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Links among student club projects, senior design projects, and international competition projects, a case study

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Links among student club projects, senior design projects, and international competition projects, a case study

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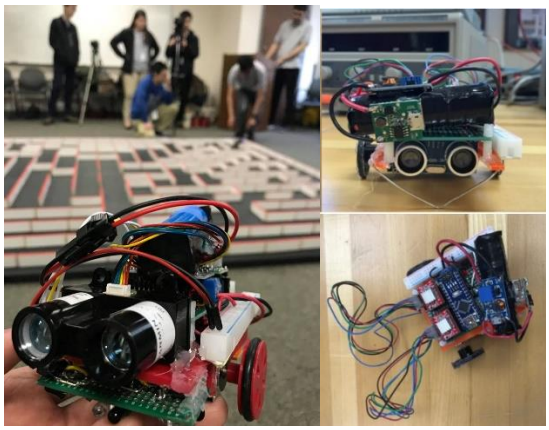
I Introduction

The concepts and applied pedagogical approaches to expose and engage engineering students to their field of study through programs leveraging hands-on, project-based, teamwork/leadership, cross/multi-disciplined teams, and career preparation concepts have been well documented in FIE, IEEE, and ASEE papers and deployed in Universities as electives, senior design, and curriculum core courses.

The curriculums such as Montgomery College development of a freshman based multidisciplinary design projects [1], indoctrinates these students to the challenges of product development and continued STEM education. Supporting this cradle-to-graduation concept, Tufts University Engineering has embraced the project-based and collaborative engineering education program [2]. Preparing an engineering student to their career, is the challenge of senior designs and collaboration with Industry [3]. To prepare that engineering student for their first career year, courses in career preparation and the business skills [4], a course derived as a student led career development [5], and others are fulfilling the industries' need for well-educated and business ready [6] students. But how does a university which has one way, or another applied these pedagogical techniques, expose students even more. At Gannon University, reinforcing engineering collaboration at a multidisciplinary and industry level is based on blending various engineering clubs, senior design, and inter-collegiate projects to participate in international competitions. This paper shows how an engineering design propagates from a small device to a complex system mimicking exposes the student to the current development challenges of the autonomous mobility industry.

Gannon University is a teaching orientated university without Engineering Ph.D. programs. How to engage undergraduate students in research projects, especially extra-curriculum research projects, is challenging from multiple aspects, including financial support, faculty advising support, students' motivation, and resources. As a case study, this paper (poster) will choose a series of student projects from different entities in a four-year period from spring of 2018 thru spring of 2021. The research projects include the IEEE student club and regional competition projects, senior design projects to solve local community and industrial problems, and international intelligent ground vehicle competition projects. These projects originated from different opportunities and evolved in variable ways. Yet they link among each other in terms of scope, content, and engineering knowledge. They all bear the commonly important threads of engineering education, namely student engagement, hands-on experience, real world design and application, as well as teamwork, time management skills, and project management skills.

II The Micro-Mouse, Macro-Mouse, and the Mega-Mouse projects



(a)

(b)

Figure 1 (a) Micro-Mouse (b) IEEE student club won the 3rd place award for Micro-Mouse in IEEE R2 SAC 2018

The IEEE student club project micro-mouse is an autonomous robot which solves a maze to find a path to a certain destination. The destination could be anywhere in the maze, and whoever can go through the discovered path faster wins the competition. Figure 1 (a) shows students' products. They won 3rd place in 2018 IEEE Region 2 (R2) Student Activities Conference Micro-Mouse competition as shown in Figure 1 (b).

The "Macro-Mouse" is a 2019 senior design project which has a five-member multidisciplinary design team consisting of mechanical, electrical, computer, and software engineering students as shown in Figure 2. This autonomous robot was designed to remove snow and simultaneously lay down salt to prevent icing. The Macro-Mouse was inspired to address the snowy weather of our city of Erie PA with an annual average snowfall of more than 100 inches. This robot can follow a predetermined route, and will start to plow the snow once it reacheds 3 inches thick. Figure 3 shows the various stages of the projects as well as the testrun.

Figure 2 the Macro-Mouse autonomous snow removal senior design team

Figure 3 Macro-Mouses and the testrun

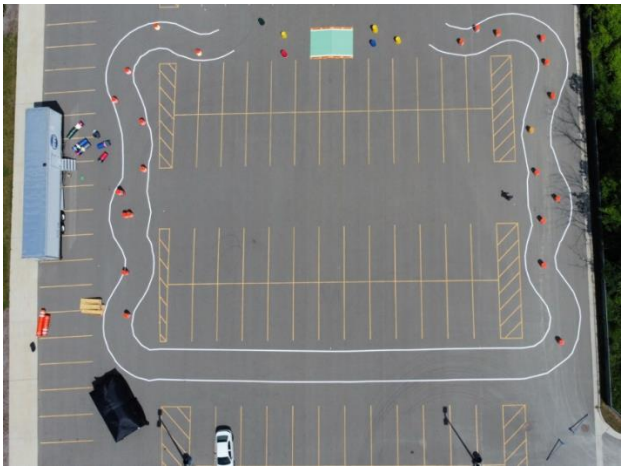


Figure 4 Sample obstacle course of Intelligent Ground Vehicle Competition (IGVC)

Figure 5. Mega-mouse at 2019 IGVC and the main team

The "Mega-Mouse" is built for the annual international competition, Intelligent Ground Vehicle Competition. It is an autonomous robot that can sense the lane path, obstacles, and navigate through a random route. Figure 4 shows one of such courses which occupies an entire commercial parking lot. The course also has a breaking segment where no track or trace is present with a ramp being included in the middle of the path. The vehicle must rely on path lane and obstacle sensing, prediction, and GPS signals to successfully localize and navigate through this segment and go back to the correct path. Figure 5 is the main team and robot built in 2019 while Figure 6 shows the new robot and the team at the IGVC in 2021.

Figure 6. Mega-Mouse at 2021 IGVC and the main team

III Links among and the evolution of these projects

Table 1. Comparison and evolution of the three "mouse" projects

	Micro-mouse	**Macro-mouse**	**Mega-mouse**
Year	2018	2019	2019-2021
Project duration	Three months	Two semesters	Two years
Event	IEEE student club project	Senior design project	International competition project
Originated from	Student regional competition	Serve local community	Industry and innovation
Funding	Student club ($200)	Senior design and department support ($2,000)	Industry sponsor, college, and other university internal funding ($15,000)
Size	Handheld	Commercial wheelchair base with additional structure	Commercial wheelchair base with structure modification
Function	Maze solving robot	Autonomous snow removal	Autonomous Intelligent Ground Vehicle
Team	EE	ME, EE, CE, Software E	ME, EE, CE, Software E, CIS, BME (UG and GR)

Table 1 summarizes the relationships among and the evolution of these projects while table 2 summarizes the common knowledge and technology thread linking all projects together. These

three projects were originated from different opportunities yet one can see a clear "growing" path from Micro-Mouse to Macro-Mouse, and to Mega-Mouse from 2018 through 2021. Students who moved through these projects are "growing" and "maturing" along with each project in terms of student engagement, hands-on experience, real world design and application, as well as teamwork, time management skills, and project management skills.

The Micro-Mouse started as a student club project and lasted for about three months.

- With a couple hundred dollars as the seed fund, it is a handheld small robot solving a maze of 16 x16 unit grid, with each unit of 18cm x 18cm.
- The project team consists of only EE students (IEEE student club members). The timeline is clear, and the team management is relatively simple and straightforward. IEEE club officers call weekly working sessions and coordinate with the department lab engineer for lab space, equipment, and materials needs.
- Students were engaged and drawn to this hands-on project since "it has more fun than lab work". They formed two groups based on interests and skills, with one group working on a commercially available kit and the other working on designing a mouse from scratch.
- The kit is a great starting point for understanding the competition and engineering requirement. Besides needing assemble, the kit also includes tutorials and template for mapping algorithm and coding. The experience with working on the kit provided design ideas for the designed mouse.
- The knowledge skills for the design group are in the areas of simple circuits, electronics, microcontrollers, simple DC motor drives. The maze mapping algorithm can be adopted and modified from the kit.
- It is an inspiring and rewarding experience for sophomore and junior students with a relatively quick turnaround timeline.

Table 2. Technology and scope of the three "Mouse" projects

	Micro-Mouse	**Macro-Mouse**	**Mega-Mouse**
Circuits	simple	complex	sophisticated
Electronics	simple	complex	sophisticated
Automatic control	simple	complex	sophisticated
Power Electronics	simple	complex	complex
Electric drives	simple	complex	complex
Microcontroller	yes	yes	yes
Embedded system	yes	yes	yes
Coding skills	medium	complex	sophisticated
GPS	no	no	yes
Onboard Computer	no	yes	yes
Sensors Types	2	3	5
Battery level	low	high	high
Image recognition	no	no	yes
Mechanical	simple	medium	complex
Emergency stop	no	yes	yes

The Macro-Mouse was a senior design project and lasted for two semesters.

- With a couple thousand dollars fund coming from student senior design and multiple department support was to address a local community winter problem. It utilizes a commercial power wheelchair's base as the foundation. With a full charged battery, it can cover a few driveways of the residential neighborhood.
- The project team consists of five seniors from four different disciplines and three different departments. The project management follows senior design timeline. Students not only attend the senior design class and complete related assignments and reports required by their own discipline, but also have weekly working sessions scheduled outside class time. Both ME and EE lab manager/engineer acted as supporting role to provide lab and workshop space, equipment, and purchasing materials needs.
- The knowledge base and the applied technology required by this multidisciplinary project are in a wide range of areas as shown in Table 2. Students from ME, EE, CE, and Software Engineering worked closely with each other. Just as in a real engineering environment, they need to speak the language that other disciplines can understand, to communicate effectively, and to work together for a common goal.
- In response to a local community need, students came up with this project idea which is inspiring and engaging. Being hands-on and solving a real-world problem motivated students to put much effort and thoughts into the project. It also enabled them to be resilient, resourceful, and able to unleash their full potential.
- The team showcased their robot during Celebrate Gannon Event which is an annual celebration of students' scholarships as shown in Figure 7. They also won the Grand Champion prize in the 6th annual Erie Collegiate Innovation Showcase [7] as shown in Figure 8. The award also included a half year free rental of an office space in Erie's Incubator, financial and marketing consulting from a professional team associated with Erie's Small Business Development Center to help them to potentially launch a startup company and to commercialize their product. The team was interviewed by local news [8].
- It is a rewarding experience for these five senior students. They went through the main cycle of the R&D of a product with a short timeline of two semesters, emerged themselves in a multidisciplinary environment, and successfully delivered the prototype of a product. Towards the end of their senior design, the engineering team had the chance to interact with business senior students to form the business plan for a potential startup company.

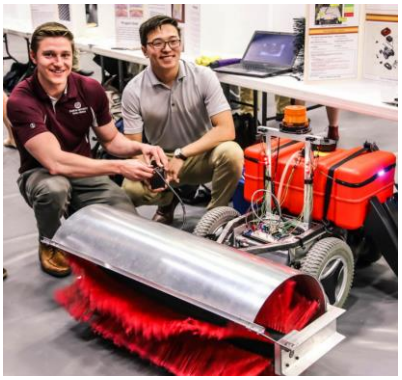


Figure 7. Showcase in Celebrate Gannon and interviewed by local TV stations.

Figure 8. the Grand Champion prize in the 6th annual Erie Collegiate Innovation Showcase

The Mega-Mouse was an international competition project and lasted for two years.

- The team has financial support from the department, college, industry sponsor, student government association, and faculty research grant. The competition course is approximately 450 feet long in an area 140ft wide and 120 feet deep. Obstacles on the course consist of various colors (white, orange, brown, green, black, etc.) of construction barrels/drums that are used on roadways and highways.
- The knowledge base and the applied technology required by this multidisciplinary project are elevated from those of the Macro-Mouse as shown in Table 2. Just using the sensors type as an example, the Mega-Mouse had camera, GPS, LIDAR, E-Stop, and Encoder. It is a sophisticated engineering system with complex hardware and software subsystems. Besides the design and fabricating, the debugging and testing were at a much more complex level than the senior design project.
- The project team consists of both undergraduate and graduate students of almost all engineering disciplines from the college. The project management was challenging since it was not tied to any regular course work or any specific student club. One passionate ECE faculty member acted as the advisor/mentor for the team. He assumed as the project manager and pointed a few sub-section project managers among the students. He brought the industry project developing and review process to the team with weekly briefing, reviewing and design meetings.
- Comparing to the senior design Macro-Mouse project, the engagement and motivation level of the Mega-Mouse was low. Except for a few key team members, other members were off-on the activity and sometimes totally detached from the team. One reason is due to the demanding of the knowledge and skills, which in certain level discouraged freshmen and sophomore students from meaningful participation and contribution. Another reason is the long timeline and no short-term milestone to celebrate. The third reason is due to the disconnection to the measurement of the curriculum. This project did not tie to any specific course nor bear any college credit. It was a purely extra-curriculum activity.
- Teaming up with one of the student engineering clubs, GUBotDev starting the second year improved students' participation and expanded the resource. The GUBotDev mobile lab (a modified full RV) acted as the onsite testing laboratory for the team during 2021 competition as shown in Figure 6.
- It is an excellent experience for the team to enter the competition and meet with other teams from all over the world. It was a fruitful experience for the key project members with one of

them being hired by the team sponsor, IAMRobtics, and continued his career as an autonomous robot design engineer.

IV Take away

The progress of these three projects in a three-year period is a unique case study showing how multiple factors affect the students' research experience and the outcome of the projects. All three projects are closely related to the electrical and computer engineering curriculum. Students applied what they learned in class to address local community problems and participated in professional competition. A few take away observations:

- For undergraduate student research, it is more effective to start from a small and simple scale which relies on fundamental knowledge. Students gain experience and confidence with success, and then can scale-up to a more complex system for more realistic objectives.
- Students are more engaged if the project duration is not very long, and they can "taste" the outcome/success relatively quickly. These "simple" yet "fun" projects can help to recruit students for more complex and more demanding projects.
- Students are more likely to be engaged if the project is tied directly to their course work (such as senior design project) or bears credits. This was the lesson learned from the Mega-Mouse project. Although a few key members sticked with the competition project from the beginning to the end, but most of the team is loosely engaged. Since the actual competition takes place in June, the month leading to the competition saw only a few students at school and working on the project.
- Effectively communication and documentation are one of the key aspects for a complex multidisciplinary project. Utilizing a team communication app and creating a dedicated document storage place are the two things that the team wished they would have done earlier.
- Faculty advisor/mentor for the complex project is one of the key factors for success. But how to reasonably count faculty member's load towards his/her teaching, service, and research is an ongoing and evolving topic depending on the specific policy of the college.
- Students gain experience of applying knowledge to solve hands-on real-world problem. They also had excellent opportunities to nurture their resilience and patience, embrace differences, and improve their teamwork skills. There were exciting and rewarding moments, and there were inevitably frustrating and confusing moments. Students learned to embrace both and claim both as winning experience.
- How to be successful with a multidisciplinary senior design project with different senior design courses from different departments. This is a question still needing answers. Use the Macro-Mouse as an example, the five team members belong to three different senior design courses with different timeline, assignments, and requirements. One of the initiatives raised from this experience is to have a common, college-wide senior design course with one single course syllabus and one set of requirements. There are ongoing discussion and debate on ABET evidence collection and asynchronous credits requirements from different department. This could be a good topic to cover for the future.

Despite all the ups and downs along the way with these series of projects, as educators, it is always rewarding to witness students' growth technically, emotionally, and professionally. All members of these teams are either landed great engineering jobs or are pursuing secondary education. We are planning to conduct student surveys for future projects.

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