Multidisciplinary Design Projects in Engineering Education

Alireza Yazdanshenas, University of Texas, Tyler

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Mechanical Engineering student form the University of Texas at Tyler (Undergrad) Will continue my education to my last days. Born in Iran and Lived in Germany for an extended amount of time. Dual College athlete yet in love with Engineering. Hoping to compete in the 2020 Olympics in the Hammer throw.

Mr. Caleb Nathaniel Nehls, The University of Texas, Tyler

Caleb Nehls was born and raised in Shreveport, Louisiana. He graduated from Southwood Highschool in 2005. After graduating, Caleb joined the United States Marine Corps and served as a Reconnaissance Marine at 3rd Reconnaissance Battallion in Okinawa, Japan from 2006 to 2010. Following his enlistment in the Marine Corps, he worked as a weapons and tactics instructor for Möbius Industries, in Okinawa, teaching Marines and sailors prior to unit deployments. Caleb and his family returned to the United States in January of 2015, when he enrolled at The University of Texas at Tyler and declared mechanical engineering as his major. Currently, he works as a tutor in the University tutoring center for Several engineering courses and is also an undergraduate research assistant in the Mechanical Engineering department.

Dr. Chung-Hyun Goh, University of Texas, Tyler

Dr. Goh has worked as a Mechanical Engineering faculty of The University of Texas at Tyler. Prior to joining UT Tyler, he worked in the Systems Realization Laboratory at the University of Oklahoma from 2012 to 2015. He worked for the Korean government after he received his Ph.D. degree at Georgia Institute of Technology in 2002. Dr. Goh is a member of ASEE, ASME, TMS, and the Institute of Integrated Healthcare in the East Texas. He also worked as a member of the board of directors in the materials and fracture group in the Korean Society of Mechanical Engineers. He has published a total two book chapters, 30 peer reviewed journal and proceeding papers as well as a co-authored textbook.

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Abstract

In the modern age the engineering filed is rapidly evolving into a complex system with the need of multiple branches of engineering know how to solve modern problems. Electrical, Mechanical, Civil, Software Engineers and even those experts outside of the engineering field should collaborate to produce quality designs and solutions for the Future. With these new elements and demands in the engineering field, engineers are expected to behave like multipurpose tools. Engineers with applicable knowledge form varying technological displaces that can be utilized effectively on demand of the projects. Likewise, the engineers of the future need to be compatible with engineers of the older generation who might have limited to no knowledge of fields outside of their practice. To succeed in the future workforce engineering students not only need technical knowledge, creativity, and soft skills, but also the quality to synergize into engineering systems that include multiple disciplines. With these new requirements of the future engineering education face a new duty of introducing challenges of multidisciplinary design and projects to its students.

At the university level, the most effective way to unify various engineering fields is by integrating students through multidisciplinary design projects. These projects encourage teams of students to tackle engineering problems more efficiently as a group rather than as individuals. By combining multiple engineering disciplines, the student is able to collaborate with peers who have a different educational background and to even collaborate with departments that have nothing to do with engineering. This enhances the student's learning experience by exposing them to nontraditional ideas, while encouraging them to cultivate their own. Most important of all, for the student all other traditional barriers are removed. Thereby the learning and application limits are set by the student rather than by the instructor, curriculum, department and even school district. By giving the students absolute control we allow them to branch out to places and people they would have never been otherwise exposed to.

Our teams have worked on multiple multidisciplinary projects in the past few months. These multidisciplinary projects included the Plane on a Pole project, T-Ball Design project, and Cellular Automata Simulation project. Each of these projects has presented its own multidisciplinary challenges which have forced the students to adapt to the modern engineering world. Lastly, the students had to reach beyond their knowledge, step out of their comfort zone and find help in many different departments and even off campus. The nature of this nontraditional classroom approach strengthened the soft skills of the engineering student, a value that is not tangible in the classroom. Multidisciplinary design projects are one solution to bridging the gap between graduate requirements and industry employers' needs.

Keywords:

Multidisciplinary Design, Plane on a Pole, Tai Chi Ball, Hot Rod Rolling, Cellular Automata

1. Frame of reference

The engineering field is quickly evolving into a complex system where the multiple branches must synergize with one another to solve modern problems. Modern engineering design is now accomplished by the teamwork of electrical, mechanical, and civil engineers. Naturally, by the evolution of engineering, prospective engineers are expected to be like Swiss Army knives with all engineering disciplines in one unit. The rapidly changing industry requires engineers to be able to effectively communicate and solve complex problems with other engineers who might have dissimilar educational backgrounds. Recently, convergent research involving many disciplinary areas becomes a new paradigm of solving complex scientific questions. Multidisciplinary research collaboration makes it possible to approach these questions in a more disciplinary-focused eye and promotes synergistic effects in exploring the opportunity for scientific and technological advancement [1]. Thus, engineering graduates must possess technical knowledge and creative skills not only in their specialization, but must be competent in all engineering disciplines. Bridging the gap between the multiple branches is a unique challenge in engineering education.

Today's engineering jobs in which a civil engineer is doing purely civil work rarely exist. In actuality, most engineering jobs are much more diverse than the engineering curriculum. Companies of today, to stay competitive, demand more and more out of their engineers because of their ability to learn and problem solve. Most engineers claim that the learning begins after graduation, on the first job and continues through the entire career. In today's world, an engineering student cannot only rely on a high GPA to help them land a job. Today's markets require an engineer who can handle diverse situations with multiple outcomes and multiple areas of knowledge. These challenges that the modern economic world demands need to be tackled and solved. It is the responsibility of universities to produce high quality engineers by providing the students with the best education possible. While it is up for debate on what engineering curriculum and what kind of standardized testing is best for producing these high caliber students, one thing is certain, you cannot beat hands on learning. At the university level, the most effective way to unify various engineering fields is by integrating students through multidisciplinary design projects. These projects encourage teams of students to tackle engineering problems more efficiently as a group rather than as individuals. By combining multiple engineering disciplines, the student can collaborate with peers who have a different educational background as well as with departments external to engineering. This enhances the student's learning experience by exposing them to nontraditional ideas, while encouraging them to cultivate their own. Most important, for the student, all traditional barriers are removed. Thereby the learning and application limits are set by the student rather than by the instructor, curriculum, department and even the school district. By giving the students absolute control we allow them to branch out to places and people they would have never been otherwise exposed to. This exposure oftentimes involves the student changes that impact the university and the community.

The University of Texas at Tyler (UT Tyler) Mechanical Engineering has offered students various multidisciplinary design projects under the supervision of Dr. Chung Hyun Goh. These projects range from independent study courses to research based courses, in which the students are challenged through nontraditional non-classroom based methods.

The teams in our laboratory have worked on multiple interdisciplinary projects in the past few months. These multidisciplinary projects included the Plane on a Pole project, Tai Chi (T-Ball) Design project, and the Cellular Automata Simulation project. Each of these has presented its own multidisciplinary challenges, which has forced the students to adapt to the modern engineering world. Lastly, the students had to reach beyond their knowledge, step out of their comfort zone and find help in many different departments as well as off campus. The nature of this nontraditional classroom approach strengthened the soft skills of the engineering students, a value that is not tangible in the classroom.

In this paper, the educational perspective and the expected outcomes obtained from multidisciplinary projects will be presented and discussed. The brief descriptions of three multidisciplinary design projects are introduced in Sections 2, 3 and 4. In Section 5, some examples acquired from the design projects at UT Tyler are introduced and the effects on project-based learning are discussed in brief.

1. Plane on a pole project

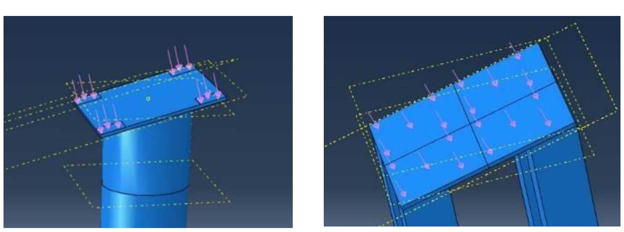
The Historical Aviation Memorial Museum of Tyler had been looking for a monument for quite some time, and finally decided to contact UT Tyler to help with the design decisions. The Museum selected an F9F-Cougar fighter, shown in Figure 1, be the official monument. This fighter jet was to be displayed on a pole to honor a deceased local veteran. The final structure of the display pole has become a volunteer engineering challenge that has jumped around between a few companies. Finalizing a safe structure that would support the plane proved difficult, given the small budget of the Aviation Museum. The Museum and the University presented this design challenge to the Engineering Department to reduce costs and still obtain a safe design.

Figure 1. F9F Cougar Fighter jet, where red dot represents the estimated center of gravity

This task was one of the best examples on how to combine an Engineering Technology Accreditation Commission (ABET, Inc.) curriculum with real-time applications through collaboration with interdisciplinary clusters. Engineering students who were up for this challenge were asked to solve the entire structural problem independently after only a few briefings and some recommendations by the professor and the customer. The preliminary studies performed have provided an optimal design of the plane on a pole by adopting the knowledge acquired from ABET, Inc. curricula such as MENG 3306 (Mechanics of Materials), MENG 3303 (Dynamics of Machinery), and MENG 3309 (Mechanical Systems Design). For example, the free body diagram (FBD) was used for calculating the applied loads to the pole structure, which supports the plane, and these values were used as the boundary conditions for the Finite Element (FE) analysis. To start this design task, the engineering students were asked to use FE commercial software (ABAQUS), to ensure computer generated validations for their proposed solutions. To successfully create these final designs, students had to reach numerous different engineering subjects and topics. Computer graphics became the first engineering topics in addition to the FE analysis. Students also had to make use of their statistical analysis skills and dig deeper into the material sciences. The multi-Disciplinary aspect of this entire project arose in the interaction of the supporting structure and the ground. Geotechnical knowledge in addition to Soil Mechanics form the Civil Engineering side of this project became a crucial to develop a secure base and a secure integration of the pole structure to the base.

The plane had been securely attached to a mounting plate, and the task, for UT Tyler students, was to design a safe support structure that would attach to the mounting plate. To simulate this ideal attachment of the mounting plate a "tie" command was used. This ideal tie further focused the study of the FE analysis on the pole structure itself. Furthermore, since it was established that the pole structure would be supported by a sturdy concrete foundation, the decision was made to incarcerate the bottom of the pole. For an aesthetically pleasing look, the plane would be supported at a 15-degree tilt. This tilt will cause a change in center of gravity, thereby affecting the force distribution onto the pole structure. To simulate the uneven distributed weight, the ¾ inch thick steel plate was sectioned into 4 different regions with 4 different pressure values applied to it. The value of these 4 different pressures was summed to be the total weight of the 12,000lb plane. Two different supporting pole structures were considered for improving the reliability of the plane on a pole. The single pole with a circular tube type and four poles with a rectangular tube type were investigated in ABAQUS simulations as shown in Figures 2 and 3. Both poles were constructed of A36 Structural Steel. The boundary conditions are shown in Figure 2.

The Von Mises effective stresses, as simulated, reached a maximum of 713.8 Pa for the first model and a maximum of 31.6 MPa for the second model as shown in Figure 3. From these results, we can conclude that the width of legs in the second model was too small and should be increased for further stability. However, even though the first model experienced much smaller Von Mises stresses, it buckled more than the second model due to the bending moment brought on by the offset center of gravity.



(a) (b)

Figure 2. Boundary conditions simulating total weight of the mounted plane onto the pole plate: (a) a single pole with a circular tube type and (b) four poles with a rectangular tube type

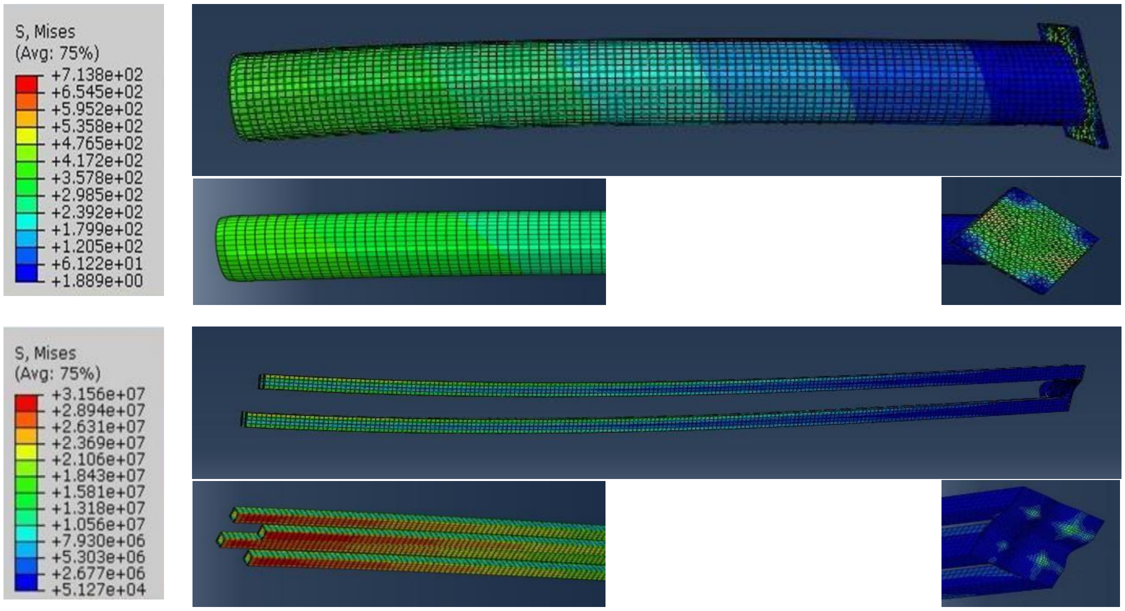


Figure 3. The von Mises effective stress distribution of (a) the first model and (b) the second model

To avoid buckling of the first structure, two treatments were recommended. The first was to fill the inside of the pole with concrete to add more stability, and the second to pull the far wing of the plane down with a wire to reduce the bending moment. These treatments can provide additional damping to stabilize the system from external forces such as strong winds.

2. T-ball design project

Health care is one of the biggest financial burdens on the American Economy. Billions of dollars are spent annually for treatments and research, and despite all the efforts, the United States still ranks poorly amongst other industrialized nations. Health spending growth in the United States for 2015–25 is projected to average 5.8 percent—1.3 percentage points faster than growth in the gross domestic product—and to represent 20.1 percent of the total economy by 2025 [2]. Despite all advancements of knowledge, very little effort and money is invested towards preventative methods. Preventative methods, which would reduce the risk of illness, are better for the overall health of a person and overall welfare of the economy. Exercise, for example, reduces the risk of cardiovascular disease significantly, which was the reason collaboration began between the College of Nursing and Health Sciences and the Mechanical Engineering department to patent a Tai Chi (T-ball) design. T-ball design project is a part of
Program proposed by Dr. Goh and his coworkers [3].

Tai Chi, a mind-body harmony exercise, is an ancient Chinese healing/martial art [4, 5], which is practiced by millions of people daily across the world. It is said that around 250 Million people practice Tai Chi in their lifetime. If those who have ever practiced Tai Chi were the population of a country, it would be the 5th largest country in the world by population after India, China, USA and Indonesia. Since the customer base of the T-Ball design is so vast, UT Tyler was left with no other choice but the “one size fits all” approach. This means that every single one of those 250 million pairs of hands must be able to handle this exercise device safely, correctly and effectively. With this in mind, every measure was taken to ensure safety of users in all age groups.

This “T-Ball” was designed based on the Yin and Yang theory so that the ball can separate into Yin and Yang parts and combine as a whole by poly-magnets during the exercise. Different ball sizes and weights for individuals to match their physical fitness and health conditions were designed [6]. The prototypes of these balls were designed and manufactured by CAD design followed by 3-D printing technique at the UT Tyler laboratory.

The one of a kind innovation, introduced in the T-ball design, has become a mixture of ancient customs and traditions and the forefront of technology. One of these new technologies is the poly-magnet, shown in Figure 4. A poly-magnet is one that has multiple north and south poles in varying locations and shapes. This progressive technology has exhibited untapped mechanical potential and will be incorporated into the T-Ball design.

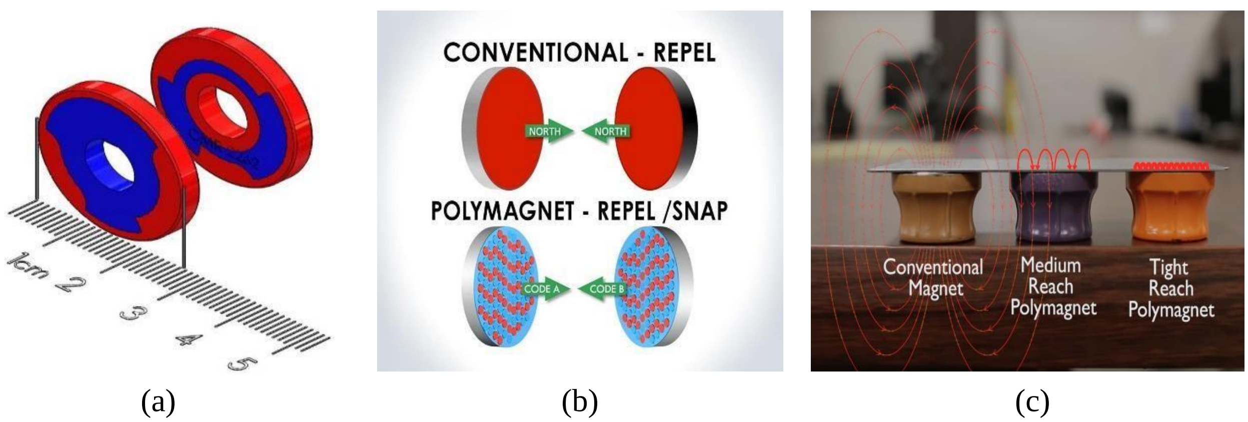


Figure 4. (a) Configuration of poly-magnet pair, (b) comparison of poly-magnet and conventional magnet: electromagnetic force emission type, and (c) electromagnetic field generation [7]

The Multi-Disciplinary interactions of this project was a requirement form the very begging. Mechanical Engineering Students needed to closely collaborate with Students of biomechanical and health sciences background to ensure desired outcomes. For example, the incriminations of weight must be optimized based on muscle adaptation theories from exercise science theories. More importantly, material selections became a safety factor which needed consultation for the health department. For example, materials that are used for industrial purposes might violate health and safety codes for when used with direct human contact. It is because of these few bridges between engineering and health science that made this project a unique experience for the students.

3. Cellular automata simulation project

Another project underway by students at UT Tyler is research into the microstructure evolution of steel billets undergoing the hot rolling process. This project is a part of the collaborative project with the Systems Realization Laboratory at the University of Oklahoma in which the collaborators are focused on developing a methodology for predicting mechanical properties of the product via the vertical and horizontal integrations in a multi-stage hot rod rolling system as shown in Figure 5 (red box) [8].

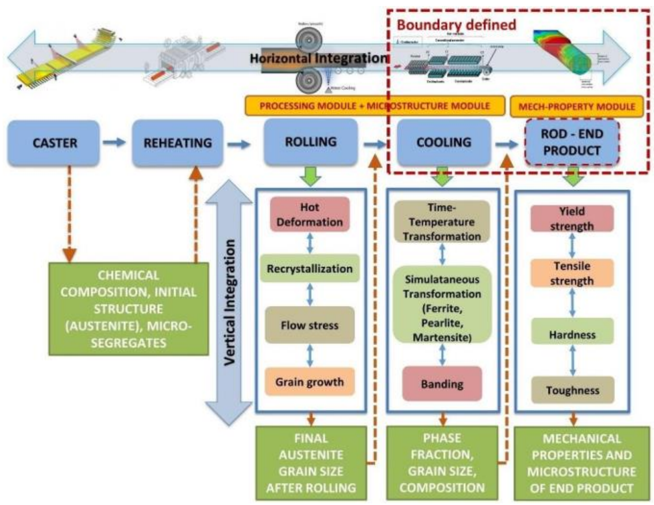


Figure 5. Vertical and horizontal integration of models and information flow [8]

In gear manufacturing, rolling is used to break casting structures and reduce casting defects. The hot rolling process involves increasing the metal temperature above its recrystallization temperature. The recrystallization process replaces deformed grains with new grains through phase transformation and grain growth in the microstructure as shown in Figure 6. Material properties such as yield strength and ultimate tensile strength strongly depend on the microstructure which evolves in this process. A customized microstructure which satisfies the requirements of the application will improve material properties as well as manufacturing cost and performance [9].

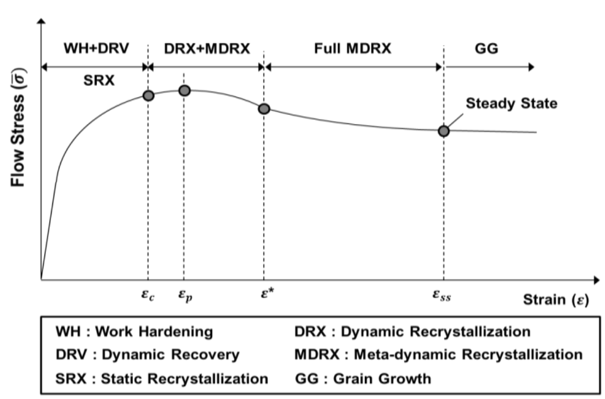


Figure 6. Schematic illustration representing the classification of recrystallization in the effective flow stress and strain (modified from the reference [10])

The main objective of this project is to develop the internal state variable (ISV)-based modeling for considering microstructure evolution in the hot rod rolling process. The task can be accomplished by two major approaches: 1) ISV model development using the user defined subroutine in ABAQUS [11], so called 'User MATerial (UMAT)', and 2) visualization of microstructure evolution using a cellular automata (CA) technique.

The hypothesis is that the first approach could be achieved by developing the algorithm for considering microstructure evolution in the UMAT subroutine, while the second approach could be accomplished by combining FE analyses with a CA technique. The focus for this paper will be the second approach, CA-based visualization of microstructure evolution in hot rolling. This approach would combine existing research in grain growth with Matlab to create a set of user defined rules for neighborhood growth or decay. Research in the microstructure evolution of steel materials has provided this team with parameters for defining grain growth within the CA model. The goal is to define the growth parameters within Matlab codes, create a script that allows the user input of initial material properties and rolling parameters, and finally simulate the microstructure evolution.

Interjecting user defined parameters for grain growth can be done in several different ways in a program as flexible as Matlab. The preliminary results allow for a user defined probability growth of material microstructure. A model of this type of growth can be seen in three regular time intervals in Figure 7. The array size for this simulation was defined as 100×100, and a 40% random probability of grain growth rate was applied for the microstructure evolution cycle. The code itself ran at a user defined limit within a for loop.

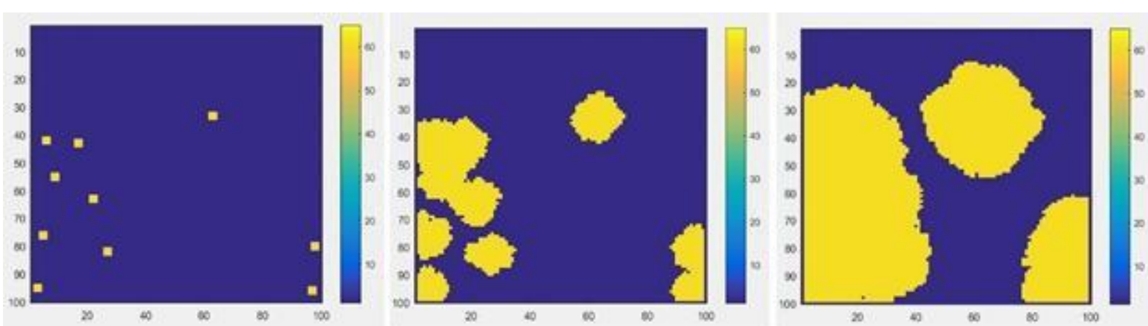


Figure 7. Grain growth given user defined growth probability

Based on the preliminary results, the updated version is currently being developed to consider grain growth parameters. Parameters such as austenite nuclei concentration, carbon concentration change, and transition rules will define the evolution of ferrite to austenite and the amount of pearlite that is dissolved.

This team includes students from mechanical engineering and materials science and the project is focused heavily in both areas. Having multiple disciplines has afforded the team to maximize potential learning and reach goals in a more expeditious manner. A one-dimensional team would require vast amounts of background research for each step taken towards every research goal. In a multidimensional team, members are able to teach each other and learn from one another as they progress towards each objective. Combining a materials science major, with little to no programming skills, with mechanical engineering students, who have only a base knowledge of materials science but proficient in programming skills, is a sound union. This, coupled with the atmosphere of a research project rather than the conventional classroom atmosphere, has elevated the learning environment to a very high level. Each team member, rather than being given a set of specific instructions, is given a task and asked to solve the problem however he/she can. Removing specific, step-by-step guidance has forced the team to look for abstract and nontraditional solutions.

4. Discussion

Various multidisciplinary design projects have become a part of the UT Tyler Mechanical Engineering program. These educational experiences so far have been a complete 180-degree change from the traditional classroom setting and have required knowledge form various fields of engineering and science. By presenting students with many challenges that a traditional classroom simply could not, the University has provided advantages that reach beyond a classroom. A shift was made from strict standardization to personalization and individual growth as an engineering student and professional.

The Plane on a Pole Project, for example, required the students to teach themselves an entire FE analysis software such as ABAQUS. The mastery of such software, in many cases, is an entire course alone. In addition to the structural aspect of the project, students were also required to expand their understanding of geology, surveying, and the effect of this large monument on the local soil and ground. Lastly, to produce any applicable results the student had to, at often times, leave campus and communicate with other engineers and owners of the project to discuss results and how they would affect the budget. These experiences have taught and strengthened the soft skills of the students while exposing them to areas of expertise required to be a professional engineer in the industry.

Combining biomechanics, magnetism, and the mechanical engineering design process, the T-Ball project has branched student knowledge, experience, and learning in many applicable directions. This nontraditional learning project has provided the students with firsthand experience in patent design and the innovative application of magnetism. Furthermore, students also learned how to work their design around safety hazards and produce a product that without national boundaries.

In addition, there are several aspects of the Cellular Automata Simulation project that are outside the primary disciplines involved. Contrary to original expectations, each team member had to acquire further understanding of computer programming languages and the integration of multiple computer software programs. This forced the team to search for solutions and techniques from other departments and areas of expertise. The ME students have also relied on their counterparts clear understanding of material microstructures for developing the next stage of research based microstructure evolution simulation. The team has coordinated with computer scientists, information technology specialists, as well as the University administration, to strengthen coding/programming skills and clarify requirements. Encapsulated in these learning interactions is the enhancement of logistics. Our communication with outside agencies had to be clear and precise in order to reach goals in a timely manner. The team's overall ability to communicate problems and collaborate on solutions with departments, inorganic to the team, has improved vastly from day one.

To assess the impact of multidisciplinary projects on students, a survey among 100 students at UT Tyler was conducted. Our interests were focused on engineering majors, however, seven other majors from the Colleges of Business and Technology, Nursing and Health Sciences, and Education and Psychology as a means of comparison. This allowed a study of the effects of research and design projects that occur outside of the regular curriculum. A sample survey can be seen in Appendix A.

Most students surveyed in non-engineering majors had not participated in research or design projects other than those required in their regular coursework, while engineering majors showed more experience than other majors at University of Texas at Tyler as shown in Figure 8.

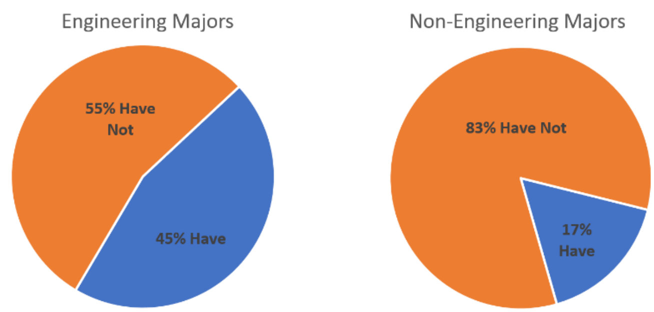


Figure 8. Percentages of students participating in Multidisciplinary Projects outside regular curriculum

When considering whether students who have conducted research or design outside of the traditional classroom, still the majority did not involve more than one major. Again, engineering majors did show more experience in multidisciplinary projects than non-engineering majors. This reflects the fact that the interdisciplinary disciplines are essential to develop recent cutting edge technology. These results can be seen in Figure 9.

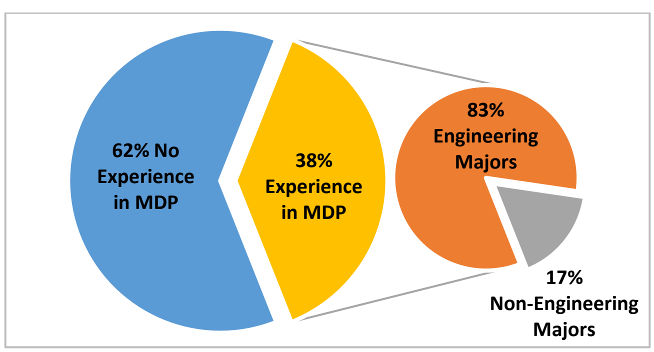


Figure 9. Percentages of students with Experience in Multidisciplinary Projects

Students were also asked to rate the synergistic effect of having more than one discipline involved as well as the effect of the project on preparing them for the work place post academia. Ratings were on a scale of 1 to 5, 1 being the lowest and 5 being the highest. The results showed an overwhelming positive rating from Engineering majors and a mediocre response from other majors. These results of the effectiveness on project success can be seen in Figure 10.

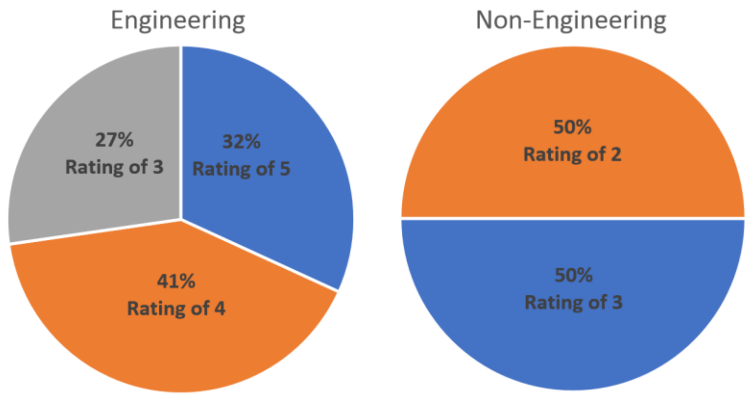


Figure 10. Rating on synergistic effects of MDPs

The results of our survey show that, within engineering majors, the effects of MDPs are positive as compared to other majors. This may indicate that engineering students understand the importance of multidisciplinary collaboration for complex systems design and problem solving. The statements of some participants in MDPs are introduced in Appendix B. Most students experienced that collaborative teamwork among various disciplines plays an important role in enhancing synergies in the MDPs.

In this paper, we focused on engineering-based multidisciplinary design projects. However, under the supervision of Dr. Goh, collaborative projects with non-engineering disciplines have also been accomplished in our laboratory. The project for developing artificial intelligence (AI)-based cost prediction model is a good example of interdisciplinary projects among departments of business and accounting, computer science, and mechanical engineering. In this project, ME students have had an opportunity for understanding the basic structure of cost estimating relationship (CER) equations and AI techniques. This professional expertise can be effectively and efficiently applied to economic analysis in the Senior Capstone Design and to further solve ill-structured problems the professional setting.

5. Concluding remarks

These types of team dynamics are not common among engineering students in the traditional lecture setting. Allowing students to form teams with multiple disciplines and to work on projects that require knowledge from many different areas of study affords them a great opportunity for broadening the scope of their skills. Many students may go through their entire undergraduate program without ever integrating with students and professionals from outside their discipline.

Over the span of these projects, each member of the respective teams has expanded their academic substance in areas they might have never ventured if not for the project setting. The ability to coordinate and engage with multiple fields in the undergraduate setting is crucial to a greater level of success for students at The University of Texas at Tyler.

In summary, interactions and learning environments discussed in this paper have the potential to produce well-rounded engineers prior to entry into the job market. Firms are demanding more from graduates right out of school than ever before. High GPA and a degree is, for some employers, no longer good enough. Expanding students' understanding in areas that directly support their discipline enables a fluid transition into diverse working environments. Multidisciplinary design projects are one solution to bridging the gap between graduate requirements and industry employers' needs.

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Appendix A: Sample Survey for Qualitative Data Collection on the MDP

Classification: ______________________ Major:________________________
(Fr,Soph,Jr,Sr,Grad)

1) Have you ever been a part of a collaborative research/design project at UT Tyler outside of your regular curriculum? (This may include Senior Capstone Projects)

   ☐ Yes ☐ No (if no, please discontinue the survey)

2) What was the mode of your research/design project?

   ☐ Competition ☐ Independent Study
   ☐ Undergrad/Grad Research ☐ ________________________

3) Was your research/design Project in collaboration with students outside of your major?

   ☐ Yes ☐ No If (yes) follow with section 1 if (no) follow with section 2

Section 1

How many different disciplines were involved in your research/design? (circle one)

1	2	3	more than 3

Please rate the effectiveness of working with a multi-disciplinary group (1 is lowest). (circle one)

1	2	3	4	5

Please rate the effectiveness of your research/design group in preparing you for post academic success.

1	2	3	4	5

How likely are you to recommend participation in a multi-disciplinary research/design for you peers?

1	2	3	4	5

Section 2

Did you ever have to request support or information from someone outside of your major for the success or progress of your research/design?

☐ Yes ☐ No

In your opinion, could your research/design project have been more successful if other members of your team were from other disciplines in engineering?

☐ Yes ☐ Somewhat ☐ Not at all

☐ Unsure

Please rate the effectiveness of your research/design project in preparing you for post academic success in your field?

(circle one)

1	2	3	4	5

Appendix B: Statements from Participants on the Benefits of MDPs

1. *Student A (Junior)*

Working in a team has always been easy for me. Having multiple members with complimentary skills is just a more effective way to approach problems. My time as a mechanical engineering student has been interesting and difficult at the same time. Not every professor presents material in a way I can understand. Yet it is mandatory that we are there. Research has given me the opportunity to choose how I learn and approach a problem. Rather than being stuck in a classroom waiting for it to be over, I get hands on kinesthetic learning with group interaction. Our research team in multi-faceted with multiple different backgrounds. This allows us to feed off each other's knowledge and accomplish things much quicker. In a traditional classroom setting when given a problem, everyone is stuck on the same thing because no one knows that one piece of information that makes it click. However, when given a team member with a different but complimentary major, that person is usually the one who has that one piece of information and things flow much quicker. Research has been, so far, the best environment for me to learn and I feel that it is superior to traditional curriculum learning.

2. *Student B (Junior)*

Prior to starting undergraduate research, all the group projects I had worked on consisted of other students with the same discipline as me. This meant that during most group conversations we would quickly arrive at what we thought was the best solution based on our collective knowledge. If there was any work that required knowledge outside our curriculum, it would just be assigned to the person who knew that most about it or whoever was interested in it. This was effective for projects designed around our discipline, as topics foreign to us played only minor roles.

With my current research, collaboration with other disciplines is required along with an understanding of what role they play. It's also the case that I am responsible for most aspects of the project that involve my discipline. This as lead me to spend much more time making sure I'm making the right decisions. Any mistakes made would only be caught by my supervisor. I greatly value what I have learned from the increased responsibility and influence. Working together with other disciplines has allowed me to learn how important it is to understand what I am doing, so I can communicate it to others.

3. *Student C (Junior)*

In our lab, we have a combination of mechanical engineering majors and a kinesiology major working in unison to do research. While my particular lab group has yet to perform any major projects involving both the disciplines, forerunner research is being done together. In a potential future project, the mechanical engineering students will do the material synthesis and analysis, then the kinesiology student will investigate how it will interact with the body. So far, by having outside perspective, it allows us to explore areas that otherwise each of the disciplines might not even know are possible routes of study. Often, stagnation of ideas occurs when members assume everyone understands the concepts so no one is speaking it aloud. In the process of explaining a concept to someone from a different field, who previously had no knowledge of the subject, we tend to understand it better ourselves, or even begin to consider the concept from a new angle.

4. *Student D (Senior)*

The Truth is once a graduate I will never be in a room of 50 engineers of the same discipline again. In the real world, I will be at a work place working with engineers form all and any disciplines and people of none technical backgrounds. In addition, the world's technology is advancing so fast that eventually all new inventions and innovations will be multi-disciplinary. To me this could mean that the engineering curriculum should change to adapt to the demands of the future. Multidisciplinary projects are the small steps that the engineering education is taking to adapt to that demand. Lastly, these multidisciplinary projects also have all the benefits of any other project, from reinforced technical learning to the benefits of enhanced soft skills.

5. *Student E (Senior)*

Multidisciplinary design projects are special because it requires a unique mindset to design and pull off a certain vision that the project requires. If only a team of electrical engineers work on a project, then most likely it will take a person with an electrical engineering mind to understand and appreciate the completed project. If a team of electrical, civil, and mechanical engineers work on a project together then it provides the opportunity for more people with different mindsets to understand and appreciate the completed project.

6. *Student F (Senior)*

Engineers collaborate with all kinds of other personal in the professional world so the college experience of doing the same thing is valuable and a worthwhile investment. Engineers need to learn how to communicate and understand the language and mindset of different engineering and industrial fields. The more exposure a student can get to these situations, the higher chance of success in the workplace that student has. Engineers can work closely with all kinds of personal like architects, construction managers, project managers, design engineers, civil engineers, structural engineers, and environmental engineers so the more exposure a college student has towards these personal groups the better off that student will be. Each field of engineering (like some of the personal listed above) has its own unique 'lingo" that goes with the field so understanding the language and mindset of let's say an architect will greatly increase your effectiveness of communication. Again, this goes down to the college level: The more exposure a college student gets to a civil engineer or an environmental engineer or any other kind of engineer, the higher chance of success that student will have in the professional world.

7. *Student G (Senior)*

The college needs to be able to focus on the educational welfare of the student with all focus it can spare. Multidisciplinary design projects are a tremendous way of providing a situation where different minds from different fields of study have the chance to collaborate and discuss the challenges at hand. Different perspectives can be an incredible valuable thing in the design world. Having different people from different academic "walks of life" is the recipe for unique and innovative engineering.

8. *Student H (Graduate Student)*

The importance of multidisciplinary project cannot be over emphasized especially in this fast-paced innovation age we find ourselves. The development rate and the diverse nature of the problems and challenges the world is faced with today requires the coming together of professionals from different disciplines. This presents a wealth of diverse knowledge and expertise from which broader perspectives, in-depth research analysis, and an innovative and cutting edge designs are made. With this in mind, the curriculum which acts as the guide from which educational instructions are executed should be adapted to prepare students for real-world challenges.