Paper ID #49554

Laser Cutters versus 3D Printers for Mechanical Engineering Projects

Dr. Dani Fadda, University of Texas at Dallas

Dr. Fadda is Professor of Practice in Mechanical Engineering. His background includes professional engineering practice in the energy industry and teaching in higher education. Dr. Fadda has worked in product research and developed patented products for chemical, petrochemical, and nuclear applications. He is a professional engineer in Texas and involved with professional organizations.

Dr. Wooram Park, University of Texas at Dallas

Wooram Park is a clinical associate professor in the Department of Mechanical Engineering at University of Texas at Dallas. He is interested in education of engineering students with the emphasis on robotics and control systems. His research mainly concer

Dr. P.l.stephan Thamban,

Dr. Thamban is an associate professor of instruction in the Mechanical Engineering department at the University of Texas at Dallas who contributes to the teaching mission of the department. He brings with him more than a decade long teaching experience and teaches foundational, introductory ME undergraduate courses and advanced mathematics courses for undergraduate and graduate students. He values and incorporates project-based learning components in undergraduate courses.

Dr. Oziel Rios, University of Texas at Dallas

Dr. Oziel Rios earned his Ph.D. in mechanical engineering from the University of Texas at Austin in 2008 where his research focused on design of robotic systems with an emphasis on kinematic and dynamic modeling for analysis and control. Dr. Rios teaches the first-year and CAD courses in the Mechanical Engineering Department at the University of Texas at Dallas. Dr. Rios has also taught courses on Geometric Dimensioning and Tolerancing (GD&T), kinematics and dynamics, and graduate-level CAD courses. Dr. Rios' research and teaching interests include: robotics, design, GD&T, and engineering education.

Session XXXX

Laser Cutters versus 3D Printers for Mechanical Engineering Projects

Dani Fadda, Wooram Park, PL Stephan Thamban, and Oziel Rios
Mechanical Engineering Department
The University of Texas at Dallas

Abstract

The use of laser cutters versus 3D printers for mechanical engineering projects is discussed in this paper. Projects with a physical build are often included in lecture-based classes and 3D printing is a viable option to efficiently fabricate plastic models for the prototypes. 3D printing is also an attractive fabrication option to students because they learn to create solid CAD models that are ready for 3D printing during their first year. However, 3D printers are often overused or misused when students print readily available components or structural components. Making a platform by drilling a few holes into a flat plate can be dismissed from the student's design considerations due to the ease of use of 3D printers and their hands-off nature (i.e., they can start a print and leave). The objective of our research is to evaluate the impact of introducing laser cutters in the first-year mechanical engineering program as an intermediate link between 3D printing and traditional manufacturing. The precise and fast laser can cut into thin flat plates allowing the students to think about designing parts in the flat and building more traditional assemblies. The use of 3D printing remains attractive, but it should be reserved for parts with complex geometry.

Introduction

Projects are given across several mechanical engineering courses to enhance the learning experience and help the students work together to attain an understanding of difficult concepts. Such projects and project-based learning have benefits reported in the literature [1]. When implemented well, the projects can have a significant impact on engineering students [2] with excellent value [3]. The projects can include physical prototypes in addition to simulations and virtual prototypes [4]. When physical prototypes are needed, the affordability of 3D printers makes rapid prototyping an attractive option since students can use 3D printers in their rooms or at the university. However, students can get too comfortable with 3D printing and often over-rely on the available printers to the point of misusing them. It is common to see a student printing a box, a pipe, a flat plate, a bracket, a bearing, or other items which are readily available online or at a store.

Purchasing raw materials seems to be obsolete in the student's mind because using traditional manufacturing devices, such as saws, drills, mills, and lathes, which are typically available in a workshop, makerspace, or machine shop, can be messy and time consuming due to training requirements. 3D printers are also attractive to students because they are hands-off since once a print job is started, students can leave to work on other things. Additionally, using traditional manufacturing methods may lead to parts not working correctly when the students manufacture complex assemblies or they don't apply or have experience with dimensioning and tolerancing.

In our engineering program, we have introduced laser cutters and found them effective in bridging a gap between additive and traditional manufacturing. The laser cutters offer the students a way to cut wood or acrylic flat sheets quickly and accurately. They help the students to create parts and think in more depth about their dimensions and assemblies.

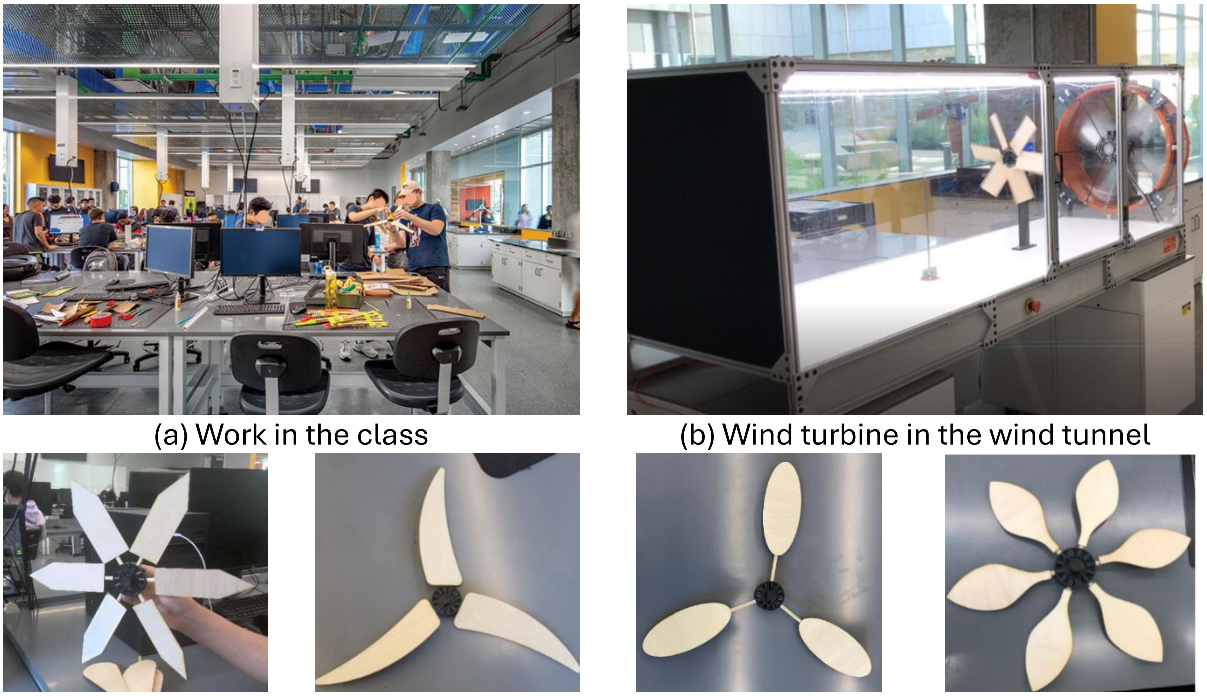
Projects in the first-year introduction to mechanical engineering class, the second-year statics class, and the third-year kinematics and dynamics class are presented in this paper. The use of a project workshop with traditional tools, laser cutters, and 3D printers to support course projects is highlighted along with the advantages and disadvantages of implementing laser cutters and 3D printers. Examples of the work by the students are also presented.

Introduction to Mechanical Engineering Class

The first-year Introduction to Mechanical Engineering class is offered in a flipped classroom modality [5]. The meeting time is weekly in-person for 100 minutes [6] while all lectures have been converted to online modules with videos that are watched before the meeting time. The class time is used for individual and group activities with the faculty and the teaching assistants. The class has multiple activities that span between 1 week and 4 weeks of the semester. Laser cutters are used in this class to fabricate prototypes for different activities. These cutters work quickly, and they are preferred over 3D printers due to their speed. Specifically, 50 students in each section of the class are grouped to design and fabricate their prototypes themselves during the class time.

Wind power generation is one activity that spans over four weeks of the semester. The students are introduced to the Betz limit and efficiency calculations in online lectures. They learn to perform calculations and generate engineering plots using Excel. They are asked to design their own wind turbine blades to generate maximum power for wind speeds less than 10 miles per hour (4.5 m/s). An AutoCAD tutorial is provided, and the students create AutoCAD drawings of their blades that are suitable for laser cutting. A laser cutting tutorial is provided and the students use the laser cutters to cut their blades from provided wood sheets. They assemble the blades as shown in Fig. 1 (a) and test them in a wind tunnel shown in Fig. 1 (b), which was designed and built by senior students as part of a capstone design class. Finally, a report is required to summarize the work done to design the blades, the calculations, and the results. The wind tunnel gives digital data for the power generated for students to postprocess. Bragging rights are given to teams with the blades that generate the highest power. Sample blades are shown in Fig. 1 (c to f).

Students cut their own blades and get familiar with operating laser cutters during this activity. They see that accurate cuts can be made in less than a minute. They learn to think about the assembly, which is required after cutting the blades. This includes attaching the blades to dowels and deciding on the blade angle while attaching the dowels to the provided hub. The requests by students to use laser cutters beyond the first year indicate that students appreciate this tool and like to use it. However, since 3D printers are abundantly available, some students also decide to 3D print their blades.



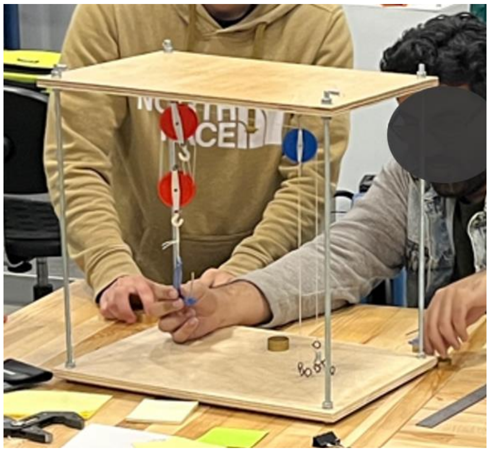
(a) Work in the class (b) Wind turbine in the wind tunnel

(c) Sample 1 (d) Sample 2 (e) Sample 3 (f) sample 4

Figure 1. First-year wind power design challenge

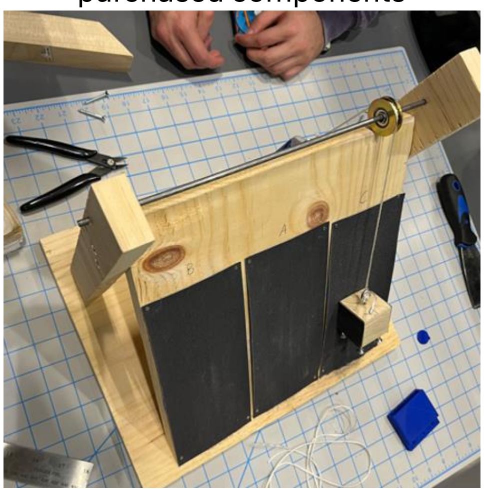
Statics Class

The statics class is lecture-based and covers traditional topics such as particle equilibrium, rigid-body equilibrium, internal forces, friction, centroids, and moment of inertia. An open-ended project is deployed in the class where students are divided into groups of five and the teams are asked to build a physical prototype that fits within a 2 cubic foot volume. Within this space, they can use pulleys, springs, beams, weights, etc., to physically demonstrate any concept taught in the class to their classmates. The project is launched approximately in the middle of the semester with three team deliverables, (i) demonstration proposal, (ii) critical design review and (iii) project presentation and report. The project has been included in the Statics course since the Spring semester of 2016. Approximately 60 students (12 teams) complete this project during a typical fall semester.

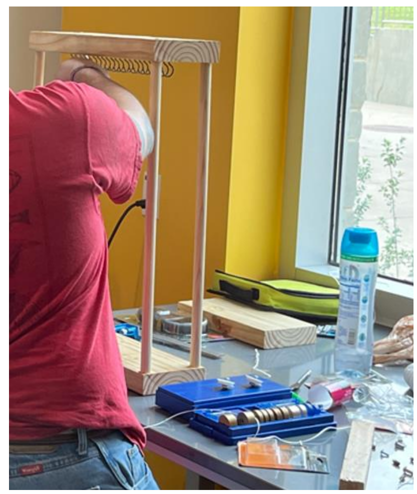


(a) Pulley system with woodwork and purchased components

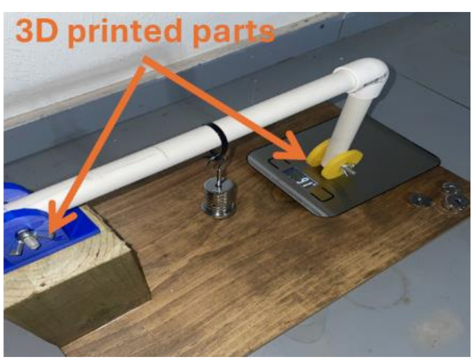
(b) Moment on a scale with woodwork



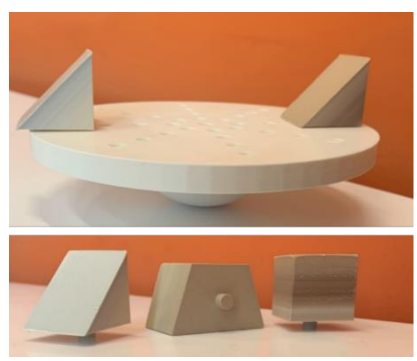
(c) Friction test



(d) Hooks for attaching weights



(e) Reaction forces with 3D printed parts, purchased components, and woodwork



(f) Centroid project completely 3D printed

Fig. 2, Statics course project

The students are guided to Laser cutters, 3D printers, and wood-working tools that are available in the fabrication facilities on campus such as the Project Workshop, Makerspace, and others. The student teams interact directly with the TA/instructor to get their project proposal approved and their critical design report reviewed. During the review, teams present their fabrication plan. They often consider 3D printing to fabricate their entire project or most of their parts. Laser cutting has rarely been proposed except for a few instances where truss members were laser cut. The instructor/TA provides the teams with suggestions on how the design can be fabricated more effectively. While 3D printing offers the ability to make certain parts that are difficult to fabricate in a relatively cheap and in a short amount of time, they need not be employed all the time.

There are several instances where the instructor/TA found the choice of 3D printing unnecessary. In Fig. 2 (a to d) we present sample projects that illustrate these. The use of 3D printing to fabricate wheels and brackets is shown in Fig. 2 (f). The exclusive use of 3D printing is shown in Fig. 2 (f), where the shown platform and objects are completely 3D printed.

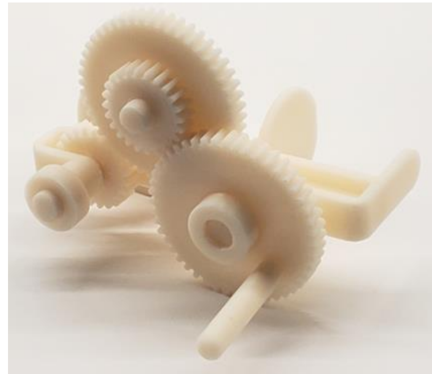
Kinematics and Dynamics (K&D) Class

The K&D is a 3-credit hour lecture-based course (Fig. 3, a) and a 1-credit hour lab for junior students in the ME department. Students are given an open-ended design project where they implement mechanisms for small machines or mechanical devices. In the project, they choose a design topic with mechanisms where they design and fabricate a working prototype. For fabrication, 3D printing is offered at no cost. However, students have the freedom to use other methods such as cutting, gluing, and drilling materials.

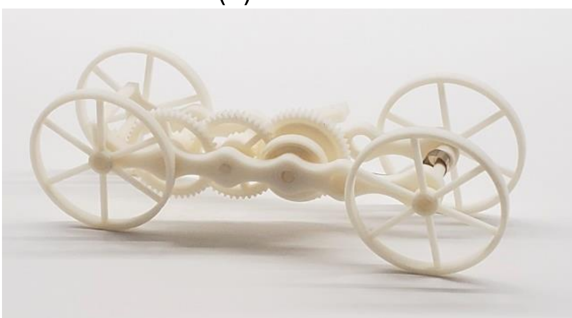
In the design project, the students learn the benefits and disadvantages of 3D printing. Although some groups make prototypes using only 3D printed parts (e.g. Fig. 3, b), many other groups use simple alternative methods to make parts for which 3D printing is not the best choice. For example, the design in Fig. 3 (c) includes a metal sheet spring and Fig. 3 (d) shows a wooden frame design that the student group manually cut using a saw and glued. Some student groups also choose to use laser cutting to make wooden base frames that hold the more complex 3D printed components as shown in Fig. 3 (e and f).

The 3D printers are made available to the kinematics and dynamics students for the class project and the students choose 3D printing to fabricate complex parts. While some assemblies include only 3D printed parts, others include parts made with traditional manufacturing and laser cutting. The students demonstrate an excellent ability to design and fabricate their assemblies.

(a) Lecture



(b) Completely 3D printed design



(c) 3D printed parts with metal sheet spring

(d) Saw cut frame and 3D printed parts

(e) Laser cut wooden frame with 3D printed components

(f) Laser cut base and 3D printed components

Fig. 3, Kinematics and dynamics open ended project

Conclusions

Introducing the laser cutters in a first-year mechanical engineering program allows students to fabricate prototypes quickly during class time. This helps them to better understand the assembly process even in the upcoming courses that they take in the curriculum. The laser cutters seem to bridge a gap between 3D printing and traditional fabrication. We find that even when our students use 3D printing, later in the curriculum, they continue to use laser cutting and traditional manufacturing techniques.

References

1. Kokotsaki, D., Menzies, V., & Wiggins, A., 2016, "Project-based learning: A review of the literature," Improving Schools, 19(3), 267-277. https://doi-org.libproxy.utdallas.edu/10.1177/1365480216659733
2. Peters, A. W., Tisdale, V. A., and Swinton, D. J., 2019, "High-impact educational practices that promote student achievement in STEM," In Broadening Participation in STEM: Effective Methods, Practices, and Programs (pp. 183-196). Emerald Publishing Limited.
3. Lechasseur, K., Wobbe, K., and Stanlick, S.E., 2024, "Beyond PBL: The Value of Stacking High-Impact Practices," ASEE Annual Conference & Exposition, Portland, Oregon. https://peer.asee.org/46647
4. Rios, O. and Fadda, D., 2019, "Using Computer Simulations in a Freshman Mechanical Engineering Course to Make Informed Design Decisions," 126th ASEE Annual Conference and Exposition, June 15 - 19, 2019, Tampa, Florida, USA
5. Thamban, PLS., Fadda, D., and Rios O., 2023, "Teaching a Developed First-Year Flipped Classroom," Proceedings of the ASME International Mechanical Engineering Congress & Exposition, Technical Paper Publication: IMECE2023-113991, October 29 – November 2, New Orleans, LA, USA
6. Rios, O. and Fadda, D., 2017, "A Mechanical Engineering Activity-Based Freshman Course," Proceedings of the ASME International Mechanical Engineering Congress & Exposition, IMECE17-72537, November 3-9, Tampa, Florida, USA

DANI FADDA, Ph.D., P.E.
Dr. Fadda is Professor of Practice in Mechanical Engineering at The University of Texas at Dallas. His background includes professional engineering practice in the energy industry and teaching in higher education. Dr. Fadda has worked in product research and developed patented products for chemical, petrochemical, and nuclear applications. He is a professional engineer in Texas and involved with professional organizations.

WOORAM PARK, Ph.D.
Dr. Park is Associate Professor of Instruction in Mechanical Engineering at The University of Texas at Dallas. His research interests include robotics, stochastic modeling, and analysis of dynamic systems. He is also interested in engineering education. He is advising the aerobotics team in the UTD AIAA student organization.

PL STEPHAN THAMBAN, Ph.D.
Dr. Thamban is Associate Professor of Instruction in Mechanical Engineering. His focus is on teaching mechanical engineering and engineering mathematics classes. His research interests are in materials processing with low temperature plasmas and process control diagnostics in semiconductor device manufacturing.

OZIEL RIOS, Ph.D.
Dr. Rios is a Professor of Instruction at The University of Texas at Dallas where he has taught undergraduate courses in computer-aided design, dynamics, geometric dimensioning and tolerancing, kinematics and dynamics of machines, and two introductory courses to the Mechanical Engineering profession. Dr. Rios' research and teaching interests include robotics, geometric design of mechanical systems, kinematics and dynamics of linkages, and engineering education. Dr. Rios has received the UTD President's Teaching Excellence Award, the Outstanding Undergraduate Teaching Award from UTD's Jonsson School, as well as the UT System Regent's Outstanding Teaching Award (ROTA).