Full Paper: Future-Ready Students: Providing Opportunities for Remote Collaboration on an Engineering Design Project

Dr. David M. Feinauer P.E., Virginia Military Institute

Dr. Feinauer is a Professor of Electrical and Computer Engineering at Virginia Military Institute. His scholarly work spans a number of areas related to engineering education, including the first-year engineering experience, incorporating innovation and entrepreneurship practice in the engineering classroom, and P-12 engineering outreach. Additionally, he has research experience in the areas of automation and control theory, system identification, machine learning, and energy resilience. He holds a PhD and BS in Electrical Engineering from the University of Kentucky.

Dr. Michael Cross, Norwich University

Michael Cross is an Assistant Professor of Electrical and Computer Engineering, teaching classes in the areas of circuits, electronics, energy systems, and engineering design. Cross received degrees from the Rochester Institute of Technology and the University of Vermont.

Ali Al Bataineh, Norwich University
Toluwani Collins Olukanni
Majd Khalaf, Norwich University

Majd Khalaf is a senior undergraduate student at Norwich University, majoring in Electrical and Computer Engineering. He is deeply passionate about DevOps engineering and machine learning. Majd has contributed to various projects and research in natural language processing (NLP) and computer vision. Currently, he is a Site Reliability Engineering intern at Walmart ASR and a Senior AI Researcher at Norwich University's Artificial Intelligence Center.

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Abstract

Successful engagement and collaboration on projects where members of the team work remotely is an essential skill for students to develop. Having students collaborate with partners from another institution can add elements of reality and relevance to a class project, creating further opportunities for instructors to prepare students for the expectations of the modern workplace. This paper details the design and execution of a class project for first-year Electrical and Computer Engineering students, with project teams comprised of students from two institutions. While the organization effort is slightly higher for the instructors than other course projects, the observed value to the students is notable. Students report more communication, coordination, and teaming difficulties on this project than they do for other course projects, but they also report satisfaction and a sense of accomplishment, and their responses to end-of-project surveys show a maturing of their understanding of effective teaming skills.

Introduction

Remote workdays have increasingly become the “norm” for many workers. Prior to the pandemic, about 6% of US workdays were remote, with the number peaking around 50% during the pandemic and currently around 28% post-pandemic, according to [1]. Whether working in-person or remotely, engineers having to work with teams spread across the globe is not a new phenomenon. Engineering teams have utilized email communication, file-sharing, video conferencing platforms, and other remote collaboration tools and processes for decades.

Developing and strengthening communication and collaboration skills in engineering students is important in preparing them for life after college. The term 21st Century Skills (21CS) has been in use for a long time to describe the future-ready skills needed by graduating students in an increasingly connected society. The Brookings Institution tracks the alignment of educational systems to 21CS, and the challenges educators face trying to enhance education and assess student attainment in response to the ways of thinking and living represented by these skills [2]. Expanded definitions of 21CS often include the 4 Cs (communication, collaboration, critical thinking, creativity) as well as metacognition, global citizenship, and one’s “ability to function adaptively and effectively within their immediate environments, globally, and virtually [3].”

The authors have published previously on efforts to create classroom experiences that are real-world relevant and authentic to better prepare students for their future as engineers [4]. Those efforts focused on using embedded systems in an introductory electrical and computer engineering (ECE) laboratory class to address real-world problems of human import. In line with this previous effort and the call to enhance education by helping students develop future-ready skills, the authors have developed a project that is real-world relevant with respect to the technical problem to be solved, the professional skills employed, and the tools and processes used for team collaboration throughout the project.

In this paper, the development of and approach to a multi-week project involving first-year ECE students from two institutions is discussed. The skills learned by the students at the institutions are outlined, showing areas of commonality and uniqueness. Results from two years of implementation and examples of student work are shared. An analysis of individual reflections and a survey administered to all participants, along with lessons learned from facilitating the assignment, are shared.

Project Approach

Norwich University (NU) is a small, predominantly undergraduate, private university with 2100 students on campus who are a mix of military and civilian students. Virginia Military Institute (VMI) is a small, state-supported institution comprised completely of military students, with 1600 students on campus. It is important to note that while both institutions have students who live a regimented military lifestyle as part of a Corps of Cadets, not all students involved in the project were cadets. The regimented lifestyle of being a cadet includes many additional schedule restrictions and demands on a student's time. At VMI, the instructor questioned whether the first-year students were developing communication, scheduling, and general project management skills as well as they should be because of the tightly controlled schedule. It was too easy for students to find times when everyone on the team could be available, and they could work in lockstep together through everything, alleviating or greatly reducing the need for task coordination, scheduling, and frequent progress updates. The authors also speculate that this phenomenon may be a challenge at many "non-military" institutions, given the prescriptiveness of many first-year engineering curricular maps and the few or single-section offerings likely at small institutions.

To create a more "real-world" relevant project environment, ECE students from NU and VMI worked in teams to propose a solution to a design task: develop a smart home device to automate a daily task utilizing a sensor, actuator, and skills learned in their first-year ECE intro course. Working in groups of 2 or 3, ECE students at the institutions applied their technical skills (circuit analysis/build/test, programming, simulation, and engineering design process) as well as professional skills (teamwork, time management/scheduling, collaborating remotely, and visual presentation) to propose a solution to the designated task. Groups were assigned by the instructors, with each team comprised of at least one student from each institution. When two students from the same institution were on the same team, the instructors prioritized making sure those students were from different sections of the course, although this was not always possible. The course meeting times and semester start and end dates for the institutions did not align, adding to the authenticity of the assignment and requiring students to navigate setting norms and developing performance expectations with their remote partners. Students were required to work on the project outside of scheduled class time and were given one lab period to support solution development. The project concluded with students participating in a joint, remote (evening) group presentation.

Table 1 details the course experiences typical of students from each institution. The project occurs near the end of an intro to ECE course in the Spring semester of the first year. Students from NU have much more experience with the engineering design process and analytical down-selection than the students from VMI. The students at VMI have more programming experience and more data visualization and plotting experience than the students from NU—the project required engaging both skill sets. Both cohorts have similar experience with respect to building and analyzing circuits and interfacing them with an Arduino microcontroller.

Table 1: Details on first-year student course experiences at both institutions.

Course Experience	NU	VMI
Programming in C/C++	3 hr Spring (co-req)	3 hr Fall (pre) + 3 hr Spring (co-req)
Introduction to Engineering (Engineering Design Process, Sketching, Report Writing)	1hr lecture + 3hr lab, Fall (pre-req)	N/A
Introduction to ECE (Circuit Building + Simulation, Arduino Programming, Report Writing)	2hr lecture + 3hr lab, Spring (project course)	1hr lecture + 2hr lab, Spring (project course)
Introduction to MATLAB (Problem Solving, Plotting, SPICE)	N/A	3 hr Fall (pre-req)

Table 2 details the timeline for the project introduction during the Spring of 2024. A similar but more compressed timeline was used during the Spring of 2023. Although project activities seem to span 6 weeks, only two class and lab periods were devoted to the project at each school. The increased lead time in introducing the project was to facilitate team introductions and workload planning and was needed due to the differences in the school calendars. In weeks 1, 2, and 4, the students at both schools had to complete other assignments and labs separate from the project.

Table 2: Timeline of project introduction at both institutions.

<table>
<tr><th>Week</th><th>NU</th><th>VMI</th></tr>
<tr><td>Week 1</td><td colspan="2">Introduce Project and Teams</td></tr>
<tr><td>Week 2</td><td colspan="2">Work with partners on own time (Brainstorm, set norms, discuss work plan)</td></tr>
<tr><td>Week 3</td><td>Lab devoted to project</td><td>Spring Break</td></tr>
<tr><td>Week 4</td><td colspan="2">Work with partners on own time</td></tr>
<tr><td>Week 5</td><td>Special University Event</td><td>Lab devoted to project</td></tr>
<tr><td>Week 6</td><td colspan="2">Evening project presentations</td></tr>
</table>

Students were assessed on their team presentation (delivery, organization, use case, and visuals), solution design (down-selection process, component selection, software developed, schematic), and self-reflection. When introducing the project to the teams, in addition to detailing the technical requirements for the project deliverables, the instructors encouraged the students to communicate with their partners early, and to develop team operational norms including the medium or channel for communication, how they store and share files, availability / schedule for meetings, and how they would handle / support a teammate who missed a meeting. The students were not directed or prescribed how to handle the previously mentioned issues, but the project introduction served as an opportunity to warn them that those issues could be more complex in the remote environment and encouraged them to address them early. Despite providing this guidance, issues related to delayed or presumably "non-responsive" teammates were the most frequent issues that students sought support and advice on.

Results and Discussion

Student Work

During a team meeting, students brainstormed potential projects and down-selected project candidates to choose a particular idea to advance. For the example work shown in Figure 1, the team considered 4 potential projects and ultimately chose to advance the "MAPI 5000 automatic plant watering system." The students ranked the projects based on team-defined criteria: cost-effectiveness, market potential, innovation, scalability, and customer satisfaction. Following the selection of the project, teams implemented the design in TinkerCAD and developed diagrams to convey functionality during the joint presentations (Figure 1).

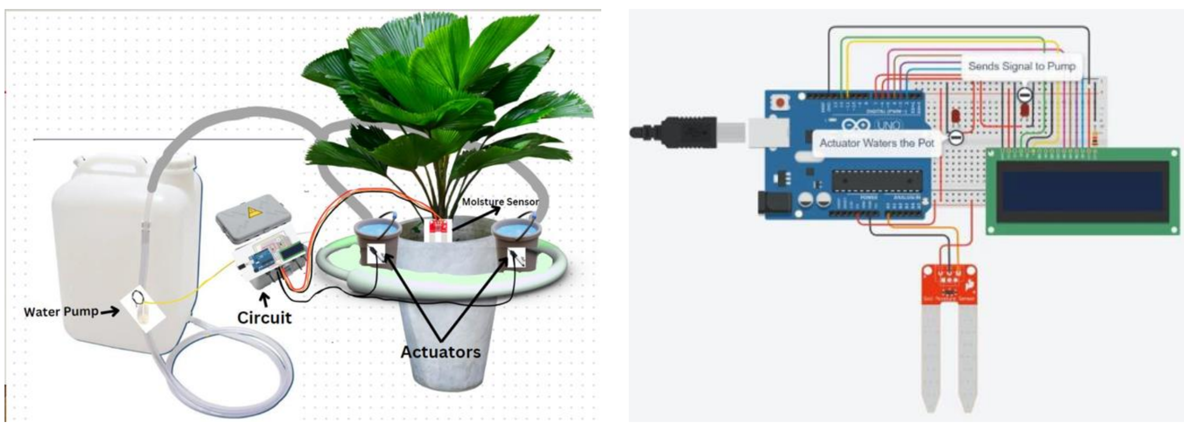

Figure 1: Visualization and TinkerCAD implementation of an automatic plant watering system.

Student Reflection

As a part of the overall project, students submitted individual, narrative reflections on the overall experience. An analysis of those reflections was conducted using Natural Language Processing (NLP) techniques and is detailed in another paper at this conference by the same authors. In addition to an analysis of student reflections, an anonymous survey was administered through each school's LMS at the end of the project. A summary of the survey results over two iterations is shown below in Table 3. Across two years of the project, 15 students from NU and 26 students from VMI responded. Of the 41 responses, 35 students identified as male, 5 identified as female, and 1 preferred not to answer. 18/18 students responded in 2023, and 23/29 students responded in 2024. The survey allowed for the collection of student sentiments on a more quantitative (Likert) scale and provided more immediate formative feedback to the instructors regarding the assignment.

In analyzing the results reported in Table 3, it is important to note that the student sentiment regarding preparedness for the project and overall success with the project was quite strong for both cohorts. However, the students' recommendation that the project continue in future offerings and the students' self-assessment of their effective collaboration is higher in the second year than in the first. Given the relatively small sample size, the change from S23 to S24 may not be statistically significant but does agree with the instructors' observations and may have resulted from the restructuring of the project to provide more lead time for team formation and coordination in the second iteration. The instructors suspect this may have contributed to greater enjoyment by the students and the sense of more effective collaboration.

Table 3: Course survey results. Numerical responses were ranked on a scale of 0 to 3 with 0 = Disagree, 1 = Slightly Disagree, 2 = Slightly Agree, and 3 = Agree.

Question Summary	**S23**		**S24**	
	$\bar{x}$	σ	$\bar{x}$	σ
What lifestyle are you?	Civil.: 4 Corps: 14	-	Civil.: 5 Corps: 18	-
EG110/EE100/EE150 prepared me well for this project	2.9	0.3	2.8	0.5
Through this project, I was able to teach my partner(s) something new	2.0	1.2	2.2	0.7
My partner(s) and I were able to effectively collaborate remotely	2.1	1.0	2.4	0.7
I would recommend this exercise continue in future course offerings	2.0	1.0	2.5	0.8
When the project began, I was worried about my ability to succeed with the task	1.9	0.9	1.8	0.9
I am pleased with what I contributed and how I contributed to this project	2.7	0.5	2.5	0.6
I feel like my team succeeded with the tasks required for this project	2.7	0.6	2.8	0.4

An analysis of student sentiments, as expressed in the free-response questions that were a part of the survey process is provided below. To conduct the analysis, the instructors worked as a remote collaborative team to develop summary themes and keywords (in italics in the list below) based on the frequency of occurrence of the theme in the student responses. Then, they selected one comment to serve as a representative example of the stated theme or key sentiment. This process provided insight into the professional skills developed and challenges overcome by the students throughout the project. The open-ended survey prompt, notable student response, and instructor drafted summary for 6 survey items is provided below.

1. ***How was this experience similar to your experience on other group projects in your intro class?***
   We utilized concepts taught in class and integrated them into our projects.; ...Also the way the work was split between the two of us was similar to working in class.
   Summary: Similar technical and professional skills/concepts and task division
2. ***How was this experience different from your experience with other group projects in your intro class?***
   You couldn't actually meet them in person to get work done. More communicating had to be done to make sure work was getting done.; ...the collaboration part was more individual and then giving updates along the way instead of working on different tasks alongside each other at the same time. *Summary: Communication and collaboration were slightly different and more difficult; more frequent communication needed.*
3. ***Describe the hardest challenge you had to overcome on this project?***
   Finding a time to sit down and get the work done especially before I knew my partner would have their piece done. Just because what I had done would limit what they could do and vice versa. *Summary: Scheduling, getting started, communicating effectively*
4. ***Describe your biggest strength or area where you shined on this project?***
   Circuit simulation and coding.; I focussed [sic] on brainstorming and researching ideas while also using my knowledge from last semester to create a decision matrix and problem statement. *Summary: Using existing skills (i.e. coding and decision matrix)*

5. ***What tools assisted in your completion of this project? How did you use them?***
   TinkerCAD was used to build a prototype of our product and the Arduino website assisted with the Arduino program. *Summary: TinkerCAD and online collaboration tools*
6. ***Is there any additional information related to the project experience that you would like to provide?***
   We had a really great experience so can't really complain. It was great to meet more ECE students.; I believe that the project was important and useful overall, and I would do it again, but I had serious issues to the point where it felt as though my partner was sabotaging the project. *Summary: Good experience for most; similar teammate issues*

Conclusion

Having students from two institutions work on a group project using tools for remote collaboration allowed the students to work through challenges with team distribution of effort and communication that are typically made easier by project teams consisting of residential students with typically similar schedules. While the students felt prepared for the project task and that they were able to succeed given the project conditions, they noted differences in the approaches and skills needed to succeed. Most notable were the differences in collaboration, communication, and getting started. Students found that their work on this project was inherently more parallelized than when they distributed tasks on a typical project. Only having short periods of time where everyone on the team could meet, with most of the project advancement happening outside of those meetings, was a noticeably different type of collaboration that necessitated more frequent and more effective communication. Finding time to communicate and establishing norms for where and how to communicate were also different for many students. Lastly, working with someone they didn't know or have previous experience with made starting the project more challenging than typical. One student said they didn't take time to get to know each other at the start of the project, which caused problems during brainstorming. It wasn't until they stepped back and got to know more about each other that they were able to move forward. The instructors noted that the students had less tolerance for someone from the other school not "carrying their weight" than they did for students from their own school—an effect seen in many online anonymous interactions and an indicator that some teams would benefit from more time spent up front getting to know each other and developing a team identity.

Some of the most frequent advice given by the instructors to the groups involved: needing to plan time to break the ice and come together as a team; establishing norms on the channel, time of day, frequency, and lead time for communications; and rehearsing the timing and transitions of presenting in a remote environment. While this advice may seem obvious, these items were most frequently mentioned as areas that were similar to but more challenging than other projects. Many students relied on Snapchat, text messaging, or MS Teams video conferencing to communicate instead of email. They also used TinkerCAD, PowerPoint, and other online office-like apps for the creation of collaborative documents. Many of the teams noted that the collaborative tools were helpful and that using them for this project was similar to their past experiences but more challenging. This sentiment could serve as a high-level summary of the overall project experience. In implementing a group design project as described in this paper, students felt prepared for the project by their prior classwork, they felt that the needed skills and overall operation of the project was familiar, but executing in this environment was different and more challenging — an additional dose of reality and challenge that the authors hope leads to growth and adaptability for the workplaces of tomorrow.

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