Journal of Positive School Psychology
2023, Vol. 7, Issue 1
Pp 373-382

Creating positive learning experience for freshmen students through engineering workshop

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Abstract
In the recent past engineering programs have generally reported declining enrollment trends; it is also widely reported that most of the drop-outs take place in the freshmen year. To address these issues Department of Electrical Engineering devised interventions at freshmen level to instill confidence and motivate them about the journey ahead. This module considers project- based activities in active and collaborative mode of learning in small groups.
Engineering Workshop is a well-established course across Engineering Programs; Typically, this module is offered to achieve a multitude of objectives such as familiarization with house-keeping at labs, safety considerations and proper usage of lab instruments. Workshop is a compulsory course at the Department of Electrical Engineering, Sukkur IBA University. This course is a set of laboratory-based activities which introduces students to a wide array of design tools, fabrication processes and techniques which would galvanizes their interest in the engineering program, inspires them to think creatively and make them resourceful to carry out any complex design and development activities later in the program.
This article outlines the learning outcomes, implementation plan, assessment policy and student feedback on the proposed intervention. Student feedback and post execution follow-up have revealed a very encouraging outcome.

Keywords: Active / Collaborative Learning, Freshmen Retention, Engineering Workshop, Maker Space.

Article History:
Received: 19th Apr, 2023
Accepted: 24nd May, 2023
Published: 24th Jun, 2023

1. Introduction:

Engineering Workshop is an essential course of any engineering program, it serves a wide range of purposes. Several instances of workshop practice have been reported in literature. The most conventional reason for introduction of this course at Freshmen level is to provide them with a wide spectrum course tailor-made to develope technical skills and competencies which may be beneficial at later stages of the program.

ELE-121 has been an integral part of the Electrical Engineering degree program since last 10 years. As a 1 credit hour (3 hours lab session per week), this module has evolved considerably from use of various measurement tools and monotonic prototyping of linear circuits on the breadboard to a broad spectrum outcome based course with special emphasis on positive student experience about engineering in general and design and fabrication processes in particular.

The freshmen students entering into the engineering program after completing their high school certificates lack the ability to think analytically, perform assignments / activities which require creativity, let alone the ability to design and fabricate a complex design using modern engineering tools. The newly revamped workshop module is a one stop solution to multiple issues namely retention of engineering students, to make them feel resourceful through exposure to variety of design and development tools and techniques, to galvanize their interest and instill the ability to think creatively.

This article delves upon four key issues (i) impart functional knowledge of modern design and rapid prototyping techniques (ii) stimulate curiosity, creativity and collaboration through active learning framework (iii) enhance the student retention at our engineering program and last but not the least (iv) the over-arching

goal is to improve the campus life experience of freshmen students by allowing them to socialize at the maker space, identifying vulnerable students and taking steps to address their academic / non-academic issues.

This module is still a work in progress. The iterative review and refinement of class activities is underway to strike a balance between academic rigour and effectiveness of learning outcomes.

2. Literature Review

Although Engineering workshop is a corner stone of undergraduate engineering programs around the world, there's a dearth of literature documenting recent trends and approaches adopted by academic community across the globe.

The aims and objectives of this module vary considerably from program to program. According to Nahvi et al (1998), freshmen year is a prime-time slot to motivate undergraduate students, many important ingredients of successful education including motivation, interest, belief in curriculum and desire to carry out assignments is still fresh. According to the authors learning by doing is a more appropriate way of enhancing freshmen experience at EE programs. In some instances this module is offered to all freshmen engineering students to give them a flavor of different specialization areas (Tiwari et al 2018) ; In literature several instances of workshop practice have been reported e.g. in (Kavale et al 2015) authors document a broad-spectrum workshop module for Freshmen students of mechanical engineering program, the authors emphasize that multidisciplinary hands-on course prepares students to work on diverse projects later in the degree program. Authors in (Garcia et al 2012) highlight the concept of "Freshmen Success" and documenting their experience of transition from theoretically rigourous traditional approach to a progressively increasing complexity design and simulation centric approach; authors suggests that project-based and active learning experiences are the best way to introduce new students to engineering discipline. El-Kishky et al (2007) have documented the experiment of including a non-conventional design and development lab i.e. hobby shop course into the freshman curriculum; according to the authors the proposed intervention creates a significant influence on the perception of incoming freshmen students. There exist several instances in literature where program management has devised a series of modules tailored around customized hardware allowing a single hardware / software platform to be used to impart progressively complex concepts spanning across multiple engineering modules. For instance Shuman et al (2008) have developed a simple robotic platform TekBots; this platform is used in consecutive semesters to build further on the concepts of analog and digital circuit design. The authors argue that contemporary engineering programs leave skills for innovative design till the back end of the program. The authors assert that such skills can be taught independent of theoretical concepts. Similar instances have been documented in (Wong et al 2011, Tewolde et al 2016).

Rapid design and prototyping skills are highly desirable for enterprising engineering graduates; in literature there are a few instances where authors impart rapid prototyping skills (more specifically) 3D design and printing skills to Freshmen students; According to Assante et al 2020, 3D design and printing promotes problem solving skills, creates excitement and draws active response from students. The usage of 3D printing is becoming common in Mechanical Engineering. However, extensive usage of such techniques has largely been overlooked in contemporary Electrical Engineering programs.

Only a few use cases of 3D printing at freshmen level are available in literature e.g. Bilén et al (2015) authors have documented a freshmen course where students used 3D design and printing techniques to model rocketry, the authors document that the proposed intervention did enhance the design and experiential learning. In Chiu et al (2015), authors have documented a pedagogical experiment involving a diverse group of freshmen students coming up with concepts of smart home appliances and prototyping them with 3D printers.

The primary focus of this module was to introduce students to the modern computer aided design and computer aided manufacturing techniques with the help of rapid prototyping tools such a 3D printers / scanners, laser cutters, usage of CNC machines for woodwork, printed circuit board design and fabrication; it is really important to provide engineering students with ample exposure to such modern tools. We have devised this intervention to introduce our students to the above listed equipment and to let them appreciate the advantages / limitations, key design considerations and parameters of different tools.

The second goal of this module is to impart Freshmen students with highly desirable attributes such as creativity, critical thinking and teamwork. According to Duffy et al (2010) the most effective techniques to foster key skills such as creativity, critical thinking, communication and interpersonal skills is essentially project-based activities in small groups with student-centered setup. According to authors regular application of these techniques throughout the degree program transforms even un-motivated students to reach higher levels of cognition such as reflection, application and comprehension. Several instances are available in the literature e.g. (Burkett et al 2014) reports the case of open-ended labs asking students to design artefacts like lamps, wind chimes, casing for minicomputer and assembly of DIY AM radio kit; the projects are implemented with reusable materials, according to the authors creative labs are perceived by students as difficult but also enjoyable. Authors of (Khalaf et al 2012) have reported their implementation of cornerstone semester design project with special emphasis on design thinking process. It must be emphasized that to promote the above specified skills, there exist a set of contrasting interventions ranging from expository discourse (Khaki et al 2014) to actively engaging students in engineering design thinking process e.g. (Khalaf et al 2012)

In our execution of this module, the assignment / activities were specifically designed to push students out of their comfort zone to think creatively (individually as well as in small groups), taking inspiration from designs available on the internet, to come up with their personalized artefacts; traversing the process to design the artefact in a suitable software and its subsequent fabrication using applicable manufacturing processes.

The third objective of this intervention is to invigorate the interest of Freshmen students and to excite them about the journey ahead. Declining enrollment and retention rate is cause of concern for engineering programs worldwide. Although there may be a number of reasons for dropouts (especially so for freshmen students) at engineering programs. One of the apparent reasons is the presence of tough courses such a Calculus and Physics in the first semester which shakes their resolve and the interest of many students fades away very quickly. As authors in (Salos-Morera et al 2019) conclude that retention rates in engineering schools has academic and non-academic dimensions such as lack of interesting subjects, lack of practical and project based learning and lack of clarity about future opportunities. According to Tinto et al (2006), (among others) the most significant factors effecting the retention of students at a program are (a) presence of academic and social support (b) opportunity of active participation in academic and social activities, (c) perception of value in what they are learning.

There is no denying that rigorous study of underlying theoretical concepts is important for the students but the management must strike a balance between theoretical rigour and other desirable skills. In this module the outcome-based nature of the lab assignments pressed the students to work in active mode of learning, ideating on their assignments with peers and instructors. The student feedback from past three iterations of this module show that working on challenging assignments and excitement of using modern tools / technologies keeps students enthralled throughout the semester.

The last but not the least aspect of this intervention is to identify students suffering from academic and/or non-academic issues, as these students have just arrived at campus and have a lot of questions / concerns about the academic policies, scholarship opportunities and career prospects; owing to the informal setup of the lab activities allows instructor to interact with students and counsel them through the uncertain period right at the start of the semester.

To the best of our knowledge the composition of such a Engineering workshop course at Freshmen level is not available in the literature. The proposed activity is although multi-dimensional and requires students to spend considerably more time to execute assigned activities. However, survey results suggest that proposed set of activities have been received very positively by the students.

Motivation:

Engineering Workshop ELE-121 is a cornerstone of Freshmen year at the Bachelor of Electrical Engineering program at the Department of Electrical Engineering. The course provides an opportunity to introduce students to the fundamentals of safety of lab equipment and wellbeing of people working in the lab and etiquettes of using electrical engineering lab equipment and workspaces. This course has been recognized as an opportunity to re-invigorate the interest of freshmen engineering students and to stimulate their creativity and curiosity; letting them see what an engineer can do when they have contemporary skills / equipment at their disposal.

It's an established fact that enrollment at Engineering programs in general and Electrical Engineering programs in particular has declined considerably over the past few years. It is also a fact that those students who enroll at Electrical Engineering program loose their interest and become disenfranchised in their Freshman year because what they had in mind was a hands-on activities and exposure to new skills while what they actually receive is an overdoze of mathematics and humanitarian courses. From survey at our program, it has become apparent that majority of drop-outs take place in the freshman year.

This workshop also presents itself as an opportunity for school visits (open house events); allowing the organizers to introduce aspiring students to the hands-on activities being carried out at the department of electrical engineering.

The lab also invigorates the maker culture among the students while giving them a comprehensive exposure to design processes and techniques. The workshop also is an ideal setup for shared learning, in an informal and fun-filled environment.

3. Curriculum Design and Implementation

This is an outcome-based learning module, every lab component of this module is designed with a specific learning outcome. The specific list of assignments/activities are enumerated in Table 2. Some of these activities span upto 3 weeks. While some of the activities are performed individually, others are performed as group activities. As a requirement for evaluation each student is required to submit his/her own report and document the processes and techniques applied to carryout the assignment.

Learning Outcomes:

This is a hands-on module which touches a broad base of program learning outcomes under the framework of Washington Accord. The specific course learning outcomes of this program are presented in Table 1.

Table 1: Specific class learning outcomes of ELE-121 (Fall 2021 Semester)

CLO	WA PLO	Domain & Level of attainment	Description
1	3	Cog-3	Demonstrates ability to design mechanical drawing using CAD software.
2	5	Cog-3	Demonstrate ability to use modern tools including 3D printer, CNC router and PCB milling machine.
3	8	Aff-2	Demonstrate the cognizance of ethics in utilization of lab facilities.

The specific learning outcomes of Washington Accord addressed through this module are:

Design and Development:

Design and Development is an indispensable component of the Program Learning Outcomes under the framework of Washington Accord. The students must have the ability to design and fabricate electrical/ electronic circuits, mechanical designs with varying specifications. The module in entrenched in computer aided design and fabrication techniques as these techniques are widely used in industry.

Modern Tool Usage:

Usage of modern design and fabrication tools such as 3D printer/scanners, laser cutters, CNC for woodwork and PCB design are instrumental for rapid design and prototyping process; these skills are highly desirable from employment stand point of view. Through this module the students are provided an immersive

experience of using modern design and fabrication tools.

Professional Ethics:

Another important attribute of program learning outcome considered for this module is the Professional Ethics, Although Professional Ethics is a vast topic this module specifically concerns itself with etiquettes and attributes of students and how they carry themselves in the lab environment which includes careful handling of lab equipment and frugal utilization of consumable lab resource.

Table 2: The week-wise breakup of Lab activities (Fall 2021 Semester)

Week	Lab Activity
0	Health & Safety in Lab Environment
1	Electrical Measurement Tools
2	Domestic Wiring
3	Vinyl Cutting
4-6	3D Design/ Printing and Scanning
7	1st term Assessment
8	Laser Cutting
9-11	CNC Woodwork
12	PCB Design and Fabrication
13	2nd term Assessment
14-15	LFR Assembly and Operation
16	Finals

The lab activity material is provided through LMS portal and students are required to submit their reports through the same. The assessment of submitted reports is performed through standardized rubrics, while the behaviour of students was observed through tally sheet as they performed the lab activities.

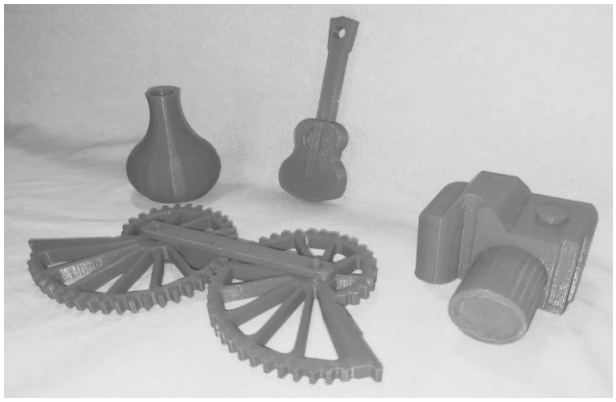
The very first session of this module was dedicated to lab tour, housekeeping, creating awareness about hazards, hazard perception, risk assessment and etiquettes of using lab equipment and workspace.

The measurement tools lab helps student to appreciate the importance of measurement units and applications of various measurement tools such as digital multi-meter, LCR meter to measure resistance and capacitance of rated components and use Oscilloscopes, fixed and variable power supplies and waveform generators to generate and measure various DC and AC signals. The activity impressed upon students the concepts of absolute / relative error and various properties of AC signals.

During the domestic wiring activity the students learned to assemble electrical circuits on switch board panels, dependency between wire gauge, current and length of conductors, techniques to troubleshoot the circuits and calculation of power consumption of different appliances was considered. In the 3rd session of the workshop students were introduced to the process of creating decals using vinyl cutter machine. As an assignment the students were asked to create a small decal for their own artefacts.

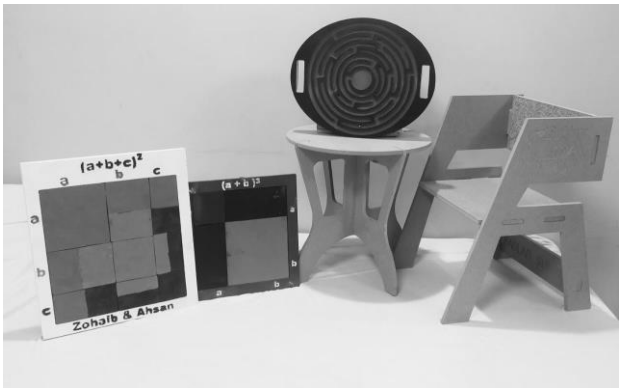
In the next lag of this course the students were introduced to Sketchup software for 3D design and its subsequent printing. The students were taught to create 3D models from orthographic designs; as an assignment all of the students were asked to design and 3D print any artefact of their choice with size not exceeding 125 cm3. With the help of teaching staff the students traversed the process of verifying their designs in the slicing software, use adequate build-parameters to generate files necessary for 3D printing. This concise activity not only helped students use CAD software to design 3D objects with mechanical accuracy but also let them appreciate the strengths and limitations of 3D printing process. The students were also introduced to the usage of low-cost portable 3D scanners to scan their own sculpture.

Figure 1: Sample specimen of student assignment for 3D design and printing assignment.



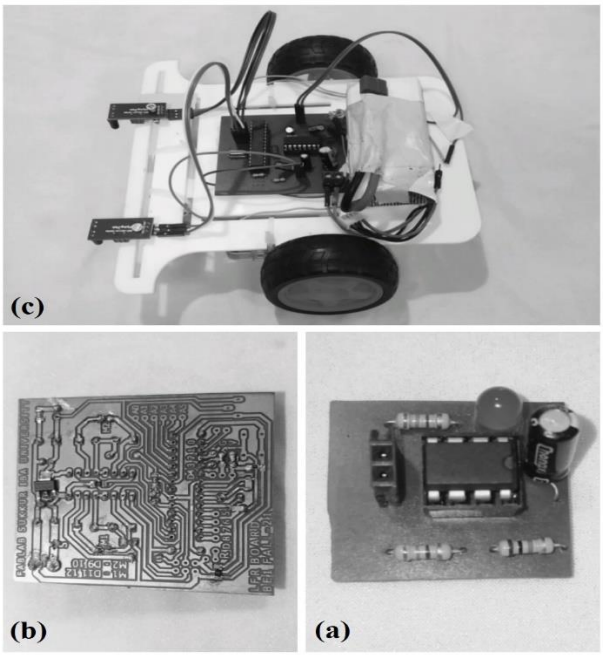
In the next lag of the module, students were introduced to woodwork activity; the students were introduced to the workflow of CNC wood and power tools available in the workshop. The students were asked to create a small wooden artefact as a group of two (2) by taking interesting design ideas from internet. The students had to ideate the design, making precise machinal drawings on paper, using computer software and/or power tools as desired. The students were also introduced to the workflow of laser cutter to let them appreciate the usage of this powerful machine.

Figure 2: Sample specimen of student assignment for Woodworking assignment.



In the final lag of this semester students were introduced to the workflow of printed circuit board design using Eagle software. As a first assignment students learned how to design a simple LED flasher based on 555 timer IC. As a part of the activity the students went through the process of designing the electrical circuit, placing components on the board layout, routing and fabricating PCB, soldering components and troubleshooting process. The module culminated in students assembling a pre-programmed line following robot. Without delving into the details of the software the students had to populated the PCB assemble the rover and make it to work as desired.

Figure 3: Sample specimen of student assignment for PCB design (a) Design and Fabrication of LED Flasher circuit with 555 Timer IC (b) Soldering of Atmega328 and L298 based circuit for a line following Robot (c) Complete assembly of a Line Following Circuit.



In our assessment, the students are introduced to a broad spectrum of new tools, techniques and workflow through this module which makes them resourceful to carry out design assignments and activities during later semesters.

Assessment Policy and Results

This is a 1 credit hour course which means a 180-minute session in the lab every week. The assessment policy of the module is tabulated below:

Table 3: Weightage of assessment activities in ELE-121

Term-1	Term-2	Finals	Performance	Lab Manual	Total
5	5	10	10	20	50

Two task-based assessments (namely 3D Design with Sketchup and PCB design with Eagle) were held as per examination policies of the university, while the final assessment consists of MCQs covering underlying theoretical concepts followed up by viva-voce.

The assessment of design and fabrication skills (CLO 1 & 2) is performed through the term exams and lab reports while CLO 3 is evaluated through standardized rubric; Detailed feedback was provided to students on their report submissions.

A separate component of assessment policy was attributed to assessment of students ethical behaviour. This assessment was performed using a tally sheet (refer to table 4) across certain labs.

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Table 4: Specimen tally sheet for assessment of CLO-3

	CLO-3 Affective Domain Criterion: Criteria a. Frugal utilization of the consumable items, etiquettes of using lab resources. Criteria b. Demonstrate cognizance of ethical and safe behaviour during conduct of lab activities.									
	Name of Student	Electrical Measurement tools		Domestic Wiring		CNC Woodwork		PCB Design		Total Marks
		crt. **a**.	crt. **b**.	crt. **a**.	crt. **b**.	crt. **a**.	crt. **b**.	crt. **a**.	crt. **b**.	10

Reports

Each student is required to submit a detailed report providing meaningful documentation of implementation of the tasks and reflecting on the lessons learned and how would they go about the task if they had to start over. This is a great opportunity for instructors to help students improve their technical writing skills, presenting their findings in an organized manner with emphasis on the proper use of graphs and images.

Results and Student Feedback:

The response and feedback to this intervention has been tremendous. The feedback of students was taken through an end of semester feedback survey. The questionnaire form and the statistics of student survey are presented in Table 5.

Table 5: End of semester survey form Fall 21 (34 Participants).

Survey Performa	SA	A	N	D	SD
Your interest in Engineering Workshop at the start of the semester.	15	12	7	-	-
Your interest in Engineering Workshop at the end of the semester.	25	6	2	1	-
You feel resourceful with design and development skills presented in this module.	18	15	1	-	-
Do you feel confident about your 3D design and fabrication skills.	26	6	2	-	-
Do you feel confident about your woodshop design and fabrication skills.	22	9	3	-	-
Do you feel confident about your PCB design and fabrication skills.	21	11	2	-	-
Do you think this course made you to think creatively and to try new solutions.	19	14	1	-	-

4. Discussion

The student feedback on this endeavor has been extremely encouraging. Almost all of the students appreciated the hands-on and outcome-based nature of this module. According to student feedback obtained through standard feedback form, almost all the participants felt that their interest in their studies improved after completion of this module. All of the participants felt more resourceful and capable to carryout engineering design and development activities after completing this module.

Table 6: Student retention trends after first semester (2018 – 2021).

Year	18-19	19-20	20-21	21-22
Admissions	68	39	47	42
Retention	55	34	41	35

The intervention was adopted from the fall of 2019, it is apparent that over the past 3 years the retention rate has improved. The module organizers encountered time management issues due to limited allocation of time to perform assignments and firm deadlines for submission of reports, one of the common issue is large number of students wanting to use same set of equipment at the same time; other issue was students choosing overly ambitious / inconsiderate design activities; instructors try to minimize these problems by providing explicit guidance about every assignment and following it up with close coordination with students throughout the semester.

5. Conclusion

The proposed intervention has been a very positive experience. The informal setting provides a platform for collaborative and active student learning, where students with apriori exposure to these techniques tend to refine their skills further, at the same time instructors ensure that the novice students also achieve functional know-how. The activity has clearly pushed the Freshmen students to think creatively; the carefully devised content introduced them to a diverse set of skills. Exposure to contemporary tools and their workflow through stimulating assignments / activities early in the program has accrued positive attitude and enthusiasm among the students.

6. Acknowledgement

The authors would like to thank the Department of Electrical Engineering Sukkur IBA University for providing necessary resources and logistical support to carry out this course.

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