UNDERGRADUATE STUDENT PARTICIPATION IN APPLICATIONS-BASED RESEARCH

David L. Stanley, Purdue University; Ronald Sterkenburg, Purdue University; Denver Lopp, Purdue University

Abstract

As the role of engineering technology in applications-based research grows, so do the opportunities for students to become involved. Some will argue that research activities should be limited to graduate students who, by virtue of their study and maturity, are typically better equipped and prepared for these roles. On the other hand, practical research of this type often demands a great deal of hands-on preparation and support of the type that matches well with the skill sets of undergraduate students. This study explored these issues, focusing on the demands of applications-based research in comparison with the readiness of undergraduate students for such activities. The benefits of these experiences for the students in question was examined and included impact on graduate school success and interest in graduate study. The National Test Facility for Fuels and Propulsion (NaTeF), a federally funded research project at Purdue University for which the lead author is the principal investigator, was utilized here as a case study.

Introduction

Undergraduate students face increasing challenges today in preparation for the job market, which is presently achieving slow growth, at best. Tuition costs are rising and scholarship funding has not grown at a rate that offsets these increases. Summer employment for students is not what it has been, often forcing students to assume a greater debt load to continue their education. Even though the economy does show signs of turning around, state tax revenues continue to fall below predictions, leading to cuts in funding for virtually all programs, including higher education. Students attempting to acquire the knowledge, skills and abilities necessary to compete in the job market following graduation are often faced with difficult choices. If financial circumstances dictate, they may find it necessary to take a job outside the university or seek employment in the university related to their field of study. Working in the academic setting, they could expect to expand their skills, knowledge and experience in their particular disciplines, while also earning money or possibly credit. Moreover, such opportunities would enable them to develop a better understanding of research. Their involvement may begin with the preparatory and foundational work that must be performed in advance of the actual research, support activities and the practices necessary to ensure high-quality outcomes. Over time, they may take part in the design and conduct of tests and experiments, which form the basis for a great deal of the application-based research typically undertaken in engineering technology disciplines. Finally, for those who may choose to continue their education beyond the baccalaureate level, participation in these activities as an undergraduate may give them a competitive advantage for graduate research opportunities.

NaTeF Research Opportunities

Undergraduate participation in research has been foundational for the federally funded research project entitled The National Test Facility for Fuels and Propulsion (NaTeF). This initiative was undertaken by a group of faculty members at Purdue University to enhance the practical aviation fuels research capabilities of the Aviation Technology (AT) program. Although this project does not involve basic research, a term widely used in academic circles, it is very much focused on practical research and development activities, which require knowledge and skills distinctly different from those found in the laboratories of science and engineering, for example. The NaTeF project lays the groundwork for a set of advanced technical capabilities, test protocol and investigative methods that will be used in future testing and development. The majority of the undergraduate students working on the NaTeF project are enrolled in the Aeronautical Engineering Technology (AET) program and have strong technical knowledge and skills and significant laboratory experience, which necessitates that they apply test protocol and procedures to achieve reliable experimental results. This laboratory background, in particular, prepares the AET students to take an immediate role in the NaTeF project.

While aviation and aerospace has almost unlimited opportunities for research, concerns with emissions, fuel costs and fuel supplies have all served to elevate the importance of research into new fuels for the aviation industry and faculty members in the AT program at Purdue University. Determined to develop a secure domestically sourced fuel, the United States Air Force plans to certify its fleet of aircraft for operation on alternative fuels and blends by 2016 [1]. With the Air Force effectively sweeping aside obstacles to progress by establishing these goals, the overall effort to develop new fuels has benefitted tremendously over the last few years. This upswell in fuels research interest led to positive outcomes in many ways for the AT program.

In the period from 1995 to 1998, AT professors David Stanley and Denver Lopp conducted research into the operation of turbine engines on turbine fuels mixed with soy methyl esters. Results of this work led to additional biofuels research involving Agricultural and Biological Engineering (ABE) and AT faculty members at Purdue. The ABE researchers developed a soybean-based bio-diesel with a much-suppressed freezing point, and the AT faculty members supervised students who conducted test operations with the fuel in a turbine engine. At that time, the AT department had a number of highly valued assets, including engine test cells and several turbine and piston engines. However, while these AT research assets had been adequate to support initial testing efforts, it was realized that both the facilities and the equipment required significant updating if they were to be used for cutting-edge fuels research in the future.

Following an evaluation of the critical needs related to fuels research, professors Lopp, Stanley and Thom developed and submitted a proposal for congressional funding to support the necessary upgrades. Federal funds, eventually totaling approximately $2.7M, were approved beginning in October, 2009, for this purpose, to be administered through the Air Force Research Laboratory at Wright Patterson Air Force Base. Four faculty members, four graduate research assistants, and as many as eight undergraduate students at any one time were working on the project year-around, which has an end date of January 21, 2012.

In the first phase of the project, work was completed on the AT turbine engine test cell to develop an advanced data acquisition system and exhaust emissions capabilities for use with the turbofan installation currently in the test cell. The expectations were that this test cell would be the equivalent of industrial test facilities with the capability of evaluating engine performance and exhaust emissions when operating on new aviation fuels. In another area of the project expected to play a very important role for fuels development, a materials testing laboratory was under development, where the effects of new fuels on aircraft materials, including gaskets, seals and o-rings, may be analyzed. This application research is critical to the future of alternative aviation fuels. It must logically be conducted in parallel with the development of new fuels to ensure compatibility and avoid wasted effort that leads to blind alleys and unworkable products.

In parallel with these efforts, work also began on establishing similar capabilities for piston engine test operations in another NaTeF test cell. Aviation gasoline, specifically 100LL - “100 low-lead” - has been under fire by the EPA for a number of years due to the fact that it contains tetra ethyl lead (TEL). Often referred to simply as “lead”, this additive, known to cause neurological problems among young children, was eliminated from over-the-road fuels in the early 1990s. However, when added to gasoline in small amounts, TEL has great value as an anti-knock ingredient, and developing a lead-free gasoline that performs as well as 100LL has proven to be a difficult task [2]. This research effort continues, and it is expected that the NaTeF piston-engine facilities will play an important role in the test and development work to solve these problems.

Along with these facility and equipment upgrades, another goal of the NaTeF project was to establish an administrative structure to support and facilitate research activities. As a part of this plan, a director would be selected to oversee the daily operation of NaTeF. Given that these test cells and the equipment therein will continue to have an educational application, it is likely this will be a faculty member with a certain percent effort dedicated to these purposes. A search was also done for a lab manager with a background in chemistry or chemical engineering for the Materials Testing Laboratory.

NaTeF Undergraduate Students

While all AT students may find a niche for themselves in the NaTeF program, AET students, in particular, bring a level of technical experience and knowledge to these activities that are a particularly good fit. AT students pursue a B.S. degree in one of three undergraduate plans of study: Aeronautical Engineering Technology (AET), Aviation Management (AM) or Professional Flight Technology (PFT). The AET program has evolved significantly over time, beginning over 50 years ago as a two-year program that included the Airframe and Powerplant (A&P) mechanics curriculum. AET is now a four-year engineering technology B.S. degree program with ABET (Accreditation Board for Engineering and Technology) accreditation. Graduates of the program may still elect to test for the A&P mechanics certificate, completion of which is indicative of a broad knowledge of the aircraft, applicable regulations and principles of repair and support. These credentials are widely valued in the aerospace manufacturing industry as well, enabling graduates to work in engineering and related positions.

While some educational emphasis in the program clearly remains on hands-on, applied study, engineering technology topics receive additional focus. Laboratory activities in this plan of study cover a wide variety of topics including electronics, manufacturing, materials, powerplant technology and aircraft systems. In the laboratory, students develop knowledge of and skills with hand tools, electrical and electronic equipment, and tools and equipment used in manufacturing and assembly. A great deal of emphasis is applied to systems engineering and integration, which is important for the support of the considerable interrelated but distinct systems required for flight. Graduates of the program are highly sought after in the aerospace manufacturing industry for their knowledge of the aircraft and associated lifecycle issues, certification and related aviation regulations, manufacturing processes, and general project management skills, to name a few. As a result of their study and experience with a wide variety of mechanical, electrical and electronic tools and equipment, practical laboratory activities, and test procedures, AET students are uniquely qualified for the test-cell environment, which makes them prime candidates for the NaTeF project.

Technology graduate students take TECH 646, Analysis of Research in Industry, which gives them many of the basic analytical tools they need to participate in funded research activities. While undergraduate students generally have not taken any of these research preparatory courses, they gain considerable knowledge of testing procedures and protocols through their extensive undergraduate laboratory experiences. Typical AET laboratory projects each begin with a research or test question to answer, a set of procedures to follow, and conclude with project outcomes, the description of which must meet well-defined criteria. This experience base has a direct application for undergraduate students working on NaTeF and other research projects. For the fuel system design effort the NaTeF students are undertaking, as an example, they must understand the demands that sound research and testing practice place on control and measurement of flow, blending of fuels, and fuel system purging procedures. Such considerations must be identified and evaluated as part of the design effort. Clearly, these experiences will be very valuable for undergraduate students as they later move into experimental and research design in graduate school.

The underpinning philosophy of the NaTeF effort has been to apply a research approach to each developmental phase of the project. The goals of the project are to create a facility, testing and development capabilities, and the fundamental testing protocol to enable practical research. Success in this project requires a thorough understanding of the requirements of research and intimate knowledge of aircraft and engine operation. From an educational perspective, one gauge of success is improved student preparation for graduate education and an increase in program enrollment.

Undergraduate Participation in the NaTeF Project

From the beginning of this initiative in October, 2009, to the present, the number of undergraduate workers has varied from a low of four to as many as eight. The number of graduate research assistants (GRAs) has remained constant at four over the course of the project, to date. The duties of the GRAs vary considerably as several of them are assigned to specific technical development activities, while one GRA is specifically responsible for oversight and scheduling of undergraduate students. This particular graduate student has taken a lead role in general work planning, recruiting and oversight of undergraduate students for NaTeF. He collects resumes and supporting information from those undergraduate students interested in working on the project, compares their skills and experiences with NaTeF jobs and tasks, and makes recommendations for student selection to the NaTeF faculty members.

Facilities preparation has been a major task undertaken largely by the undergraduate students on the NaTeF project. They have been given the charge of scoping the work and determining the supplies and equipment necessary to accomplish the various jobs, which range from planning the positioning of and facilities requirements for the exhaust emissions and data acquisition equipment to be installed in the test cell to painting and all the preparation work that entails. Undergraduate students have planned the logistics and timing of the work at each step along the way involving activities on three different floors in the building, all of which are test cell interrelated.

Undergraduate students are designing the new fuel system for the test cells. The current phase of work for NaTeF was primarily focused on the turbofan test cell; however, several test cells comprise the NaTeF facility, and a new fuel system is necessary for the research activities and the continued educational function of these engine facilities. Fuel storage, the fuel distribution system to the test cells, and control of the fuel are interrelated but separate design efforts undertaken by the undergraduate students, with mentoring oversight provided by both the GRA and the faculty members in charge of the overall NaTeF project. The teams working these fuel design elements meet routinely to ensure that their separate efforts meet the overall goals for the complete system.

Considerations for the fuel system design include:

- Fire code for the fuel storage area, distribution system, and the test cells
- Engine requirements for fuel quantity and pressure

- Storage tank size, selection and location
- Sizing of the distribution system
- Experimental / research requirements for alternative fuel and fuel blending capabilities
- Access for delivery of fuel to the storage tanks
- Remote control of the fuel system

As a part of this fuel design project and other related work, undergraduate students were charged with specification of the equipment to purchase. They had to develop a detailed understanding of the NaTeF research anticipated for the future in comparison with the capabilities of the equipment under consideration for that purpose. These NaTeF experiences give them a solid foundation to build upon as they move towards graduate school.

Although not specifically a part of the NaTeF effort, a number of AET students are supporting the research effort by undertaking projects in their senior design course that address specific NaTeF issues. One of these efforts is to establish a safety program for the test facilities, while the other is focused on developing operational procedures for the test cell. For both of these specific projects, students must evaluate the educational and research use of the facilities, conduct a survey of the stakeholders involved in fuels research, and develop procedural documentation to be followed by NaTeF personnel.

As indicated earlier, one measure of success in this project is the preparation of undergraduate students for graduate school, and increased program enrollment. Although the results to date are largely anecdotal, due to the short duration of the project to date, NaTeF undergraduate student workers have generally displayed an increased interest in pursuing graduate study. It is unclear as to the real cause of this; however, these students do appear to be better prepared for graduate school as a group than those who came before them. It is the opinion of the authors that participation in the applied, practical research of NaTeF leads students to develop an improved understanding of research and experimentation, in general, which will serve them well in graduate school.

USMC-funded Research Projects

Aeronautical Engineering Technology students are also involved in several other funded research initiatives, including the United States Marine Corp (USMC) project on the CH-53K rotor blades. According to professor Sterkenburg, the lead AT investigator on this and other USMC-sponsored projects, the undergraduate researchers are involved in all steps of the research process: recognizing a problem, literature review, developing experiments and running experiments, purchasing materials, collecting data and reporting the research results in a journal or conference proceedings. The outcomes of this project were significant and included the following [3]:

- Titanium quick patch repairs for use in battle-field conditions
- A new hybrid structural joint
- Environmental testing procedures to determine the effect of foreign matter on composite materials

A notable outcome of this project was a patent granted for the hybrid structural joint developed from composite materials. AET students also participated in another USMC-sponsored project to research the use of ribbonized organized integrated (RIO) wiring systems. Students investigated the applications of RIO and prepared a report on its advantages and disadvantages for the sponsor. It should be noted that a common element extending through all of these research activities and the AET curriculum is data collection and interpretation. Virtually all test and research work is heavily dependent upon accurate and repeatable data collection which, in turn, is very much reliant on sound instrumentation and careful adherence to consistent procedures in the test cell. It should be no surprise that data, instrumentation and procedures are strongly emphasized throughout the AET undergraduate laboratory experience.

The AET Curriculum

Research and student projects in engineering technology programs are generally applications based and focused on the needs of the industry. Realizing this, the AET faculty developed two new courses, AT 496 Senior Project Proposal and AT 497 Senior Project, to fill a void in this area. Elements of Six Sigma, which embody process improvement, are at the heart of many of the senior design projects, and are taught and utilized throughout the AET curriculum. It is expected that senior design projects, where possible, will address industry problems and issues with the idea that students will develop an understanding of the challenges and expectations they will face in their careers. Some of the projects focus on NaTeF technical challenges, in which case the stakeholders are primarily the faculty members overseeing that work. The structure of the senior project courses relies heavily on student teams, primarily due to the fact that such a model creates an industry-like environment for complex project and problem solving. Team projects also demand a high level of organization, cooperation and communication, all of which are fundamentally important tenets of an engineering technology education.

While these courses are designed for seniors, the AET faculty have resolved that new research opportunities occurring earlier in the undergraduate experience should be introduced, a strategy which will not only pay dividends for research but will also provide an essential revenue stream to support the laboratories for the fundamental mission of education. This is increasingly important during times when funding generated by tuition and state support cannot be expected to meet the needs of these programs in the future [4]. This interest in expanding student experience in research supports the educational model of a research-focused university, deepens the education students receive, and is foundational to the technology philosophy for collaboration with industry [5]. Engineering technology research must provide value to industry to resolve practical, applications-based problems and challenges. Incorporating this philosophy early on with engineering technology students adds value to their education, while also building the partnering relationships with industry.

Conclusion

As engineering technology programs, in particular, advance the model of industry-based and practical research, the opportunities for undergraduate students to participate in these activities are expanding. The rationale for active collaboration between undergraduate programs and industry is clear. The research opportunities afforded by such relationships are appropriate to the mission of the educational unit; the experiences students gain prepare them for their careers, and the industry sees the benefit of investing in the programs.

The appropriate role for undergraduates in research must be established and several considerations apply. First and foremost, a match between the demands of research and the readiness of the students must exist. Much of the research effort undertaken by the AET program is applications-based, and very practical in nature. It often demands a great deal of hands-on work and preparation, but may also involve considerable test work, which includes a thorough understanding of standard protocol and procedures. In the case of test work, experimental design, set-up and operation are often a large part of the effort. In the NaTeF project, undergraduate students, with the mentoring guidance of graduate research assistants and faculty members, are undertaking these elements with great success.

Faculty members in the Aeronautical Engineering Technology program are currently funded for several research projects of the type that create opportunities for undergraduate student participation. In the NaTeF case study example, a great deal of student effort is focused on facilities planning and preparation and specification of equipment. All of this work has been guided by a research philosophy, with focused inquiry into future plans and essential capabilities laying the groundwork for sound decision making. In the USMC-sponsored research project, students participated in experimental design for testing purposes as well as the actual conduct of the actual research. For both the NaTeF and the USMC-sponsored projects, undergraduate students formed an effective workforce to accomplish the tasks at hand. One undergraduate team utilized their background and experience to design an entirely new fuel system for both test cells, including storage tanks, pumping system, pipes and control. Another team developed a complete safety system for the turbine test cell, while a third assisted a faculty member in the design and fabrication of a test rig for use in compatibility studies. The AET curriculum emphasis on laboratory projects, testing and protocol, and process management prepares these students to participate effectively in these initiatives in appropriate roles. It is also fitting that the demands of research and project work have led to significant changes in the curriculum to better prepare students for their roles in these activities. AET program graduates are finding employment with aerospace companies in engineering positions where their broad knowledge of aircraft, support and repair processes gives them an advantage over others.

Finally, it should be noted that, while the evidence is anecdotal at this stage, there appears to be a direct correlation between undergraduate participation in applied research and increased interest in graduate school. Moreover, these students generally are better prepared, more enthusiastic and more productive in graduate school than students who have not been involved in research projects. This only makes sense, as one might safely assume that undergraduate students taking such an interest are more highly motivated for higher education.

Acknowledgments

The authors are thankful to the editors of TIIJ for their support in the development of this document.

References

[1] Scheurich, H. & Jernigan, M. (2010). USAF makes history with alternative fuel. Retrieved from http://www.fox10tv.com/dpp/news/USAF-makes-history-with-alternate-fuel

[2] Stanley, D. (2009). The Intersection of New Aviation Fuels and Powerplant Development. *ATEC Journal*, 31(1), 11-15.

[3] R. Sterkenburg (personal communication, December 27, 2010)

[4] Sterkenburg, R. & Stanley, D. (2009). Preparing Aviation Maintenance Personnel for the Support of Next Generation Composite Aircraft. *ATEC Journal*, 31 (1), 5–9.

[5] Sterkenburg, R., Eiff, G., Lopp, D. & Leasure, M. (2001, August). *The Unique Challenges and Advantages of Developing an Interacting Partnership Between an Aeronautical Technology Program and Major Air Carriers*. International Conference on Engineering Education, Oslo, Norway.

Biographies

DAVID STANLEY is an Associate Professor in the Aeronautical Engineering Technology program at Purdue University. He is the principal investigator of the NaTeF project and co-director of the Air Transport Institute for Environmental Sustainability (AirTIES) Center. Prof. Stanley teaches primarily powerplant courses. He may be reached at dlstanley@purdue.edu

RONALD STERKENBURG, Ph.D., is an Associate Professor in the Aeronautical Engineering Technology program at Purdue University. He is the lead AT investigator for the USMC-sponsored programs, and has directed several design / build / fly projects in which students from engineering and AET worked together to achieve impressive results. Prof. Sterkenburg may be contacted at sterkenr@purdue.edu

DENVER LOPP is a Professor of Aviation Management and an award-winning teacher at Purdue University. He is a Co-PI of the NaTeF project and co-director of the Air Transport Institute for Environmental Sustainability (AirTIES) Center. Prof. Lopp has led many aviation industry collaborative projects involving undergraduate students. Prof. Lopp may be contacted at denver@purdue.edu