Project Workshop to Enhance Project Based Learning in the Statics Course

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Abstract

The statics class is usually offered as a lecture-based course in a mechanical engineering curriculum. Active learning methodologies and projects are often used to enhance the student learning outcomes. While active learning can be achieved in the classroom, projects need an outside space for collaboration and prototype building. Students in the statics course at our university have had access to a project workshop for two successive semesters. We present discussions based on students' work who used our project workshop. Sample student projects are presented to give a flavor of the concepts tested in the statics class. In this paper we describe that such a safe and non-intimidating facility can be an excellent resource to support project-based learning in lecture courses.

Introduction

Statics is a foundational course in the Mechanical Engineering undergraduate degree program. It is offered as a lecture-based course at our university. While active learning methodologies [1] have been employed in the course, a project-based learning component was introduced in 2016 to further enhance the student learning outcomes.

The learning experience in the course includes foundational theory and problem-solving. Additionally, project-based learning (PBL) fosters collaboration and investigation while students think about important questions on a subject [2]. In the professional life of an engineer, most tasks pertain to working on projects where an engineering solution is attained within a time constraint. Therefore, even during their engineering education, it is valuable to develop project work experience.

In mechanical engineering courses there are several opportunities to introduce project-based learning. Yet, for successful completion of projects that require a physical prototype, students need space and resources (tools). The project workshop [3] in the mechanical engineering department at our university is a facility developed to provide our students with an environment where they can build physical prototypes for their course projects. At the outset we mention that though our project workshop facility incorporates the maker culture: "a philosophy where individuals or group create artefacts that are rebuilt and assembled using software and/or hardware" [4], it functions differently from that of a makerspace, hackerspace, or FabLab.

Fundamentally a makerspace is an open-ended environment where ideations can materialize to prototypes through diverse peer-to-peer interactions and learning. Our project workshop is similar to an engineering workshop or a machine shop where engineers go to fabricate their already designed and engineered prototypes. The distinction between a typical engineering workshop and makerspace is discussed in the article by Youmans [5]. In Youmans work students' perceptions of limitations (access and safety) of engineering workshops are presented. We discuss how those limitations are addressed in our project workshop. The project workshop [3] concept in the department is to provide students with space and resources that they can use to fabricate physical prototypes after all the engineering and purchasing is complete.

Project workshop

The project workshop is a 2850 square-foot space shown in Fig 1. It provides a safe and inviting work environment for all students to work with tools for sheet metals, soft metals, wood, or plastics to fabricate parts and/or assemblies. In Fig. 2 some sample tools that are housed in the facility are shown, and a more comprehensive list of is available at the project workshop webpage [3]. The facility also has computer workstations with engineering design software.

The major factors that educational institutions/engineering departments consider when trying to operate an engineering workshop are the cost associated with the personnel required to maintain operation, the cost associated with the equipment and supplies, and safety considerations.

Regarding personnel, the workshop is currently run with two student workers and a supervising professor. The student workers are employed, where each student works about 12 hours per week. The supervising professor manages the weekly operation of the workshop and offers office hours in the workshop as part of their overall teaching load.

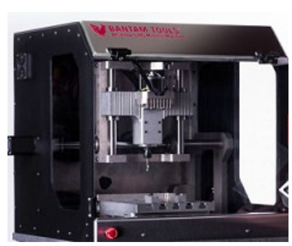
The project workshop was developed with the support of students in the department that it currently serves. Specifically, an individual instruction “Shop Design” course was offered in the spring and fall semesters of 2022 and 2023, where registered students engaged actively in setting up the workshop and selecting the equipment. The equipment selected by the students was procured gradually based on the availability of funds. As for supplies, the course projects require that students set a limited budget and create their engineering designs based on materials within their budget. They purchase their own materials per demand from their own engineering drawings. No materials are stocked or supplied in the workshop except for essential equipment consumables. The cost associated with the employment of student workers and the essential shop supplies are borne by the mechanical engineering department. These costs fall within the overall maintenance and operational budget of the department.

While the cost of starting and operating a project workshop can be excessive in relation to available budgets, it is important to note that the workshop presented in this paper can have a slow start with a commitment for growth. First, space is needed, then tools (shop vac, vice, hacksaw, measurement tools, wrenches, set of screw drivers, a chisel set, hand drill etc.) for simple projects can be added in stages. Once the workshop is operational with such modest equipment, additional manual equipment such as a table saw, chop saw, drill press, table-top mill, table-top lathe, router, sheet metal shear, sheet metal brake, riveting guns, injection molders, and CNC equipment can be procured as the budget allows over time. Additional costs associated with lab supervision can be factored in when newer equipment is added to the workshop. At our department we have addressed that by employing student workers with a faculty member mentoring/assisting those students and providing overall supervision of the workshop.

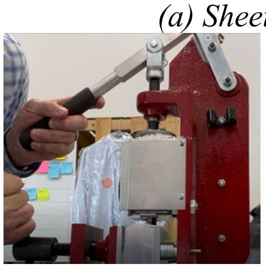
As for safety, students are required to complete four training modules. These are general safety, shop safety, personal protective equipment, and machine shop training. Most of the tools available in the workshop are equipped with safety features. Each tool/station has a user manual written by students for future students and posted on the workshop's webpage [3]. Much of the content available on the webpage, was developed by students in the department. The students are allowed to use this equipment without supervision as long as two or more people are present in the workshop. Other tools have locks on their power cord, and they are accessible only in the presence of the supervising professor. The schedule of the supervising professor and the student workers are made available on the webpage. The rules for the workshop are clearly posted, and students are informed of the continuous video recordings of the workshop. Moreover, audits of the equipment are performed routinely by the safety staff of the university and the workshop is next to a high-traffic corridor where most of the workshop is completely visible from the outside (Fig. 1).

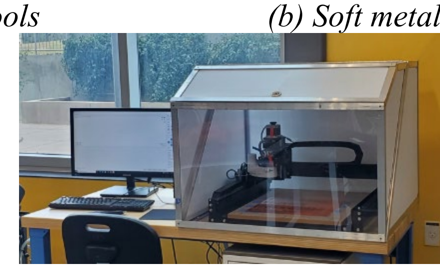
Fig. 1, Project Workshop

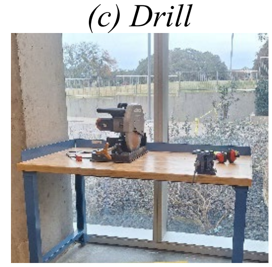

(a) Sheet metal tools


(b) Soft metals mill


(c) Drill


(d) Injection molder


(e) CNC router (housing by the students)


(f) Chop saw

(g) Hand tools *(h) 3D printers* *(i) Scroll saw*

Fig. 2, Some Equipment in the Project Workshop

Project workshop and makerspace (subtle but important differences)

In our introductory section we mentioned that our project workshop differs from a makerspace. Makerspaces are invaluable facilities that serve to stoke creativity in future engineers [6] but a facility like our project workshop primarily serves to educate students on the methodical (disciplined) fabrication aspect of engineering.

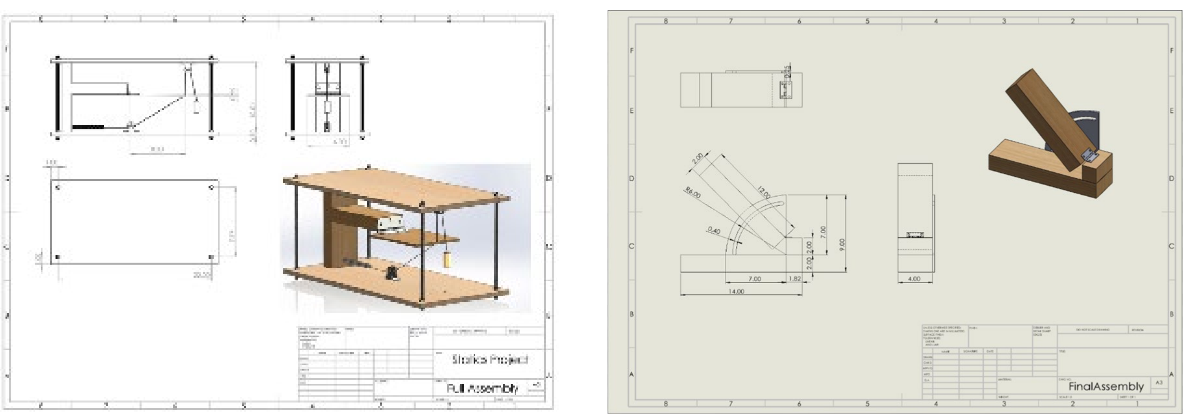
At a project workshop students are expected to walk-in with engineering drawings, materials supplies, adequate preparation about the tools that they will use to fabricate their part, and factor in the time commitment to getting it done. After fabrication, students are expected to gather up their materials and leave a clean workspace for others to use. In essence, while makerspaces are primarily exploratory environments, the project workshop is primarily a protype fabrication environment. There are a wealth of articles highlighting the merits that makerspaces play in the education of future engineers [7-8]. It is noted that the engineering school at our university has a makerspace and a fully equipped machine shop as well. While parts and projects can be fabricated in makerspaces, we strongly believe that a project workshop aids students uniquely in an engineering department. When a project is assigned in a course, students in the department have in the project workshop a facility that primarily caters to the fabrication aspects of their projects. Thereby, it is a valuable complement to the educational mission of the department. In the next section we describe the project-based learning component in our statics course and illustrate the merit of the project workshop to the student fabrication needs.

Project-based learning in the statics course

Project-based learning (PBL) in traditional engineering courses is often introduced with project components along with traditional lectures as reported by Mills and others [9]. The statics course in our department is a lecture-based course with a project-based learning component. Typically, the project is introduced halfway through the semester. Students, in teams of three to five, are tasked to build a demonstration set-up that illustrates a concept that they have learnt in the statics class, and they are required to produce actual measurements. The topics that are covered in the course are particle equilibrium, rigid-body equilibrium, structural analysis, internal forces, friction, centroids and moment of inertia. While the project problem statement is open-ended, the overall size of the set-up (<2 cubic foot) and functional requirements are specified to the students. For example, the fixture must allow testing the concept in multiple configurations, so the setup is interactive in a live demonstration to the class.

The project component is assessed based on three deliverables namely (i) demonstration proposal, (ii) critical design review, and (iii) project presentation and report. For the first two team deliverables, teams meet with the instructor/TA. Demonstration proposal is a deliverable where the teams present their plans along with a brief description of the statics concept that they intend to demonstrate with their set-up. Projects are approved when the instructor/TA deems to be within the scope, and it is not a repetition of a project by another team. During the critical design review, teams present their engineering drawings (samples shown in Fig. 3). They also present free body diagrams, sample calculations, and describe the variations of experiments that they will conduct with their set-up.

During these meetings, teams also discuss their plans for fabrication. Within a diverse group of students in a typical classroom, teams have the option to choose facilities such as makerspace and even tool-equipped garages in addition to the project workshop. It is noted that until the critical design review stage of the project, teams are expected not to initiate fabrication or purchasing of materials. We emphasize that the PBL component in the statics course is directed through these stages and the “build phase” is the last stage of the project. Since students build their prototypes after engineering work is complete and the raw materials are purchased, we believe that the project workshop becomes a more suitable facility for their project fabrication needs.



(a) Moment balance demonstration setup *(b) Friction demonstration setup*

Fig. 3, Sample student drawings

The PBL component in the statics course has been offered since the year 2016 at our department. From a pedagogical perspective PBL component allows students to synthesize and evaluate the subject material that would not otherwise be possible with mere classroom lecturing. Student feedback on the PBL component has been overwhelmingly positive. It is noted that total student enrollment in the statics course in a fall semester could be in the range of 150 students in multiple sections. Typically, a single section will have a maximum of 60 students. When teaching multiple sections, the instructor has had up to thirty projects during a semester. Though we introduced the PBL component to our statics course in 2016, from Fall of 2023, students have had access to the project workshop to work on their statics course project. In this work, we have considered student projects from the two semesters Fall of 2023 (one section, 12 project teams) and Spring of 2024 (one section, 10 project teams). Table 1 lists the number of teams that used the project workshop to fabricate their projects, and the various statics concepts studied through those projects. In Fig. 4 sample fabricated projects are shown.

Table 1, Statics Projects in the Project Workshop

Semester	Enrollment	Teams that used the project workshop	Statics concept studied
Fall 2023	59	6	• Moment balance • 3D particle equilibrium • Friction • Pulley system • Support reactions
Spring 2024	42	3	• Moment balance • Mechanical advantage

(a) Moment balance system *(b) Friction system* *(c) Pulley system*

Fig. 4, Sample Statics Projects (Fall 2023)

These sample projects illustrate that simple prototypes can be fabricated employing tools in a project workshop. Prior to the availability of the project workshop students often resorted to fabricating such set-ups over a weekend at someone's home or dorm room with various degrees of fabrication success. We realize that the facility indeed caters to those students who need a functioning workshop environment to work on their course projects.

Conclusions

In this paper we have presented the details of a project workshop that aids engineering students to fabricate their engineering course projects. At our university, students have accessed the facility for their statics course projects. We summarize that the project workshop offers an alternative option to machine shops or makerspaces. With the availability of such facilities, it is possible to effectively inculcate project-based learning in engineering courses. Since access to machine shops can limit scaling to large classes and even intimidating for undergraduate students, especially those in the early semesters of their degree programs, the project workshop offers students an inviting and non-threatening environment to work on their projects.

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