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Evaluation of Undergraduate Summer Research Internships in Various Advanced Manufacturing Projects

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Abstract

Undergraduate Research is one of the essential components in enhancing student learning and skill sets in critical thinking and creative inquiry. Tennessee Tech University has several opportunities to help students gain extensive summer research experiences through creative inquiry activities. During the summer semester, students and faculty members jointly work on a number of research projects as part of an NSF REU Site, Creative Inquiry Summer Experience Program, Campus Sustainability Program and Quality Enhancement Program (QEP). This paper will report the findings from projects performed in summer 2016 with accomplishments and evaluation findings from each of the four projects.

Background

Project based learning is a commonly practiced educational methodology used in many higher educational institutions [1]. Instructors usually assign their project components as part of their class assessment component before the semester ends. Students usually work in a group and complete the deliverables of the assigned projects. Senior Design Projects or Capstones (as part of an ABET [2] or ATMAE accreditation [3]) are advanced versions of this practice and their tasks and expectations are usually larger than the project based learning expectations.

Summer long research projects are usually referred to as Research for Undergraduates (REU) and they last between eight and ten weeks. Research students work on their assigned projects in intensive research meetings, trainings, laboratory experiments/simulations, and presentations [4].

In Summer 2016, four undergraduate junior and senior students in various engineering departments of the college of engineering worked with an engineering professor and successfully completed four different manufacturing related research projects. In this paper, brief highlights will be provided on each project and an evaluation component collected at the end of the research program will be provided.

Projects

Green Manufacturing Project

The objective of the project was to create a proof of concept to turn recycled water bottles into a 3D printable filament through a multi process system. The research required learning the process and functions of a granulator, a washing method, vacuum oven, and an extruding device. Initial work was spent researching all the proper equipment, granulator, and vacuum oven. Then, the rest of the time was spent researching PET plastic preparation procedures such as heating temperature, and dry time. This project was funded by the Tennessee Tech Sustainable Campus Committee which also provided used water bottles from around campus. The iMakerSpace in the Tennessee Tech Volpe Library was where the team met every Thursday to discuss the project with the research professor. The iMakerSpace is also where the Filabot X2 Extruder, and washing machine are located to use.

The main goal of this project was to create a fully sustainable printable filament that Tennessee Tech University, iMakerSpace, and surrounding schools can use at no cost. Besides being the first collegiate research of its kind, this project expanded on the fundamentals of how to make a sustainable process from the simple recycling of water bottles around campus. As previously stated, the ultimate goal was to make 3D printing free to all students in the iMakerSpace. Preliminary results obtained throughout the summer research provided some initial filaments obtained from the extruder. However, their utilization did not provide a successful outcome that campus students could fully use in 3D Printing machines.

Innovative Mold Manufacturing

According to SME (formerly known as Society of Manufacturing Engineers, www.sme.org), there is no other method of manufacturing that surpasses injection molding in quantity of parts produced per year shipping about $373 billion in goods in 2012 alone. This is mainly due to the widespread implementation of the proper equipment in many different industries producing more parts, at a faster rate, and at a lower cost than any other method of manufacturing. The only downside to injection molding is that there are high costs associated with the molds themselves. A mold is a part required in the process that contains the geometry of the desired part; molten plastic is injected into this to form intermediate or final parts. For example, if a company wants to manufacture a plastic Christmas tree stand, a single prototype mold would cost anywhere from $3,300 (for a one-time use mold) to $13,200 for a longer lasting production mold. These costs are not unreasonable if the company is going to be producing thousands of these stands, but what if the initial design does not work for one reason or another? Perhaps the company even had a major change in their design or was about to produce a new generation of parts. In either case, they would have to start with a new mold, costing a similar amount, making the barrier to innovation very expensive. This is a problem that many companies have, and since the cost of the molds are so high, many companies keep their old molds on hand for reference. Large companies like General Electric and LG have complete warehouses full of molds that were only used once or twice as iterations of parts that end up on a washing machine. This is where 3D Printing can make a huge difference.

With 3D Printing, companies can produce inexpensive parts to test, form, or fit their designs. These companies can 3D-print these parts and test them for often pennies on the dollar. One Christmas tree stand would cost $2.75 to 3D-print and test versus a minimum of $3300 to injection mold. The problem is that 3D-Printing is much slower and is not a viable mass production method. But if one could 3D-print a mold that would last for just a few hundred parts, then companies could fit their entire warehouses of spare molds digitally into a flash drive the size of a stick of gum. This is already being done with some high-end 3D Printers that cost anywhere from 50 to 500 thousand dollars. If printing of injection molds can be done with big, expensive machines; why can it not be done with an inexpensive desktop machine that prints in the same material?

The objective of this project was to take an existing 3D Printer (Ultimaker 2 Extended Plus) and upgrade the extruder on it so that higher temperature materials (like polycarbonate) could be printed on it. Polycarbonate is the same material that safety glasses and most prescription glasses are made out of. It has good thermal properties and has been used for injection molding water bottles in the past. The objective was to print injection molding molds out of the polycarbonate and then inject common plastics into these molds using the injection molding machine found in the iMakerSpace. The parts produced via injection molding were carefully examined and compared to parts out of a traditional steel or aluminum mold which the iMakerSpace already possesses. In addition, the parts that come out of the 3D-printed molds were compared to standards set by the SME.

Additively Innovative Dinosaur Manufacturing

The objective of this project is to take molded replicas of original dinosaur bones and scan them with a handheld scanner so that a 3D model can be replicated in a software tool and saved as a data file. Once the 3D model is obtained, the next step is to 3D print them using the provided 3D printers in the iMakerSpace out of the provided PLA or ABS filaments. This project also explores additive manufacturing methods to create physical models of any design or object which will essentially be an option for a cheaper, faster, and more reliable solution into manufacturing many models of the dinosaur.

Initially, entire dinosaur bones were scanned using a Go!SCAN 50 scanner by Creaform, then the scanned meshes were modified using Meshmixer. The bones were printed using a number of fused deposition modeling printers. Finally, all bones were assembled with the newly designed and innovated joints. From this starting point with the dinosaur, this project fully constructed the dinosaur, design a stand for displaying the completed work, and do research on joints needed to assemble the bone segments.

Materials Handling Knowledge Base Development

There is a high number of materials handling equipment (i.e. conveyor, crane, fork truck, bowl feeder, cart, hopper, chute) used in the manufacturing facilities. Their function is to make the manufacturing process flow smoother and more functional. The objective of the research was to organize and restructure the currently available instructional resources in material handling to make them more modular and accessible by the engineering students. First of all, a list of most commonly used materials handling equipment was identified. Then, they were tabulated with their use, components, innovations, utilizations, and enhanced picture capabilities. The major contribution was to list a high number of references for every application and add more current figures to enhance student learning.

In each materials handling equipment, categories (i.e. utilizations, components, advantageous, innovations) were explained with short bullets. At the end, references were listed. The details of the Web references were specifically cited to clarify the sources to course students. Sample short video clips were also added for each equipment.

Evaluation of the Summer Research Projects

At the end of the research projects, each student completed an IRB approved research survey without identifying their identity. The survey that was used to assess the program provided feedback to the instructor about students' perception of their own competence and skills they gained through the summer research projects. The following section provides the findings of this survey tool.

Evaluation Methodology

The methodology describes an evaluation of four undergraduate junior and senior engineering students' experiences as they each worked on a different manufacturing related project during the summer 2016 semester under the mentorship of the third author of this paper. The topics of the four research projects were:

- Restructuring materials handling systems curriculum for user-friendly access
- Producing molds via additive manufacturing
- Recycling plastic water bottles into a printable filament
- 3D Printing dinosaur bones

This evaluation consisted of a retrospective pretest survey that was given to the students at the end of the research program. The survey questionnaire addressed their level of interest in their specific research topics, critical thinking skills, innovation and creativity skills, lifelong learning skills, research experiences, interest in the graduate school, and demographic information. A few open-ended questions were also asked about the participants' experiences regarding the entire summer research program.

Evaluation Findings

The purpose of this study was to measure the changes of undergraduate engineering students' creative inquiry skill sets. The survey that was conducted to measure the student growth showed that students gained substantial knowledge and experience from this summer research program. The results displayed that research projects also reinforced students' interest and decision to continue in STEM fields.

The first question asked about the students' interest in their research topic. Figure 1 shows the distribution of responses to the question on both the retrospective pretest and posttest. Response choices were: not interesting at all, slightly interesting, moderately interesting, very interesting, and extremely interesting. All four students indicated that their topic was at least very interesting on both the pretest and posttest. The level of interest may have increased slightly for almost all of them as the response choice "extremely interesting" was selected by three of them on the posttest whereas, three had selected "very interesting" on the pretest.

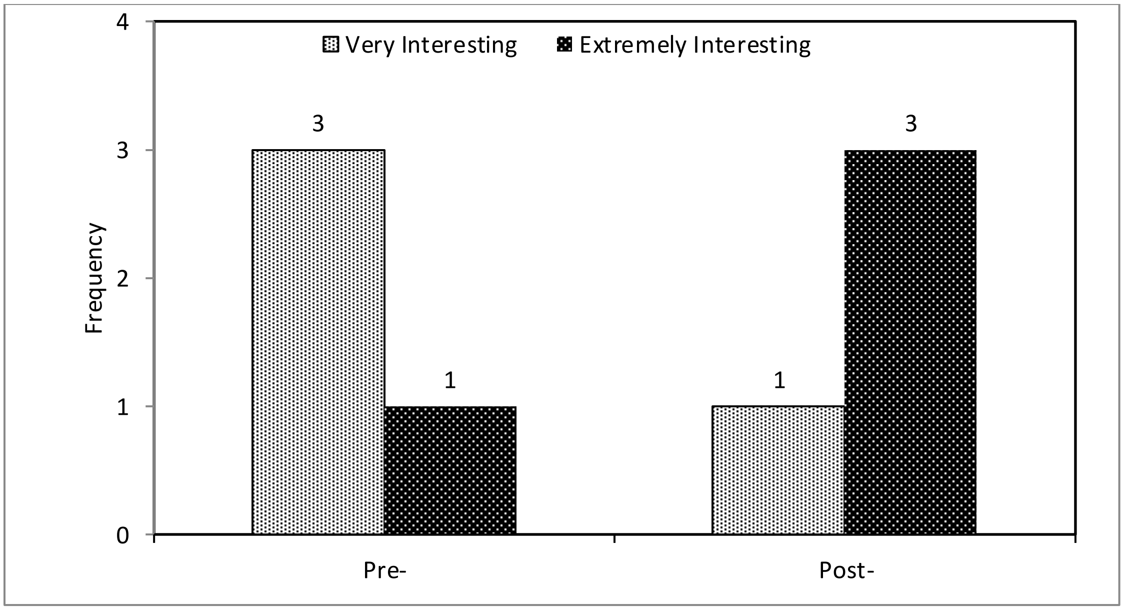

Figure 1. Distribution of responses on question gauging students' interest in their research topic

The second question asked the students to rate their level of critical thinking at the start and end of the summer research program. Response choices were: none, low, moderate, and high. On the posttest, more students (three) indicated that their critical thinking had improved from moderate to high.

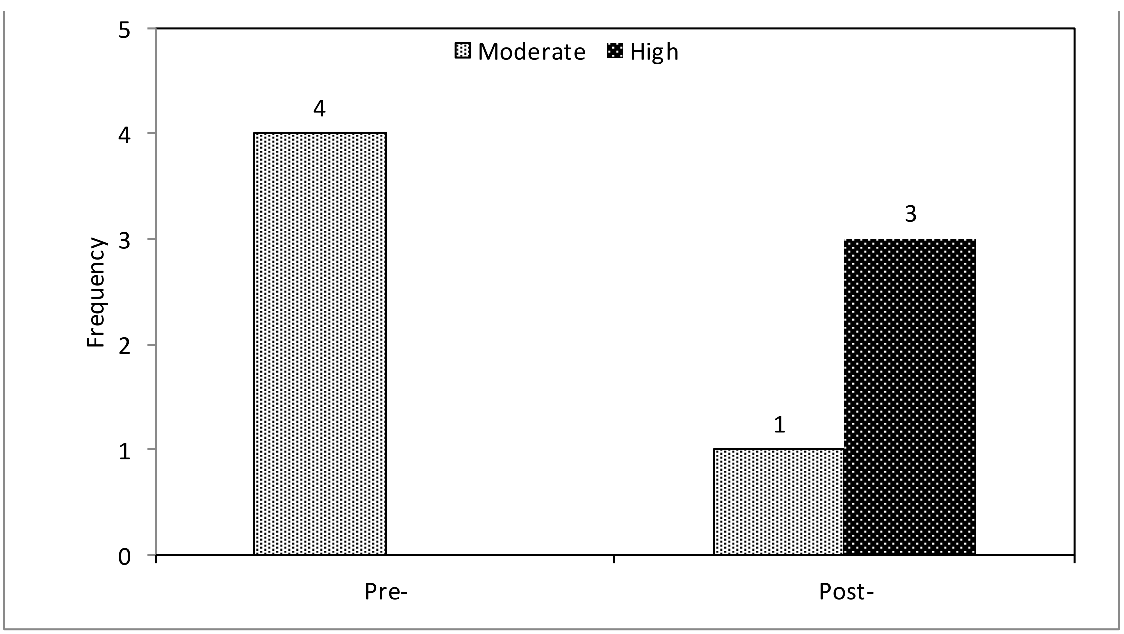

Figure 2. Students' level of critical thinking skills at the start and at the end of the summer research program

The third question asked about the students' level of innovation/creativity skills at the start and at the end of the summer research program. Figure 3 shows student responses to this question. Response choices were: none, low, moderate, and high. Similar to critical thinking, three of the students indicated that this skill had increased from moderate to high at the end of the program.

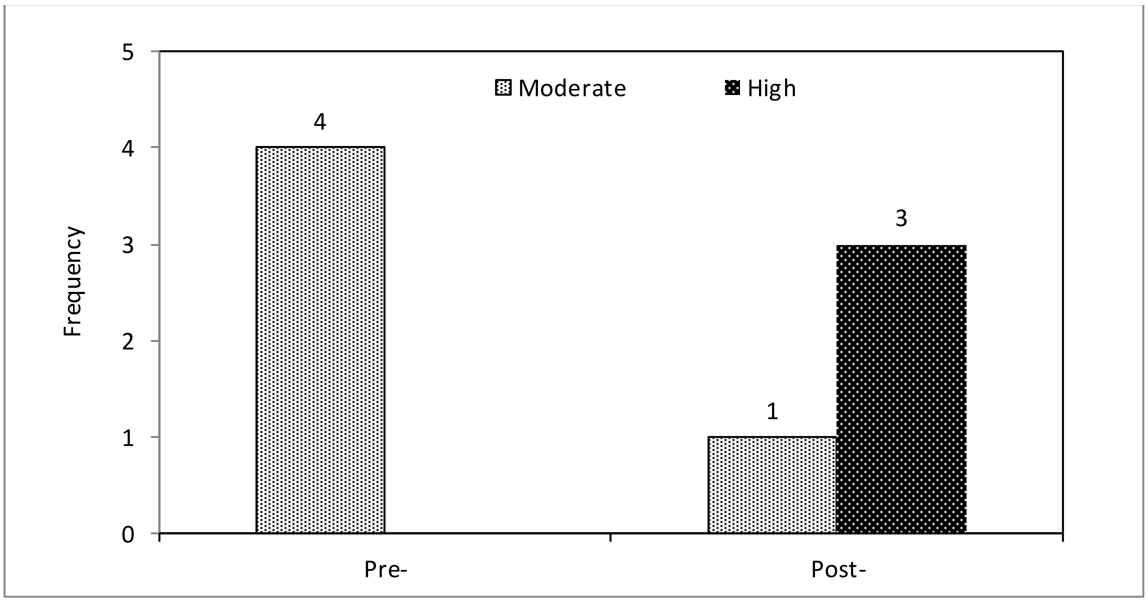

Figure 3. Students' level of innovation/creativity skills at the start/end of the summer research program

The fourth question asked about the students' level of lifelong learning skills at the start and at the end of the summer research program. Figure 4 shows the distribution of responses to this question on both the retrospective pretest and posttest. Response choices were: none, low, moderate, and high. When students described their lifelong learning skills, there was not much change from pre to post. Only one student indicated that his lifelong learning skills were higher at the end of the summer research program.

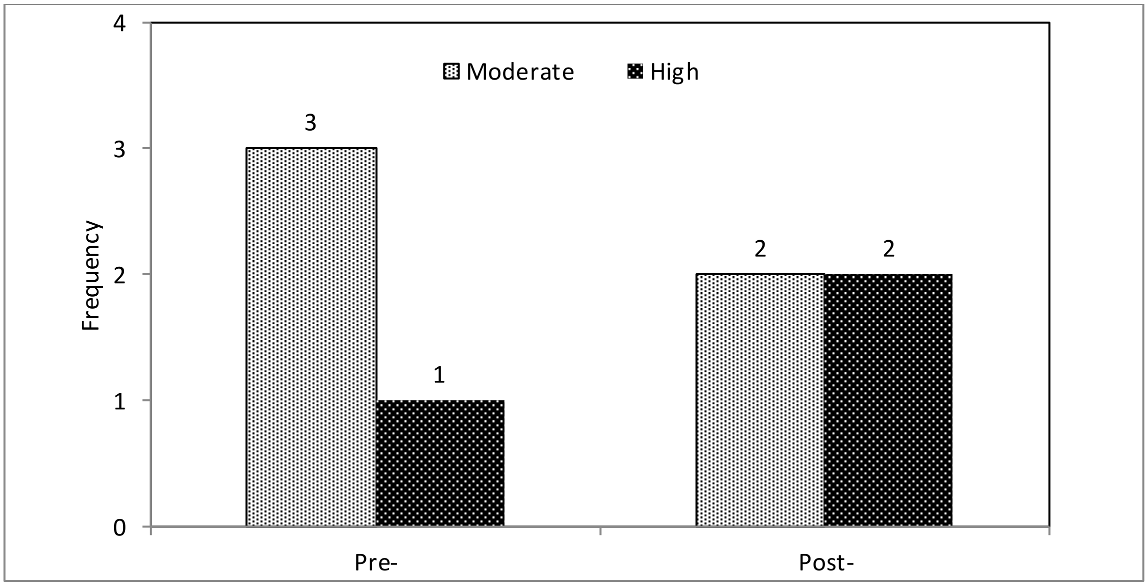

Figure 4. Students' level of lifelong learning skills at the start/end of the summer research program

The fifth question asked about the extent of influence that the summer research experience had on their interest in research in general and, more specifically, research in manufacturing engineering. Figure 5 shows the distribution of responses to the question. Response choices were: strongly reinforced, reinforced, neither reinforced or undermined, undermined, strongly undermined. All four students indicated that their interest to do research in manufacturing engineering was at least reinforced by the summer research program.

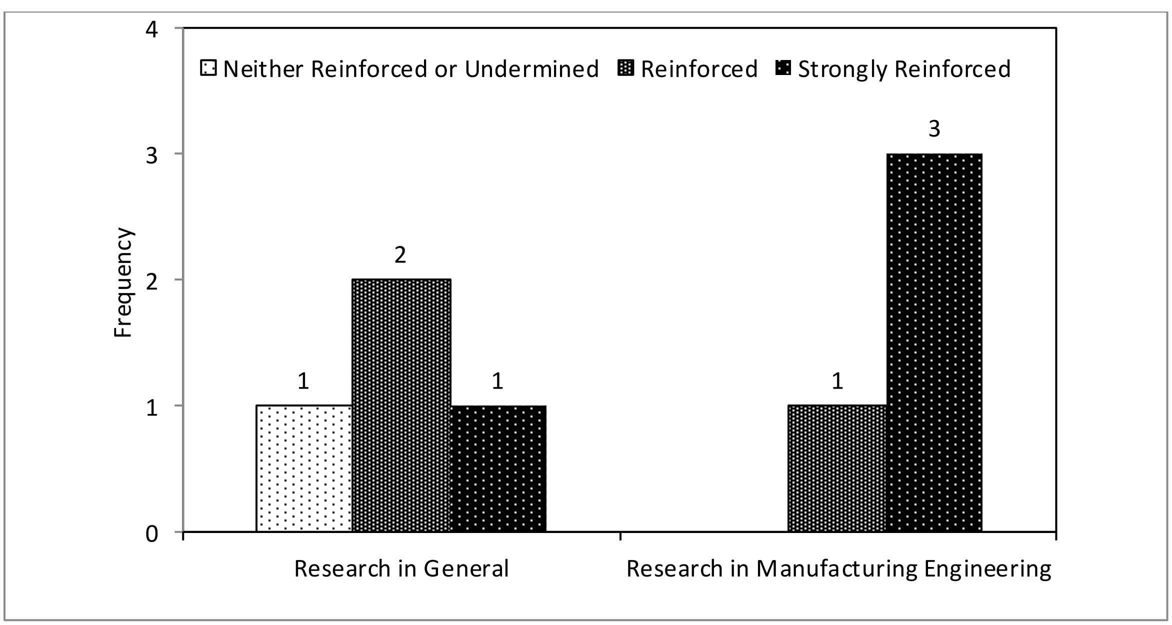

Figure 5. Responses on the extent of the summer research experience on students' interest in research manufacturing engineering

The sixth question was about the extent of the summer research program on students' decision to enter and to continue in the field of manufacturing and/or mechanical engineering. Figure 6 shows the distribution of responses to this question. Response choices were: strongly reinforced, reinforced, neither reinforced or undermined, undermined, strongly undermined. All four students indicated that their decision to enter and to continue in the field of manufacturing and/or mechanical engineering was at least reinforced by the summer research program (two indicated that their decision was strongly reinforced by the summer program).

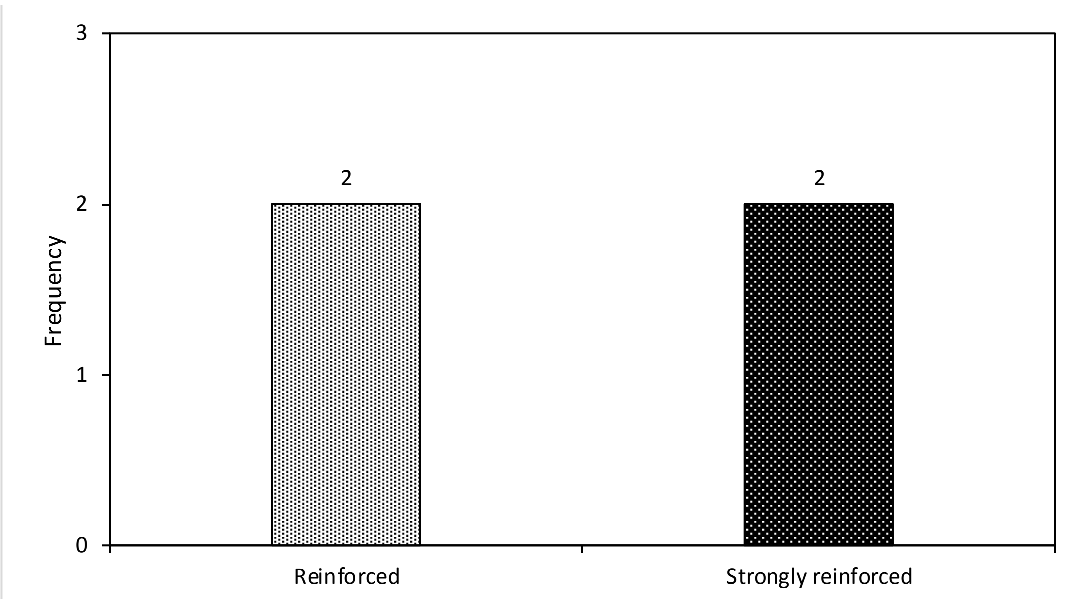

Figure 6. Responses on the extent of the summer research program on students' decision to enter/continue in the field of manufacturing/mechanical engineering

Discussion

Regarding the research projects, all students had favorable reviews. One of the open-ended questions asked about the students' positive aspects of summer research experiences. Students stated that the summer research program increased their creative thinking abilities, broadened their skills, helped them to decipher large amounts of information that will be necessary in higher levels of study, and allowed them to gain substantial experience in 3D Printing. They expressed that this program taught them to streamline the process, organize the given information, apply the knowledge of the projects, overcome obstacles, complete a project within a given timetable, and work in a new field where the topic has not been covered yet.

Regarding the open-ended question about the students' experiences during the program, one student indicated that summer research and internships are the best ways to gain experience and knowledge. The student believed that in the field of Engineering, programs like this are necessary for a conductive learning environment. Another student expressed his enthusiasm toward this program by stating that this incredible learning experience reinforced his reasoning to go into the field of advanced materials and polymers. Engaging learning opportunities in undergraduate research allows students take an ownership of their research projects, develop critical thinking skills, and learn to solve problems as a team.

All students articulated on the rest of the questions that participation in this program reinforced their decision to enter and continue in the field of manufacturing/mechanical engineering and encouraged them to consider studying engineering on the graduate level. Most of the students also found the summer research experience to be substantially rewarding and stated that it was very likely that they will continue with the assigned research in the future.

Conclusion

This study examined the undergraduate engineering students' creative inquiry progress during a summer research program. The survey described how these projects in this program connected the student creativity and research. As expected, the students found this program to be very rewarding. Students who were involved in the projects stated that the program helped them gain crucial knowledge and skills in engineering, reinforced their interest in future research, and gave them invaluable experiences in manufacturing research. Evidence from this study indicates that creative inquiry is a great learning tool that instructors can use to involve students in active exploration, analysis, and synthesis and to teach them crucial knowledge and skills in engineering.

Acknowledgements

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