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Supporting creativity and innovation in STEAM undergraduate curriculum through hands-on learning

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Supporting creativity and innovation in STEAM undergraduate curriculum through extracurricular hands-on learning

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Abstract

Faculty from several colleges offered an intensive summer program with the objective of impacting student engagement in multidisciplinary research activities through specific curiosity and networking. George Mason University funded 10 undergraduate students who participated in the intensive (full time) ten-week program. Faculty recruited high school students in addition to the undergraduate students. Summative evaluations of outcomes were performed for all projects and formative evaluations throughout the summer in weeks 2, 6, and 10; post-surveys were completed after the summer program. In this manuscript we discuss our methods, delivery, and preliminary outcomes observed in the intensive multidisciplinary program for STEAM undergraduate students, and show some of the minimal viable products delivered, as well as research outcomes by the teams. (This is a "work in progress" manuscript.)

Keywords

Engineering design cycle; multidisciplinary summer experience for undergraduates; intensive summer; project-based learning.

Introduction

We examine here the short-term impact of a hands-on, project-based intensive summer experience for undergraduate students. Motivated by prior research showing that creativity is driven largely by specific curiosity (1) and that positive project outcomes are correlated with the sense of ownership (2), we proposed and delivered a 10-week intensive (40 hours/week) summer program to undergraduate students majoring in STEAM. We recruited from a diverse pool of applicants (64 undergraduate applicants from 14 different majors). The selected cohort included 10 undergraduates, 3 high school students, and one graduate assistant. The diversity in majors (Biology, Computer Science, Bioengineering, Game design, Psychology) and level of study (freshmen to seniors) as well as the split in females/males (6/4) contributed to the multiple perspectives and insights during the program. Four faculty (Cyber Security, Social Work, Mathematics, Electrical Engineering) were directly involved with the organization of the program, and 20 other faculty and community partners were involved as customers.

Figure 1 shows an overview of the summer internship schedule with workshops and extracurricular activities. For the first two weeks of the program, students were introduced to the design cycle and offered hands-on activities related to enhancing creativity (for example lateral puzzles and 30-circles), brain storming, convergence, emergence, and divergence, affinity mapping, scamper, collaborative sketching, and SMART goals. During those two weeks faculty

and community partners ("customers") were invited to attend the workshops and pitch their problems or projects. There were over 25 projects or problems pitched to the summer students. Students were often curious about those problems and brainstormed solutions during the pitches. By the end of the second week each student had an individual interview with a faculty mentor to discuss their strengths and weaknesses in relationship to the projects pitched. Students were asked what their "favorite" 5 projects were and asked to describe why. The faculty mentors redirected student's interests to the projects that fit with their specific curiosity and possible impact (for ownership purposes).

	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	week 9	week 10
Introduction & expectations	Peixoto									
Human subject research/ addiction	Matto									
Sensors/actuators		Peixoto								
Virtual reality basics			Grad student							
App development				Zhang						
Data analysis					Seshaiyer					
Digital story tools						Grad student				
Journal club	►	►	►	►	►	►				
Lab meeting / project updates	►	►	►	►	►	►	►	►	►	►
Lab outing (lunch/dinner/movie)	►		►		►		►			►
Project design review					►	►	►	►	►	
Program evaluation/feedback			►			►				►
Writeup (poster/digital story)										
School visits (middle/elementary schools)										
Presentations/submission to MARS										

Figure 1. Summer schedule with details of lead faculty (or graduate student) and social activities/enrichment ("Lab outing"), as well as outreach ("School visits")

From the third week on each student was involved in at least 2 projects and some students took all 5 projects. Each student became the project manager for one project. A list of projects and their websites is available online (website). There were 13 projects, with 85% performed by teams of 3 to 6 students (one individual project and one two-person team). 92% of the projects were completed and delivered by the 9th week of the summer. One project was discontinued due to its simplicity. Figure 2 shows an example of how the project distribution was performed (these are only sample projects out of the 13 projects). In this example, student A would have been the project manager for the first project but a team member for the second and third projects.

Project	Stakeholder/customer	Team members	Website
Exoskeleton for mirror-therapy	Bioengineering faculty	A (PM), B, C	http://childexo.onmason.com/
Greenhouse water system	Sustainability Office	B (PM), C, D, A	http://autohydroponic.onmason.com/
Linguistic racism	Cyber Security and Education Faculty	C (PM), D, A	http://lr22.onmason.com/
Wearables reliability	Psychology Faculty	D (PM), B	http://relyoneeg.onmason.com/

Figure 2. Project self-assignment and outcomes: students selected which projects and then decided who would be project manager, with the constraint that each student could only manage one project, but be a team member on several other projects. Examples of stakeholders are also shown in this figure, as well as the websites created for these projects.

Teams presented minimal viable products (MVP) to their faculty or community partner customers by the 5th week of the program, and obtained feedback on how to improve the project. Examples of MVPs delivered are available in the websites of projects (a full list of websites is available), (3) and a sample of those products is shown below in figure 3. Working every day, all day long (7 hours or more per week day), led to much faster turn-around time for deliverables than in our previous summer programs, especially during covid, when teams were only meeting over zoom. On the other hand, team dynamics became more apparent earlier than in previous summer programs. All teams delivered final video presentations, as well as written reports. 60% of the projects were submitted for publication at national conferences (BMES, biomedical engineering society), or journals. Final videos for all projects were presented during the university's undergraduate celebration (available online: website). (4)

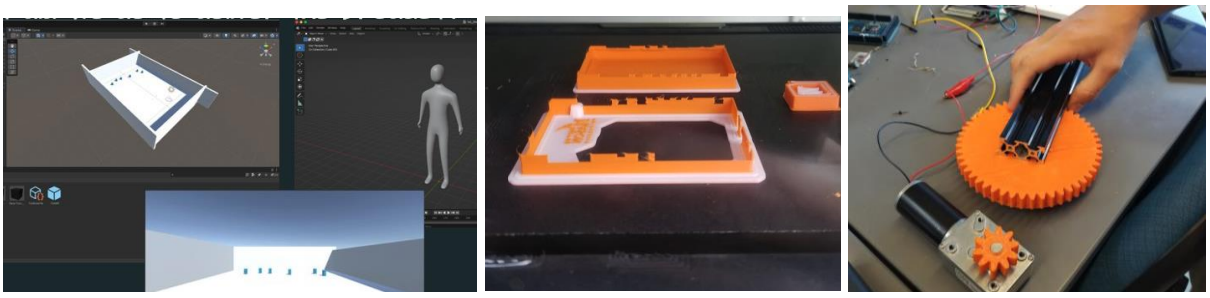

Figure 3. Samples of minimal viable products (MVPs) in software and hardware-centric projects that were designed, tested, and built by summer undergraduate teams at George Mason University.

Assessments, Results, and Conclusions

Learning outcomes were assessed through surveys, individual meetings with faculty throughout the summer, and in published results with data acquired in the summer and authored by the students who led each project (5, 6, 7, 8). In previous summers, during REUs (research experience for undergraduates) our team of faculty led individual projects with undergraduate students working alone or with one graduate student. Outcomes from those projects rarely

included websites, publications, or further research. Based on our exit survey results, the interventions tested in our program which yielded the most significant results and were the most impactful for the students were: 1. team-based approach instead of individual projects; 2. social activities every other week with the whole group, in the middle of the work day; 3. expectations of deliverables set in the beginning of the program (website, video, report, publication); 4. daily check-ins with each team, following a scrum-agile framework (9).

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Holly Matto

Holly is an Associate Professor in the College of Public Health, Department of Social Work at George Mason University since 2011. Prior to that, Holly taught theories of human behavior, direct practice, and research methods in the master's and doctoral programs. She has over 20 years of research and practice experience in the field of addiction science and has conducted treatment intervention studies with diverse clinical populations. Over the past several years, she has been working with interdisciplinary colleagues to develop interventions that help patients monitor their biobehavioral state and deliver personalized patient-specific self-regulation strategies. Specifically, her work examines how change in visual sensory input can be used to regulate autonomic nervous system activity.

Linghan Zhang

Linghan is an Assistant Professor in the College of Engineering and Computing, Department of Cyber Security Engineering at University. Her research interests lie in wearable sensing, human computer interaction, and cybersecurity. She is especially interested in physiological signal- and biometrics-based HCI research.