Prioritizing Experiential Learning in the Classroom

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Experiential learning, also known as learning by doing, is a crucial aspect of the undergraduate educational experience for mechanical engineering students. It provides students with hands-on experience and practical skills that are essential for success in today's competitive job market. Employers are increasingly seeking individuals who have a strong foundation in computer-aided design (CAD), programming, and an understanding of manufacturing processes, and experiential learning provides students with the opportunity to develop these skills in a real-world setting. In addition to providing students with valuable technical skills, experiential learning also helps students find their passions in engineering. By working on real-world projects, students can explore different areas of mechanical engineering and discover the areas that interest them the most. This exploration can help students to identify their strengths and weaknesses, and to determine the best career path for them. For technological breakthroughs to continue, engineers not only need to learn the foundations of engineering, like material science, electrical properties, force and stress relationships, etc. but they also need to learn how to implement current technologies to solve complex engineering problems. According to *The Importance of Supporting Engineering Education*,

> When students have access to better teaching methods, more information, and new technologies or tools - they improve their creative and learning potential. Creative engineering students at all levels, and particularly in postsecondary institutions, develop astonishing breakthroughs while still in school. Professors and teachers usually work closely with these students to refine their ideas and bring them to fruition. Universities are well-known hotbeds of innovation. A significant number of life-changing

> advancements are either developed in colleges and universities or began there. Some of these ideas lead to startup companies that become household names - Microsoft, Facebook, Dell, and Google, to name a few (Baldesarra, 2017, p. 2).

This Thesis serves to inform individuals about the importance of modern educational techniques and the direct relationship it has not only on university recognition, but more importantly, recent graduate success in the workforce. This research will also report on the significance of engagement in engineering clubs and societies for gaining practical hands-on experience with projects like building race cars, planes, robots, and more. By incorporating more experiential learning into UVA's (and many other Universities in the US) mechanical engineering undergraduate education, student's will be well-prepared for success in their careers and will be able to make a significant contribution to the industry. Actor Network Theory (ANT) will be used as a lens to guide this research and ideation because it allows us to see the relationship that students, faculty, industry partners, equipment and facilities, and administrative policies and procedures all have on experiential learning at the undergraduate level.

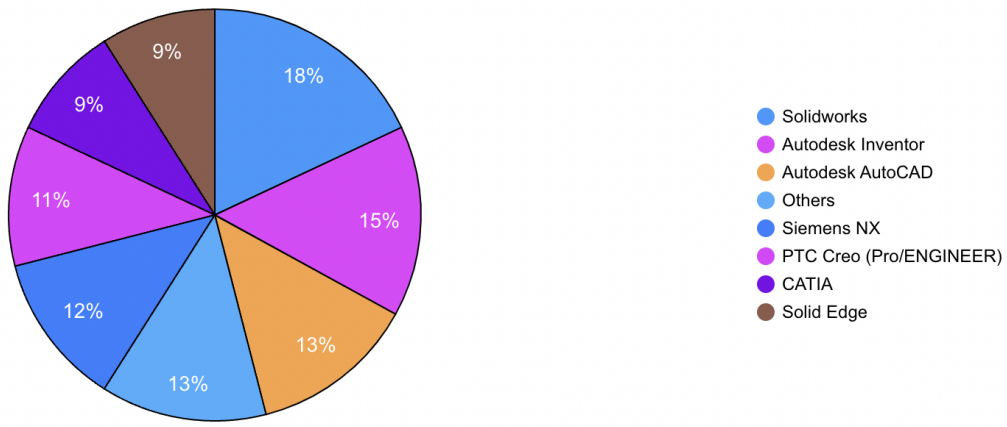
UVA, being one of the best public universities in the country, attracts students all across the globe. The university prides itself on its academic excellence and studies have shown that UVA's School of Engineering and Applied Science has grown in popularity significantly over that past five years. Most of UVA Engineering's top rankings are in undergraduate computer science as well as online masters for civil, mechanical, and systems engineering (UVA School of Engineering and Applied Science). With the continued attraction and growth of UVA Engineering, it is important that students have the best experience possible so this growth can continue and UVA can uphold its reputation. With that being said, the following information is

provided to show a student perspective on one of UVA's smaller departments, mechanical engineering.

Within the Mechanical Engineering Department at UVA, there is only one, one credit required lab devoted to CAD and is taught using Autodesk Inventor (*ME & AE Undergraduate Curriculae*). While it is better than nothing, this class is structured in a way that almost all assignments are accompanied with step-by-step instructions for making models, which any good engineer knows is not the right way to teach CAD. It also uses software that is not commonly used in industry ("Introduction to Mechanical Engineering", 2022). On the contrary, the university provides students with a free Solidworks license yet rarely uses it in coursework, even though it is industry standard. The figure below shows the CAD market share with Solidworks leading at 18%.

Figure 1

CAD Market Share Statistics (Enlyft. (n.d.))



Another required class within the Mechanical Engineering Department that deals with more hands-on education is Mechatronics, which "surveys basic electronics, electromechanical

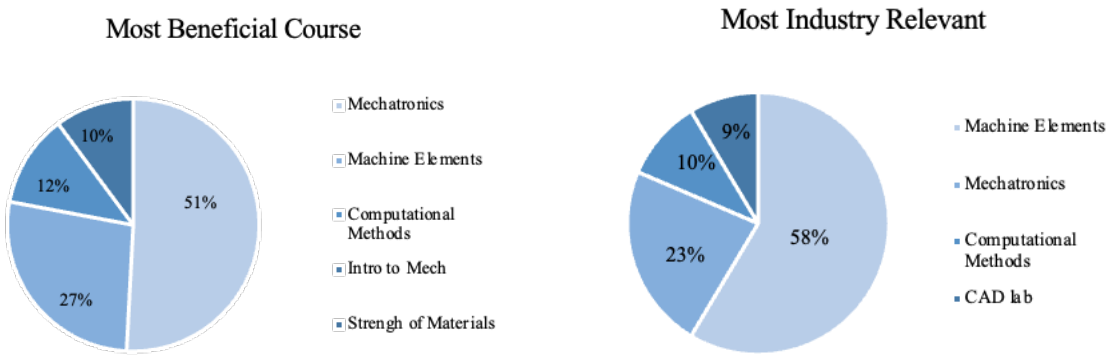
actuators, analog and digital signals, sensors, basic control algorithms, and microcontroller programming" ("Mechatronics", 2022). This class is recognized by many students in the department as one of the most relevant "real-world" courses and is extremely beneficial, but realistically, most mechanical engineering students would benefit more from a course of the same complexity and incorporate similar teaching styles, focusing rather on design, simulation, and manufacturing. This is not to discredit the course in any way, because in our current day in age, an understanding of electronics is key to any engineer's success, but to understand wiring and electrical components at a higher level than CAD as a mechanical engineer, is a cause for concern.

Figure 2 below contains data obtained from a Mechanical Engineering (ME) Curriculum Survey given to 32 fourth year mechanical engineering students. This survey was written and distributed by myself and is not published online. The chart shows the four highest rated courses for two different categories:

1. Most overall beneficial required mechanical engineering course with Mechatronics ranking the highest at 51%.
2. Most relevant for gaining industry knowledge and skills with Machine Elements and Fatigue in Design ranking the highest at 58%.

Figure 2

Mechanical Engineering Curriculum Survey Results (Created by Author)



Based on the ME Curriculum Survey, Mechatronics ranked number one for being overall the most beneficial required course within the department. A condensed list of learning objectives is as follows:

1. Fundamentals of electricity
2. Binary numbers and how computers work
3. Analog and digital input and output
4. PWM and motor control
5. Peripheral devices
6. ADC and sensors

The ME Curriculum Survey shows that this course was extremely beneficial because of the hands-on weekly laboratories that involved both hardware and software. Students were able to control motors, create LED light displays, make video games, and as a final project, use techniques learned throughout the semester to improve a manufacturing method. The class not only challenged students in a way that not many classes have, it excited them and was "worth the struggle". Machine Elements and Fatigue in Design ranked number one for being the most beneficial for gaining industry knowledge and skills (ME survey). Some key course objectives can be seen below:

1. Buckling
2. Shock and impact
3. Reduction factors
4. Fluctuating stress
5. Shafts, Gears, Bearings, Springs
9. Screws, Welds, Joints

Students emphasized that the curriculum is extremely beneficial, but the teaching style is slightly old-fashioned. While the class provided very important information to the students, it didn't capture the student's interest to the level it has potential to. There were a handful of projects that incorporated CAD and FEA, but students have claimed that it was fairly simplistic and not a challenge to solve.

Based on the ME Curriculum Survey, computational methods is one of the highest rated courses for potential to be the most relevant course in the department because it "introduces

numerical modeling concepts used in engineering simulation tools like computational fluid dynamics and structural mechanics analysis software" ("Computational Methods", 2022). Unfortunately, the way it is taught, is still tailored to understanding the mathematics behind these analyses. While the course does provide multiple coding projects, they are not very challenging for 3rd and 4th year mechanical engineering students and this only accounts for roughly 30% of the material taught in class. The course does not reach its full potential by not providing learning tools and engaging projects for complex softwares. The class should focus more on how students can use a variety of software efficiently, rather than having students do simple, but tedious hand calculations for over 50% of homeworks. Figure 2 shows some of the most commonly used software in industry for mechanical engineers, according to MechaniCalc, Inc that could be implemented in Computational Methods.

Figure 3

Most Used Software for Mechanical Engineers

MathCAD	Nastran
Solidworks	Microsoft Excel
Unigraphics NX	Visual Basic for Applications (VBA)
CATIA	MATLAB
Ansys	Python

Sherry Sorby, a previous president of the American Society for Engineering Education, believes that "rather than forcing students to memorize the intricacies of the chain rule in taking derivatives, would it not be better to teach them to use mathematics to model physical phenomena, to question numbers that magically appear on their calculator readout, or to know when to apply the chain rule and where to look it up when needed" (Sorby). In the same article, Sorby states that it's commonly perceived that promotion depends on research, rather than on one's effectiveness as a teacher and there are many students at UVA that agree with this claim. This is not to say that research is not important, but in the university space, a student's education should always be the priority and professor's should be rewarded based on the success of their students.

Overall, students value their time at UVA because of the beautiful campus, amazing school spirit and activities, and most importantly, the clubs and organizations they join. Sure, being able to say you got a degree from UVA is of course the biggest takeaway, but not the education itself. The activities students participate in outside of the classroom are not only some of the most important memories students have of their college experience, but also the most relevant for finding jobs and establishing their careers. Because of the lack of relevant industry knowledge gained in the classroom, the best job opportunities (for the most part), are given to students that participate in competitions such as Formula SAE, Baja SAE, SAE Aero Design, American Solar Challenge, and more. These competitions provide students with professional development in not only mechanical engineering, but also aerospace, computer, electrical engineering, and more. SpaceX for example, mentions in all of its entry level engineering positions that members of the collegiate design teams mentioned previously are prioritized and preferred in the recruiting process.

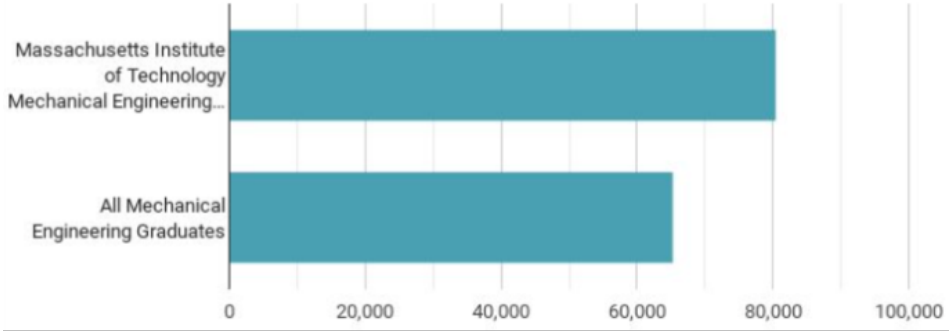
Massachusetts Institute of Technology (MIT) has been recognized by many sources including Edurank, US news and World Report, and Best Accredited Colleges, as having the best and more innovative mechanical engineering department in the United States (College Factual). While there are many reasons for this, one reason is because professors engage students in more advanced projects in the classroom that allow students to dive deeper into traditionally taught mechanical engineering courses. According to AdmissionSight, MIT is widely regarded as having one of the best mechanical engineering departments in the US due to several reasons including :

1. Strong Faculty: MIT's mechanical engineering department has a faculty of highly renowned scholars and researchers who have made significant contributions to the field.
2. Cutting-edge Research: The department is at the forefront of cutting-edge research in various areas of mechanical engineering, including materials science, robotics, and energy systems.
3. Interdisciplinary Approach: Mechanical engineering at MIT is integrated with other disciplines, such as electrical engineering, aeronautics and astronautics, and nuclear science, providing students with a well-rounded education.
4. Hands-on Experience: MIT places a strong emphasis on hands-on experience, and students in the mechanical engineering program have opportunities to work on real-world projects, design challenges, and research initiatives.
5. Strong Industry Connections: MIT has a long-standing reputation for its close relationships with industry, and the mechanical engineering department has strong ties with companies in a range of sectors, providing students with opportunities for internships, co-ops, and career placements.

Additionally, MIT's post graduate income analytics are in favor of my theory that universities that emphasize the importance of hands-on experience and innovative teaching methods, result in increased average post graduate income. Figure 3, obtained from the article *Mechanical Engineering at Massachusetts Institute of Technology,* shows MIT's mechanical engineering graduates' average salaries versus a pool of mechanical engineering graduates from universities across the nation.

Figure 4

Salary for Mechanical Engineering Majors with Bachelor's Degrees



CollegeSimply, who sources their data from the Department of Education, states that UVA Mechanical Engineering graduates make on average $63,4000 annually. Compared to MIT at roughly $80,000 annually, this is roughly a 20% decrease. On average it takes 3 plus years for entry level mechanical engineers to accumulate a 20% increase in pay. Most of MIT's success comes from their incredible faculty that consists of world renowned scholars and researchers. Now, "engineering faculty do not have to be social psychologists, cognitive scientists, or cultural anthropologists, but to design effective courses and implement effective classroom pedagogy, they must have a general understanding of the most relevant research findings" (Ambrose). This,

along with more classroom engagement, is where I believe UVA mechanical engineering professors lack.

Research on cognition clearly indicates that students learn best by doing—by identifying types of data, formulating problems, discussing alternatives, weighing options, choosing among formulas and tools, justifying decisions, and so on. Students, and people in general, do not learn nearly as well passively. When pairing the required curriculum with projects that fascinate students and allowing them to solve much more advanced problems using modern engineering tools, a student will gain so much more. Not only do students retain more information from doing more hands-on work, they also develop a sense of accomplishment which leads them to want to do and learn more (Freeman). With the rapid growth of technology, many recent mechanical engineering graduates that do not have this type of education or participate in collegiate engineering clubs or have prior engineering internships have a more difficult time finding a well-paying job. This is partially because of their lack of knowledge in one or more of the following:

1. Computer Aided Design (CAD)
2. Computer Aided Manufacturing (CAM)
3. Computer Programming
4. Finite Element Analysis (FEA)
5. Computational Fluid Dynamics (CFD)

This does not include having a good understanding of manufacturing processes, how to design for machinability, or how to design or build things in large, complex systems. While there

are Universities that have successfully adapted to more modern teaching styles, while also complying with ABET curriculum requirements (like MIT), the number is few. Employers are looking for engineers who are proficient in using the latest technology and software to streamline the design and analysis process and create innovative solutions. The use of technology can also help to reduce the time and resources required for manual calculations and prototyping. This allows engineers to focus on more strategic and creative aspects of the design process, such as exploring design concepts, improving product performance, and addressing environmental concerns. The integration of technology in mechanical engineering education is no longer a luxury but a necessity. It is essential for students to gain hands-on experience with the latest tools and software to prepare them for the rapidly evolving field of engineering.

Engineers must possess good problem-solving skills and be able to understand complex systems. Courses like calculus, physics, thermodynamics, strength of materials, etc. do in fact help weed out individuals that don't possess characteristics of good engineers and these should still be taught in a traditional way using hand-written numerical methods. I believe that after successfully completing these "weed out" courses, students should be allowed and encouraged to use a variety of computing methods when doing assignments and examinations. For example, rather than requiring students to solve complex partial differential equations by hand, spend a smaller amount of time explaining the theory and derivation, then allow students to for example, write their own scripts to solve the problem. This not only saves a student over 50% of the time it would take them to do it by hand (if they have the learning tools to make them efficient programers), but it also aids in their programming skills, which most employers find substantially more beneficial (Baldesarra, 2017). In fact, many companies now look for some

level of programming experience when recruiting mechanical engineering graduates. These skills are very beneficial when it comes to any type of simulation or test engineering which are subdivisions of mechanical engineering (paired with computer science and systems engineering).

The book *Experience and Education*, written by John Dewey, focuses on his theories with regards to progressive education. He claims that in traditional education, teachers are clearly distinct from students in learning environments, knowledge and skills are conveyed from textbooks and teacher-centered lectures, and that students are passive and obedient. Dewey's theory revolves around two principles. The first being that all past, present, and future experiences of an individual exist simultaneously. Each experience shapes the kinds of experiences learners encounter and their attitudes toward new experiences. The second being the equal importance of considering internal and external conditions of learning. Dewey states that one of the greatest criticisms of progressive education is its lack of subject-specific curriculum. As a counter argument to this claim, Dewey believes in the application of the scientific method, forming and testing hypotheses based on empirical observations. He does mention that progressive educators have to work harder to understand their students better and tailor courses to the current world around them because so many external factors play a role in how students learn, but that any good educator that is passionate about teaching shouldn't be scared to take that extra step. While his theories may seem extreme to some, his core beliefs are very important in the world of education. Learning by doing and allowing more creative freedom in the classroom will produce individuals who are more driven and will want to be lifelong learners.

Conclusion

The world we live in is developing very rapidly, and engineering students should be learning about evolving technology and not solely the foundations of technology that have been developed over the last 5 centuries. While it is important to learn a base foundation of one's area of study, most engineers work in a very specific sector where they only require an in depth understanding of a select few topics. There is no correct way to train the engineers of the future, but there are certainly ways to provide them with enough education and resources to be able to bring their ideas to life and make technological breakthroughs. Learning these tools and software not only enhances the efficiency and accuracy of design and analysis processes, but it also provides students with a competitive advantage in the job market. This thesis serves as a persuasive essay on the direct impact that more modern teaching styles and experiential learning have on recent graduate success, which goes hand in hand with the success of a university's engineering department.

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