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Partnership in Undergraduate Research Experience

Practical laboratory and work experience has been helpful in reinforcing the undergraduate educational experience. With limited resources, individual organizations may struggle to give a student a well rounded opportunity. Most undergraduates work within internships or cooperative educational frameworks with one entity. At South Dakota State University, the Product Development Center (PDC) has initiated a collaborative research project with the USDA Agricultural Research Service (ARS) in Brookings for the benefit of undergraduate students. This collaborative framework with the United States Department of Agriculture ARS grows from three key aspects. First, the students at both the ARS and the PDC exchange concepts and work interactively on projects. This provides a wider scope to how their research efforts connect to the greater scope of both the PDC and ARS. Second, the PDC and ARS pool equipment and laboratory tools which would be prohibitively expensive for each individual organization to operate. Students can observe and utilize these devices to add breadth to their experience. Third, students work together with Manufacturing Engineering Technology faculty and Bioprocess Engineers. This adds another perspective to solving research problems. Further, the ARS is a federally operated lab while the PDC runs with supervision of the state university. The goal of the paper is to provide a functional framework for enhancing the undergraduate research practice. This paper shows the synergistic nature of sharing resources for the improved educational experience of the student. Two examples of the student involvement will be illustrated based on the three aspects of interactive projects, pooled resources, and different perspectives. One student primarily used a background from manufacturing engineering technology with knowledge in CNC machining. The other student used an educational background from physics and fundamental science.

Introduction

Engineering and technology departments have a long history of developing partnerships with organizations external to the university in order to augment educational and research efforts, to ensure that curricula are aligned with current industrial needs, and also to streamline and increase the impact that these departments can have in the larger industrial community. A few examples include alliances with companies such as engine manufacturers¹, hand tool manufacturers², precision engineering data storage manufacturers³, electronics, metal, HVAC, and other manufacturers⁴. Additionally, some academic institutions have developed partnerships to commercialize research and technology breakthroughs⁵.

One avenue that some departments consider is to partner with a government agency, or one of the federal laboratories. NASA, for example, has been involved in academic partnerships with engineering programs⁶.

Along similar lines, the goal of this paper is to discuss a partnership that has been developed between the Department of Technology and Management at South Dakota State University (SDSU) and the North Central Agricultural Research Laboratory, which is a federal laboratory,

and is part of the United States Department of Agriculture, Agricultural Research Service (USDA-ARS).

The major concept behind this collaboration is to pool resources and efforts to develop bio-based manufactured products (Figure 1). In addition to the increased research capability when an academic department partners with a federal laboratory, there also exists much potential for student learning experiences with this endeavor. Opportunities exist for students to work and learn both on campus and in the federal laboratory.

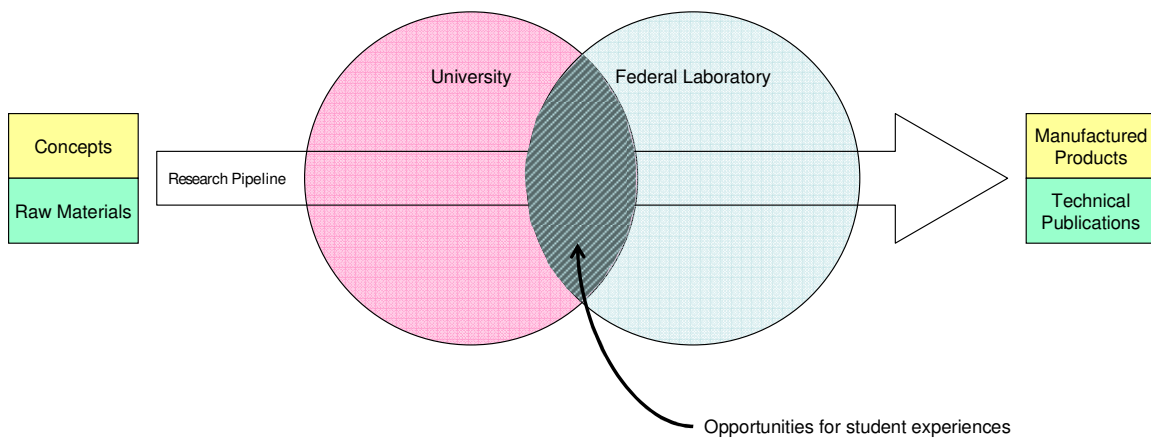


Figure 1. Concept for partnership between SDSU and USDA-ARS laboratories.

Practical laboratory and work experience has been found to be helpful in reinforcing the undergraduate educational experience. With limited resources, individual organizations may struggle to give a student a well rounded opportunity. Most undergraduates work within internships or cooperative educational frameworks with a single company, agency, or department. At South Dakota State University, the Product Development Center (PDC), which is housed in the Department of Technology and Management, has initiated a collaborative research project with the USDA Agricultural Research Service (ARS) in Brookings. This endeavor provides many potential benefits for undergraduate students. Many students find it rewarding to apply the techniques they learn in the classroom. Further, active learning in the laboratory reinforces the classroom knowledge and builds on teamwork skills necessary to perform in the technical fields of science and industry.

This paper discusses a framework to utilize active learning concepts through experience. First, the framework builds on student exchange across disciplines. Second, the paper illustrates shared resources. Third, bridging two professional fields, each student has the opportunity to learn from distinct professional approaches. Finally, this paper shows the framework implemented for both a Manufacturing Engineering Technology student as well as a Physics student.

Background

Learning Types

For years universities in the United States employed the lecture style delivery method for teaching students in the engineering fields. Over time, however, faculty have come to understand the benefits of applying active learning techniques. Recently, class projects are increasingly used for teaching engineering design⁷. It is constructive to review major types of active learning to better appreciate why industrial experience is helpful.

Prince⁸ describes four aspects of active learning. First, active learning contrasts with the lecture format. In other words, the students perform an activity and are engaged in that endeavor. This activity approach brings the academic content to a more tangible event for the student. Second, collaborative learning builds on the team aspect. This style of learning connects the team members as they work toward a common outcome. An important trait of collaborative learning is that the student is not work independently. A third type of learning can be described as cooperative learning. Similar to collaborative styles, cooperative learning is different in the sense that the team members are judged individually for their results. The members are not competing against each other as they attempt to achieve cooperative incentives. The final method discussed by Prince⁸ is problem-based learning (PBL). Problem-based learning requires self-learning. PBL is usually performed in a team environment. However, it is possible that an individual would embark on this style.

Experience is important for engineering and science students. Students appreciate connecting their course work with relevant applications⁹. Without a personal work history, appropriate use of engineering techniques may be compromised, or at least insufficient. Farr¹⁰ argues that a capstone engineering course develops essentials skills and connects coursework.

Types of Experience

Students can gain experience through several types of situations. A case study is often used in early management classes. This approach can be done in an active learning environment with role play as students take on different characters. But, the case study fails to give the students a feel for the analytical aspects of a laboratory.

Next on the spectrum of experience is the class project. In this environment, a student or team applies the course material in a controlled scenario. Due to the condensed time available in the class setting, students are limited to the depth and breadth that can be addressed. Some curriculums have implemented capstone style experiences for engineering students to give adequate time for students to apply their contemporary techniques. The capstone is a course which pulls together most key components of the student's course work into a culminating project.

The Cooperative Education Division of ASEE¹¹ defines cooperative education as a program preparing students for professional employment by integrating academic coursework with practical work experience. These students typically alternate semesters of full-time work with periods of full-time, on-campus study. The students benefit by building on academic content year by year with increasingly more demanding work assignments. With several work periods of nearly six months each, a student adjusts to the idiosyncrasies of the organization and can focus on the technical aspects of the job.

Internships are another opportunity for students to gain application work experience. Internships are usually one or two terms. A student intern over the summer may not have the time within an organization to fully acclimate to the business environment before the term ends, however.

Benefits

The Society of Manufacturing Engineers¹² suggests it is critical for organizational competence to have employees working effectively with others on teams. Further, Katz¹³ encourages students to communicate and coordinate with other disciplines. It is beneficial for students to experience this team environment before embarking on full-time employment following graduation.

Student Exchange

The PDC at South Dakota State University has initiated a collaborative research program with the ARS. This program consists of a framework which facilitates undergraduate research experience. The foundation for this experience is built on three pillars (Figure 2). First, is the student exchange; second, is the shared resources; and third, is the mentor exchange. This paper will discuss each of these items of the foundation.

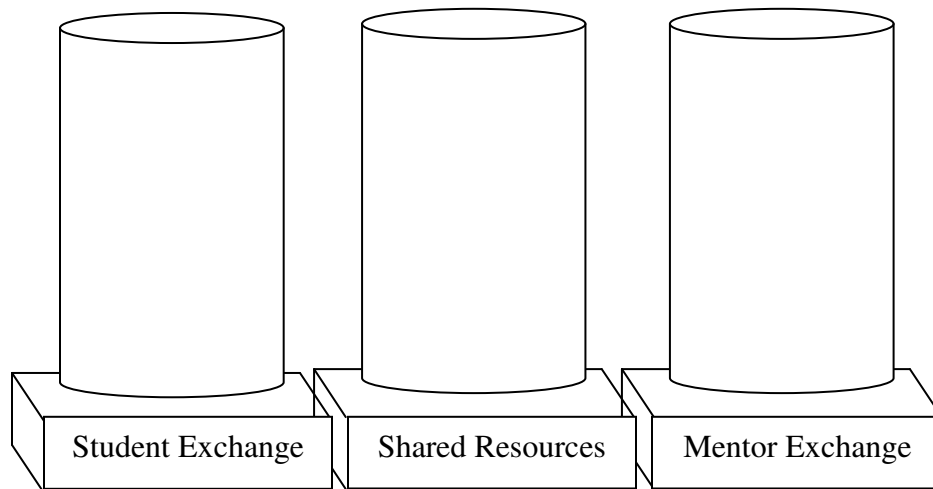


Figure 2. Foundation for Research Partnership.

The first pillar is the student exchange opportunity. By connecting students from different fields of study, the students gain three benefits. One, the students exchange conceptual approaches to solving research questions. Students from different disciplines will take a slightly dissimilar angle to develop solutions. Second, placing the students on a team creates an interactive group. This allows for a cross-functional project team. Third, as the team members work together, they take a wider scope of understanding and appreciation of how their individual discipline supports the research.

The second pillar is shared resources. Very few academic units have unlimited financial support. Due to this constraint, sharing resources becomes essential. And, as research entities work together, synergies develop. Rather than consuming limited capital for equipment purchases, these research units can work together. Considering available laboratory equipment at one facility, the other does not need to duplicate that piece of equipment. Collaborating entities receive another benefit of less overhead costs, since only one laboratory must maintain and staff a particular device. Further, since many laboratory and machine shop tools are highly specialized, sharing access to these devices gives students the opportunity to see equipment outside of their primary educational field.

The third pillar of this foundation is mentor exchange. Similar to the student exchange, the participants gain by interacting with other professionals external to their primary field of study. In this particular example of the PDC and ARS, the collaborative team involves manufacturing and bioprocess engineering. Another contrast of the two mentors relates to the parent organizations. Both the state university system and the federal government are represented. The students observe the different aspects of constituency and technology transfer of the state university compared to the federal agency.

Student Examples

Student #1 Experience

The student majoring in Manufacturing Engineering Technology participated in an unpaid 300 hour internship with the PDC. The objective of the internship involved creation of test specimens for a designed experiment studying factors related to biofillers. The student created solid model computer designs of “dog bone” specimen geometry. These designs were converted into mold cavity designs. The student programmed and operated a computer numerically controlled (CNC) mill to cut the mold cavities. Then, using DOE (designed experiments), the student mixed fillers with plastic matrices at various levels to determine influence on resulting molded specimen strength. The student conducted tensile strength tests at the ARS research laboratory. This internship covered many aspects of manufacturing technology, and connected the student to the use of agricultural based products into industrial applications.

Student #1 Results

The test specimens were molded with a plastic matrix and particles of distillers dried grain with solubles (DDGS). During the tensile tests, the fractures were found to be inconsistent. In other words, the cross section surface area varied from specimen to specimen. The molding protocol will need to be modified in future trials to more adequately address the cross section area for calculations of the tensile strength and other physical properties of interest. These findings were beyond the scope of the manufacturing student’s time to complete. However, future trials will build on this understanding in order to harvest better measurements.

Student #1 Lessons Learned

The manufacturing student gained a broad based view of applications of manufacturing technology in a laboratory research setting. While the student was not funded, he did complete the 300 hour work experience, during which he was focused on receiving a commission as an officer in the United States military. Due to his training schedules, and thus intermittent laboratory work, his research experience was used to support the ongoing, larger collaborative research work between the ARS and PDC. The student gained an appreciation of materials research, and the opportunities for fabricating industrial products from agricultural components.

Student #2 Experience

The student majoring in Physics participated in a paid summer work experience at the ARS research laboratory. A delineated project was assigned with the goal of developing bio-based composite materials using biofillers and adhesives. After receiving appropriate training, the first two weeks were essentially an open-ended investigation by the student to become accustomed to the laboratory techniques, processes to be employed, and typical behavior of the materials. At this point in time, the student and research advisor, who was an ARS research scientist, developed a formal experimental design. The following eight weeks were then devoted to executing this experiment, collecting data, and writing a report. In fact, this report is currently in preparation for submission to a peer-reviewed scientific journal – which in itself is an excellent opportunity for undergraduate students.

Student #2 Results – Summary of Student Project

Interest in renewable biofuel sources has intensified in recent years, leading to greatly increased production of ethanol and its primary coproduct, Distillers Dried Grain with Solubles (DDGS). Consequently, the development of new outlets for DDGS has become crucial to maintaining the economic viability of the industry. In light of this, this preliminary study aimed to determine the suitability of DDGS for use as filler in low-cost composites. The effects of DDGS content, particle size, curing temperature, and compression on flexural strength, modulus of elasticity, water activity, and color were evaluated for two adhesive bases. Resin was found to be greatly superior to glue in terms of mechanical strength and durability: resin composites had maximum fiber stresses of 150-380 kPa, while glue composites had values between 6 and 35 kPa; additionally, glue composites experienced relatively rapid microbial growth. In resin composites, both decreased particle size and increased compression resulted in increased mechanical strength, while a moderate DDGS content was found to increase flexural strength but decrease Young's modulus. These results indicate that DDGS has the potential to be used in resin composites to both improve flexural strength and reduce production cost.

Student #2 – Lessons Learned

Through this experience, the student employee had the opportunity to learn and apply several new topics, including Design of Experiments, laboratory procedures for composite preparation, physical and mechanical property testing methods, data analysis, and formal report writing. All of these were new to the student, but will potentially be very useful tools as the student progresses into upper level classes, and ultimately after their university education. The advisors, both on campus and in the federal laboratory, also learned several lessons from this experience.

Foremost was the fact that capable students, when given direction and instruction, as well as adequate resources with which to carry out a specific research project, can learn and perform at very high levels.

Conclusions

The PDC and ARS have established a mutually beneficial collaborative research framework. The team has created synergy to give students meaningful projects helpful to the regional economy. Students are able to step outside their primary fields of study and use their skills to augment research. The PDC and ARS partnership gains as well, by tapping into a pool of motivated, talented students hungry to contribute to a better world.

Other institutions can implement a model like this to support their efforts as well. It is important to give the students sufficient understanding of how their work makes a contribution. A student's motivation wanes when they fail to see the connections between their efforts, applied research, and the real world. Conversely, as the student witnesses the outcomes of their contribution to tangible applications, a sense of urgency and satisfaction builds.

This partnership in undergraduate research is built on student exchange, shared resources, and mentor exchange. Participating students gain an appreciation of how their skills contribute to the regional agricultural and industrial economies. As the PDC and ARS research progresses, each iteration builds on the knowledge achieved by the previous students' contributions.

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