and preform experiments is critical for college education, especially for those integrated curriculum. How to systematically train students on these skills during their undergraduate study period becomes a topic to study.

2. Method:

A series training strategy has been proposed and tried from freshman year to junior year by the author. It was the hope that it will help to improve the hands-on skills, which will in turn to get student ready for their capstone project in senior year.

Freshmen year, students just graduated from high school. The training is focused on good practice – learning by doing. Students are expected or trained to follow the lab instruction carefully; complete lab activities in group manner; record experimental data in an organized way; do the post-experimental data analysis; derive conclusions based on experimental result; and write technical lab report. The lab apparatus would be set up for students. A detailed lab instruction will be provided, as well as the data table. In this phase, the purpose of the lab activities is focus on enhance motivations, and at the same time, to show students how an experiment was designed; what the data sheet should look like; how to write a lab report, etc. This training can be tied to any lab content, and it is generally been done within the introduction to engineering courses.

Sophomore year, training is focused on able to design data table based on provided lab procedure, and understanding the difference between theory and experiment. Students will be guided to learn how to design an experiment activity to verify the theory, and identify the error source. For example, moment of inertia is an important topic for Mechanical Engineering major. It is used in multiple courses like Status, Dynamics, and Strength of materials. A lab activity named "rolling rigid body" was designed to help student understand and able to utilize this concept in a vivid way. Students were given multiple objects with different shape, size, and materials. Some of them were made in same materials, but in different dimension. Some had same dimensions, different materials, so had different mass. Some were made of same materials, but different distribution of the mass. Students were asked to calculate the time required to roll these objects down a ramp, and then experimentally measure it. Students would be reinforced the knowledge of moment of inertia that they learned from the lecture. At the same time, they would need to think how the lab procedures should be taken in each step; what need to be measured; what should be measured first; how the data table should look like to make the presentation of data clear and easy to read; how to reduce the measurement error, etc. In this phase, students are guided through the experiment procedures without detailed steps provided. They will have opportunities to discover that there are many ways to perform an experiment, some are better than others. This practice lead students think actively, instead of just following the instruction.

When students reach to junior year, the training is focused on design the experiment method. Students will need to consider all the possible methods using the available tools, and choose the best one they think. For example, students were asked to measure the dimeter of a small hole on a container. Some team decided to use optical method. Some used fluid Bernoulli theory. For the fluid method, some team chose to use the constant head, while others used reduced head. Once students chose their method, they needed to figure out what the set up should look like; what materials they would need; what the procedures they were going to follow. As the result of this lab, students identified a method they could use, and made it happen. They performed the experiment they designed, and reported the result. At this stage, lab experience is more like multiple mini design projects, which still can be tied to the lecture content, but add in more active thinking, design components. By now, students are ready to move on to capstone design project that requires higher level of design and performance skill.

3. Assessment:

Initial assessment of this method is done by sending questionnaires to students in two consequent years. The responses were collected at the end of sophomore year and the end of junior year. Same group (about 30 students) responded the questionnaires. Students were asked to self-rate their abilities that listed in the questionnaire on a 1 to 5 scale. 1 means poor and 5 means excellent. The result based on the average rating is listed in the following table.

Table 1: Questionnaire results

Questions	End of sophomore year	End of junior year
1. How well do you think you can follow instruction, preform an experiment, and record your measurements for future data analysis?	4.33	4.59
2. How well do you think you can read the instruction, design a data table for recording your measurement before you perform an experiment?	4.12	4.36
3. How well do you think you can design an experiment based on available tools, and analyze the error sources.	3.57	3.67
4. How well do you think you can design and build an experimental set-up, and preform testing to verify or demonstrate a theory you learned in a particular course?	3.11	3.71
5. How well do you think you can design and build an experimental set-up, and preform testing to solve a real engineering problem with a limited budget?	2.99	3.38

The questions in the questionnaires were designed following the author's lab objectives for different year/stage. By sophomore year, students should be able to perform question 1 and 2 very well, which also agreed by the data from table 1. Question 3 and 4 are the goals for junior year, which to get students ready and be confident to move on the Capstone project. Question 5 should reflect the result of Capstone project, which has not happen for this group of students. It is reflecting their confidence rather than an evaluation of their skills at this point. Clearly from the table, all the skills were improved during the junior year, especially the design and solve problem aspects. Following figures gives better view about the improvement of the skills over junior year.

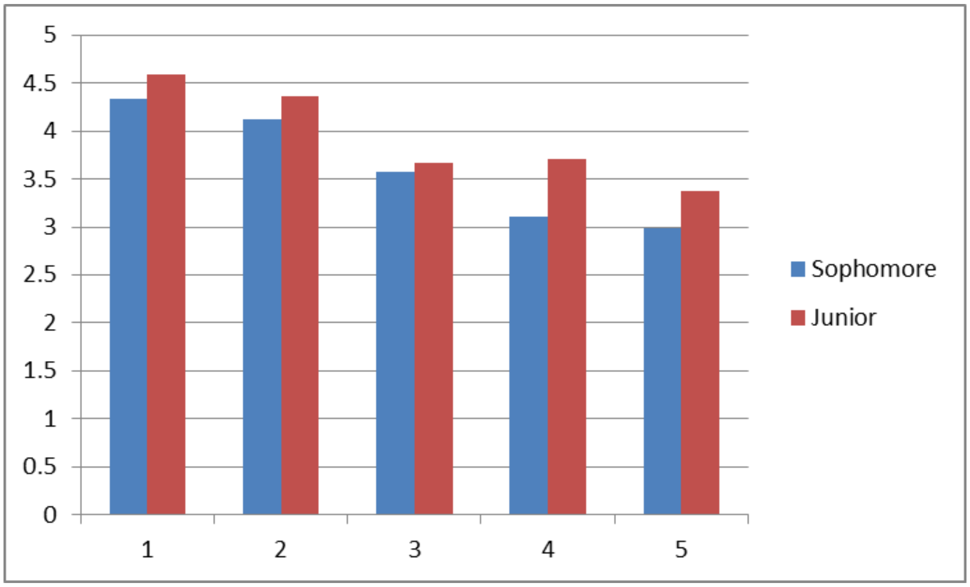

Figure 1: Questionnaire results

4. Conclusion

The goal of engineering education is to prepare students to engineering practice. Therefore, instructional laboratories have been essential part of undergraduate program. Basic skill training can be applied to lab courses on the different stages/years. The content of hands on experience will be different from one major to another, one course to another. But, the objectives can be applied to all engineering courses, or majors. To be able to systematically train students on these skills during their undergraduate study period are important. It is especially true for some integrated curriculum, since the hands on activities are tends to focus more on the content than the skills. It is not easy to maintain the consistence of the instruction when the hands on experience are offered by multiple courses and different instructors. It will help if some simple format objectives, skill list for different level courses were created.

Reference:

[1] L Lin, J. Smith, S. Knittweis. “Combination Unit to Support Instruction in Thermodynamics, Fluid Mechanics and Heat Transfer”. ASEE 2013 conference proceedings AC2013-6647L.

[2] Feisel, and A. Rosa. “the role of the laboratory in undergraduate engineering education”. Journal of Engineering Education. Jan. 2005. P121-130