

Work-In-Progress: Early Student Exposure to an Entrepreneurial Mindset in Engineering Research

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Abstract

Many studies have indicated that research experiences can be beneficial to undergraduate students. However, these experiences are not given the same importance as coursework by faculty and administrators designing curricula and undergraduate research (UGR) programs. In addition, UGR experiences could be greatly improved by the incorporation of an entrepreneurial mindset (EM) and entrepreneurially-minded learning (EML).

This project has three objectives to impact undergraduates concerning research early in their program of study: (1) Knowledge, having awareness of basic facts about research; (2) Mindset, understanding the entrepreneurial mindset and its role in research; and (3) Motivation, lowering barriers to entry for undergraduates contemplating opportunities to engage in research.

This work emphasizes connecting first- and second-year undergraduate students with research opportunities. Through a series of inspiring and intellectually stimulating videos, this project establishes the potential for students to create value for themselves and their communities by engaging in cutting-edge research activities. The videos and associated classroom activities are organized into modules using five fundamental questions: “What Is Research?,” “Why Should I Get Involved In Research?,” “What Is The Entrepreneurial Mindset?,” “How Does Research Get Done?,” and “How Can I Get Involved In Research?.” Through each of these topics the objectives of knowledge, mindset, and motivation are addressed. The project team has begun implementing these modules in first year engineering courses where students are introduced to broad themes in their major field of study. These introductory courses are the logical target venues for engaging undergraduates early in their academic careers.

Students who engage with this content in the classroom will be surveyed to assess the effectiveness of the modules. There is a plan to conduct student surveys at the end of each course and one-year post exposure to evaluate both the immediate and long-term impact of the materials. The project team hypothesizes that students who engage early with the videos and paired curriculum will be more likely to participate in research and remain engaged for longer. Preliminary survey results support this hypothesis, showing students self-report learning gains and an increased interest in research and research-related careers.

This project is part of a Kern Entrepreneurial Engineering Network (KEEN) initiative to infuse EM into UGR ecosystems at universities and use it to address common challenges in undergraduate research faced by faculty in a range of institutional settings. Faculty and

administrators intent on boosting the productivity of UGR programs and engaging students will be interested in the development of this framework.

Project Purpose

With the decline in undergraduate enrollment experienced nationwide (Fall 2021 at 3.1%) [1], it is important to retain currently enrolled students, especially in STEM programs. Participation in undergraduate research (UGR) can provide incentive for students to finish their degrees and contribute to the recruitment and retention of students in STEM.

Industry is very interested in the preparation of students that graduate from STEM programs. As a result, most universities do have Industrial Advisory Boards which “discuss the current research themes and their relevance to emerging industry needs. “ [2] Industry benefits from helping identify skills (technical and professional/soft) that would be required by the students to be successful. One way that industry can be involved in research is to fund Industry-Based Projects which intentionally embed undergraduate research [3]. Previous literature demonstrates clear academic, professional, and personal benefits for students who are involved with research. Sadler and McKinney [4] studied the literature on the impact of scientific research on undergraduate students. They saw consistent benefits for students due to their involvement in UGR, such as better career aspirations, confidence, understanding the nature of science, intellectual development, scientific content knowledge, and a variety of specific skills. For example, the National Science Foundation’s Research Experiences for Undergraduates (REU) program provides appropriate and valuable educational experiences for undergraduate students through participation in research. This program has been very successful; however, REU programs typically involve juniors and seniors. There are an increasing number of REU programs for freshmen and sophomores [3], although there is still a need to expose undergraduates to research early in their undergraduate career.

Russell et al. [5] surveyed 15,000 people to develop a profile of an undergraduate researcher. They found a positive connection between undergraduate research and an interest in STEM careers and graduate study. They also discovered that early repeated exposure to research fuels the undergraduate student’s enthusiasm, which is a key element for retention and success. Earlier exposure is better, suggesting that new efforts should focus on the freshman and sophomore years, as well as fostering STEM interests in elementary and high school students. Hernandez et al. [6] specifically address underrepresented students in who engage in undergraduate research concluding that these students benefit with better academic performance and graduation rates, higher acceptance into graduate school, and long-term scientific workforce participation. Based on this research, exposing students to research possibilities early in their academic career, especially for minorities and students with a low socio-economic status, can spark an enthusiasm and therefore help improve retention and success. The students are made aware of opportunities previously unknown to them. This is a good first step in their academic journey. However,

Madan and Teitge [7] identified that first year students are overwhelmed by the academic process and do not even know that research is an option, let alone how to get involved. They also state that any academic institution can enhance its undergraduate curriculum by promoting research to those who show an interest as well as those who might not otherwise know how to get involved.

The barriers to participation in research by students early in their undergraduate careers can be overcome with a combination of two approaches: (1) introducing students to the research process early with structured opportunities for student involvement, and (2) fostering a mindset in undergraduate students that improves motivation and interest in research-related activities. The project team proposes to accomplish both goals through a series of classroom modules that focus on developing an entrepreneurial mindset (EM) in early undergraduate students.

EM refers to the three key concepts of curiosity, connections, and creating value. For more than a decade, faculty involved in the Kern Entrepreneurial Engineering Network (KEEN) have introduced EM in undergraduate courses. Engineering education efforts have benefitted by including EM in the classroom through learning objectives designed around these concepts. However, EM has not yet made the transition to UGR experiences. This paper describes a multi-institutional project to develop a framework for implementing EM in UGR and for using EM to address common challenges in UGR faced by many institutions. The work is the first of its kind that emphasizes the entrepreneurial mindset in the context of UGR. The five segments of this project are shown in Figure 1.



Figure 1. An EM-Driven Framework for Undergraduate Research

A faculty survey was developed and distributed to participating institutions to better understand faculty perceptions and motivations when involving undergraduate students in their research work. This is a work in progress, but 50 responses have been collected so far across four universities. Figure 2 shows faculty responses to the question: “What is your biggest concern about working with undergraduate students?” The results indicated the most significant concern (45% of the responses) is “Short duration (no deep / prolonged engagement)” Many students find out about research opportunities when they are juniors or seniors, and close to graduation. As a result, it is worthwhile to communicate research opportunities to students earlier in their undergraduate study to address this common concern.

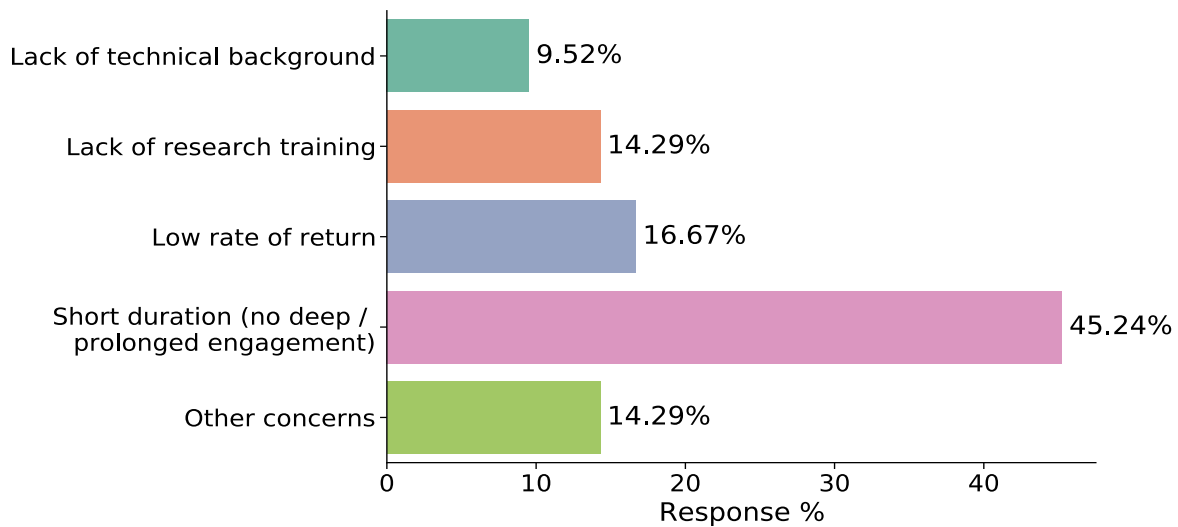


Figure 2. Faculty Responses to Question “What is your biggest concern about working with undergraduate students?”

In order to increase early participation, overall participation, and productivity of students in UGR, early exposure to research opportunities and an understanding of relevance of EM within research are crucial. In particular, this work-in-progress paper outlines the progress toward the early exposure of undergraduate students to research. This work aims to achieve three objectives for students: (1) Knowledge, providing awareness of basic facts about research; (2) Mindset, developing an understanding of the entrepreneurial mindset and its role in research; and (3) Motivation, lowering barriers to entry into undergraduate research opportunities. To achieve these aims, the project team is developing a series of five modules containing paired video content and classroom activities and a bank of comprehensive instructor resources. This project targets first year engineering experiences (FYEE) for the implementation of these materials to impact students early in their college experiences.

The modules are intentionally not targeted to any specific engineering field but address topics that are broad enough to apply to most engineering research laboratory settings. The topics are intended to stimulate thought around a possible research involvement. Specific skills not addressed in the videos would be acquired in each laboratory as required. Because of the short, focused nature of the materials, these modules can be easily implemented into existing curriculum in any course but especially in FYEE courses. The adoption of these videos and/or activities by each university will require an individualized approach to determine the optimal utilization of the materials and to select the specific modules to be implemented.

Early Exposure Content Development

The approach taken by the project team was to develop short videos paired with accompanying activities to introduce undergraduate students to the concept and context of research, the entrepreneurial mindset, and ways to get involved in UGR. The videos serve the main objectives of giving students the necessary knowledge, mindset, and motivation to productively engage in UGR. The activities serve as the active-learning component to solidify and operationalize the content from the videos. The activities are largely focused on giving students experience engaging with these concepts, exercising an entrepreneurial mindset, and connecting them to local and national opportunities.

Early Exposure Videos

The project team has developed a series of inspiring and intellectually-stimulating videos that emphasize the potential for students to create value for themselves and their world by engaging in cutting-edge research activities, thus, developing intrinsic and extrinsic motivation structures. The videos are designed to answer basic questions that students might consider when learning about research and deciding whether to get involved. The videos can be used in a synchronous or asynchronous setting and would ideally be implemented in FYEE courses where students are introduced to broad themes in their major field of study. The videos also introduce the principles of the Entrepreneurial Mindset as formulated by KEEN, which are the 3 C's of Curiosity, Connections, and Creating Value. This formulation is consistently used by the numerous partner institutions of KEEN. Each video centers around a question which also serves as the title of the video. The five short videos are as follows:

1. What Is Research?
2. Why Should I Get Involved in Research?
3. What Is the Entrepreneurial Mindset?
4. How Does Research Get Done?
5. How Can I Get Involved in Research?

The use of short videos as a learning tool is not a new concept, but one that has its roots in the “flipped” classroom model [8]. In a survey of educators by Kaltura, a leading classroom capture video company, 93% state that videos improve the learning experience. Students like videos because they are more engaging, can be watched anywhere and anytime, increase knowledge retention, assist in the learning of any subject, and help the students become more technologically literate. Faculty like videos for similar reasons: they increase student engagement, offer flexibility, allow faculty to offer flipped classrooms and remote learning, give students opportunities for feedback, and allow faculty to be facilitators. The research has also shown that shorter videos, around 5 to 10 minutes, let students learn without getting overloaded with content. Other literature shows that 69% of people would rather watch a video than read an article, and that by doing so their content retention increases by 35% [9].

In a study at a large research university in the Southeastern United States, students were generally positive about using pre-class videos for their courses [10]. In this application, a 20-minute video was not considered unreasonably long. The students had definite suggestions for improvement, such as that the videos needed to be professionally produced and thoroughly tested on the proper equipment before being released to the students. Videos should be kept short and accompanied by some sort of pre-class learning activities, which also should not take too much time. The research also suggested that the videos cover the learning content and present it in a clear and concise manner.

As a result, a professional videographer was engaged to help shape the scripts to maintain a short length while still educating undergraduate students about research. The project team also chose to deploy these videos in a classroom environment under the supervision of a faculty member in order to facilitate student engagement.

Early Exposure Activities

In concert with the videos, this work incentivizes students to investigate topics of active research and ways of getting involved in undergraduate research through classroom activities and homework assignments. These activities are paired with a specific video to reinforce the core messages of that video. These activities give students the chance to actively engage with what research is, how it affects society, how entrepreneurial mindset affects the process of doing research, and what they might gain by becoming involved with UGR. The activities paired with each video are as follows:

What Is Research? This video is paired with two activities, a “Minute Paper Reflection” and an “Interview with Researchers”. The purpose of the minute paper activity is to have students reflect on their conception of research in order to expose students to research as a career path and to address misconceptions about research. The activity begins with an open discussion among the students about their understanding of research. The instructor then directs students to watch the

“What is Research?” video. Students will complete a reflection activity at the end of the video. The purpose of the “Interview with Researchers” is to expose students to actual researchers. Students will interview a current researcher about their perspective on research and the research process. The researcher can be either a faculty member or a graduate/undergraduate student.

Why Should I Get Involved in Research? This video is paired with an activity that asks students to reflect upon different goals of getting involved in research. Students will complete a short reflection activity (“minute paper”) before and after watching the video. The questions before the video will prompt the student to think about the benefits of research and the factors that motivate people to do research. The post-video prompts will guide students to reflect on their original ideas and share these with their peers.

What Is the Entrepreneurial Mindset? This video is paired with an activity called “Technology in Daily Life.” The purpose of this activity is to expose students to the stories of how products that they use every day progressed from ideas and experiments to physical products. Students will first view the “EM in Research” video before brainstorming a list of products they use in their daily lives. They will then find reference materials in order to summarize the history of research and innovation which resulted in the creation of that product. This activity can be run as either an individual written assignment or a group presentation. The second paired activity is called “Exploring Research Opportunities.” The purpose of this activity is to have students start to make mental connections between problems they see around them and the research interests of faculty at their university. After watching the “EM in Research” video, students will be asked to take these connections and brainstorm ways that the research could impact those daily problems.

How Does Research Get Done? For this video, students will participate in an activity called “Find a Grant Program.” The purpose of this activity is to remove the “mystery” about how research gets done. Students gain a basic understanding of how a lab is funded and research is accomplished. This module addresses how a research question is translated into actual lab work by discussing the types of research (basic and applied), outlining the process of applying for funding to a proposal being selected by a funding agency, and the preparation /purpose of lab facilities. Students will find a grant program and summarize the program guidelines and profile one successfully funded project.

How Can I Get Involved in Research? To help students connected with research opportunities, this video is paired with “Research Opportunity Bingo.” In this activity, students will receive a “bingo” card with different tasks designed to help them identify ways to get involved in research on their campus. Students will mark off a square for each task they complete until they mark off all squares in a single row/column/diagonal. At their discretion, instructors can award prizes for different types of “bingo” (e.g., “X”, blackout).

Evaluation

The project team expected that students who engage early with an EM-driven framework for UGR will be more likely to participate in research in the future and remain engaged in STEM fields. For assessment purposes, a 22-item survey was developed to evaluate the impact of the videos and activities on student engagement and motivation. The survey will be taken by undergraduate students after they have completed a course with the developed modules embedded. To evaluate the long-term impacts of the new curricular materials, the team has also planned a follow-up survey to be sent out to the same students one year after completing the course. The survey adapts the retrospective gains model used by the Undergraduate Research Student Self-Assessment (URSSA) [11].

In the first year of this project, faculty at three of the partner universities implemented at least one activity from the new EM-driven framework. Students participating in these activities were enrolled in a range of introductory courses, including Engineering Mechanics and Engineering Design. Thirty-six students participated in the initial round of surveys, where the majority were either first- or second-year students (22/25 responses). On a scale from 1 to 5 (none, little, moderate, good, great), the majority of respondents cited “good gains” or “great gains” as a result of participating in the EM-driven activities. On the same scale, 42% (12/28 responses) of respondents endorsed perceived improvements in their “ability to explain the process of research” and “confidence in [their] ability to persuade a colleague that a discovery adds value in multiple ways” (Figure 3A). A similar proportion of students (39%; 11/28 responses) responded that the activities resulted in “great gains” in their “recognition of the connections among engineering and scientific disciplines” (Figure 3A). Furthermore, the majority of students responded that they were more likely (rated 3, 4, or 5) to contact a professor about undergraduate research (81%; 22/27 responses), apply for internships with a focus on research (78%; 21/27 responses), or apply to a Masters or other professional degree program (74%; 20/27 responses) after completing the course materials (Figure 3B).

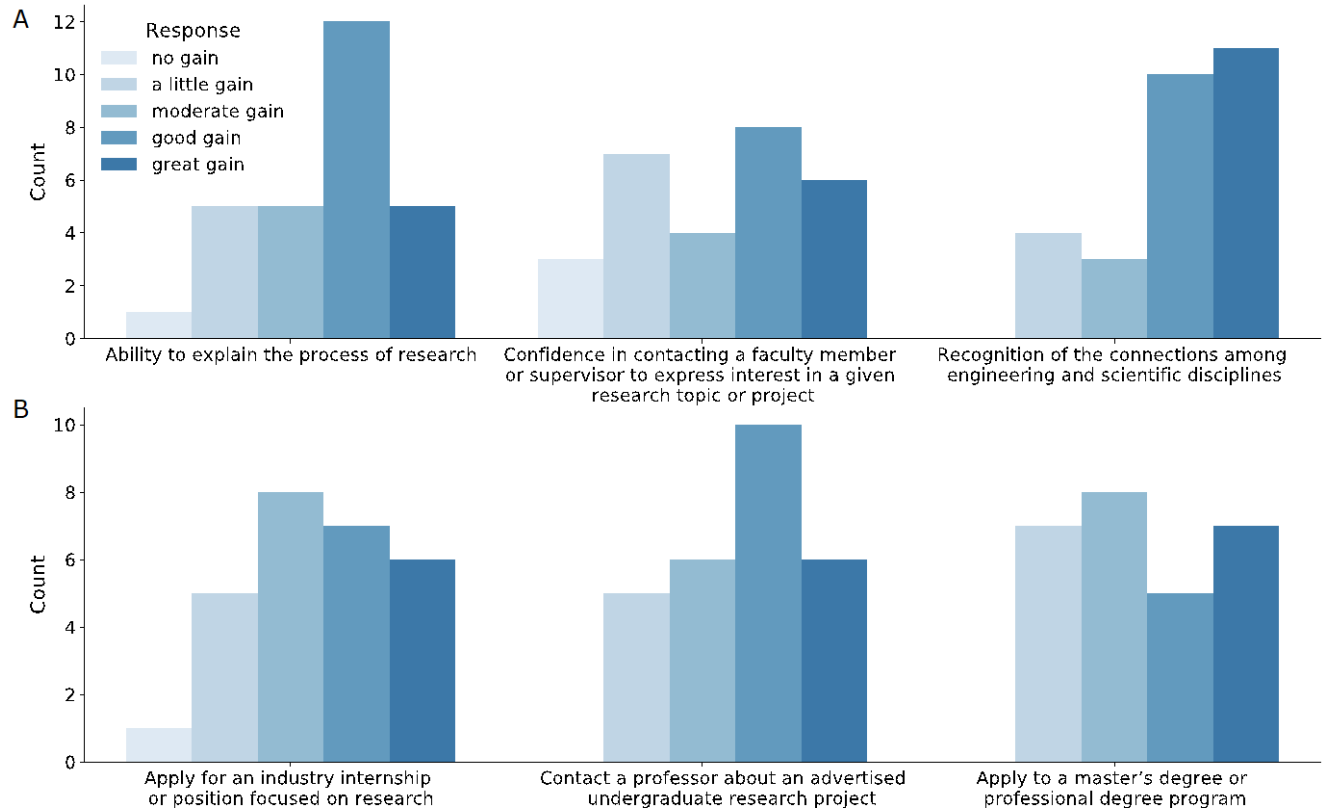


Figure 3. Responses from the early exposure survey administered to undergraduate students after completion of course materials.

The preliminary survey responses are consistent with the expectations of the project team. The team anticipates that it will continue collect data from the participating universities and deploy the one-year follow-up surveys. In addition, as the development of the curricular materials is completed, all students will have the opportunity to be exposed to the full range of content, which the team expects will improve the overall effectiveness of the intervention.

Discussion and Conclusions

This work emphasizes connecting first- and second-year undergraduate students with research opportunities. A pilot survey shows that students involved in one or more of these early exposure modules endorsed perceived gains in their understanding of research and desire to engage in research activities. The current results will contribute to improvements in the activity design and inform the research team about additional requirements for a robust implementation of the modules.

The development and preliminary implementation of the early exposure modules serves a larger goal to incorporate EM into UGR and these modules are designed to impact many stakeholders. There are people who would be interested in the success of this project to increase student

exposure to the concepts of research. Undergraduates will benefit from their involvement in research and expanded understanding of their career opportunities. Students who engage in research will develop technical skills in the laboratory; however, it is often the professional (or “soft”) skills emphasized in the project materials that set these students apart from their peers. Faculty who engage in research and would like to enhance the productivity of their research group will benefit from the enthusiasm and unique perspectives and skills that a new student can bring to the research group. In addition, by including first-year undergraduate students in the lab, these students will gain maximum exposure to the research environment over their academic career and faculty will have increased continuity in student participation. There is also an opportunity for graduate students to gain valuable experience by mentoring undergraduate students on technical and professional skills for research projects. Overall, academic institutions will benefit as they have the potential to retain more undergraduates and cite the expanded UGR opportunity as an additional attractive dimension of their STEM programs during recruitment. Ultimately, industry, business, and the economy will all benefit from the infusion of qualified engineers and scientists with research experience into the workforce.

In parallel efforts, the project team is also implementing workshops to help faculty implement the principles of EM in undergraduate research and developing training modules for current undergraduate researchers to develop EM in their research endeavors. Taken together, this framework provides a robust and sustainable approach for inspiring, training, and connecting undergraduate students to the world of engineering research.

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