This column provides examples of cases in which students have gained knowledge, insight, and experience in the practice of chemical engineering while in an industrial setting. Summer internships and co-op assignments typify such experiences; however, reports of more unusual cases are also welcome. Description of the analytical tools used and the skills developed during the project should be emphasized. These examples should stimulate innovative approaches to bring real-world tools and experiences back to campus for integration into the curriculum. Please submit manuscripts to Professor W.J. Koros, Chemical Engineering Department, Georgia Institute of Technology, Atlanta, GA, 30332-0100.

Challenges of Implementing

A JOINT INDUSTRIAL–ACADEMIC RESEARCH PROJECT

As Part of a Nontraditional Industrial Ph.D. Dissertation

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To many people the notion of a distance-education doctorate in engineering may seem ridiculous enough by itself, but add the fact that the prospective student intends to maintain full-time employment as a senior process engineer with a chemical manufacturing company, and the ridiculous notion appears to become an impossibility. Indeed, convincing a university and a corporation, two notoriously inflexible institutions, to do as much "outside the box" thinking as was required for this endeavor was no small task. Despite the potentially daunting obstacles, however, and through a unique partnership between Evonik Degussa Corporation in the United States, Evonik Degussa GmbH in Germany, Auburn University, and the University of South Alabama, this seemingly impossible proposition has become a reality.

This article will describe the conception and organization of this unique and very nontraditional research project from the perspective of the student who is close to completing this

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unusual journey. At each step along the way, compromises from all parties have been required, but in the end an environment was established whereby everyone stood to gain from the process. As each step of the process is described, it will be accompanied by some first-hand lessons learned from the experience.

A WIN-WIN-WIN SCENARIO

The real key to making this unlikely dissertation project a reality was to negotiate a scenario where all parties involved —the student, the universities, and the company—had something to gain from a successful collaboration. For the student the benefit is clear, the chance for achieving the Doctor of Philosophy degree while maintaining a career. For the universities, the benefits include exposure to industrially relevant research and processes and the opportunity to apply theory to real applications. Additionally, universities can benefit greatly from the improved intellectual diversity stemming from adding industrial experience to academic research groups. For the company, the benefits come from the creative thinking required of the Ph.D. student, which can lead to an increased potential for innovation. Additional company benefits come both from the infusion of fresh mindsets into the research and development process and from establishing a relationship with the university to identify talented students for future employment, as well as the opportunity for corporate branding. By establishing a win-win-win scenario, everyone is motivated to find a way to ensure a successful outcome.

RESEARCH OBJECTIVES

The research project was originally conceived as a conceptual process-development project for the production of an industrial chemical from renewable, bio-based feed stocks.[1] The original objectives included the development of a conceptual process and an assessment of its economic viability. In addition, laboratory experiments were to be carried out to gather the data needed for the process-design activities. This industrial project in and of itself, however, would not necessarily have contained sufficient academic rigor for a Ph.D. dissertation. To address this potential shortcoming, the original project has been incorporated into the other systems-engineering research work at Auburn University. In this way, the project could be given a broader scope, yet the original goals were preserved by including the industrial application as a case study.[2]

In nontraditional projects like this one, it is incumbent upon the research advisor to ensure the resulting dissertation has sufficient depth. This was accomplished by ensuring that there was enough flexibility in the scope to allow the student to follow leads and dive more deeply into avenues of interest that arose as the project progressed. Because of this, the project evolved significantly as it moved along. In fact, the final results were quite different from what was initially envisioned. This means that care must be taken in choosing a research topic. The project must have a clear focus, but be open enough to allow the creativity that is vital to intellectual development of the student. Particularly projects that include the development of generally applicable methodologies or mathematical techniques are good candidates. In this way the development of the methodology or technique can be openly published, whereas the results of the application of the methodology or technique to the specific industrial research topic can remain proprietary. By framing the research in this way, the practical outcome desired by the industrial partner and the scientific contribution desired by the university can both be accommodated.

With any collaborative research project, the different parties involved do not necessarily share the same objectives. This project is no different; therefore it is important to ensure that the objectives of both the university and the industrial partner are defined and addressed. The academic objectives are usually based on a "process of discovery" where scientific merit is favored over specific results. From the perspective of the university, the ultimate goal is the advancement of scientific knowledge on a research subject. The objectives of the corporation, however, usually have a different focus. In industry, the objectives are usually based on predefined deliverables with economic viability being considered at each step. From the perspective of the corporation, the ultimate goal is a positive return on the research investment. Framing the research project to incorporate the objectives of both the university and

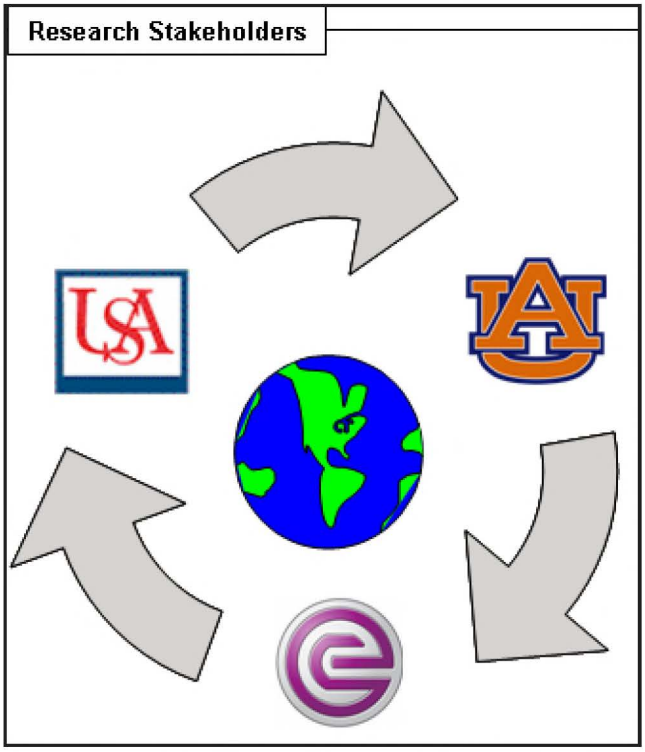

Figure 1. *Stakeholders in the proposed research project.*

the industrial partner is important for successful collaboration. Developing a clear scope of work with the principle objectives defined improves the likelihood of satisfying the expectations of all the research parties.

ORGANIZATIONAL CHALLENGES

When defining the scope of the research project, several organizational challenges had to be addressed to ensure a successful collaboration. First and foremost is establishing the need for flexibility from the student, the university, and the industrial partner. Research is a fluid process and it is nearly impossible to force the process to fit into a rigid schedule. From the student, flexibility with regard to work and study schedules is needed; from the university, flexibility with regard to residency requirements and in what order the individual requirements of the Ph.D. degree are met is needed; and from the industrial partner, flexibility with regard to work hours and vacation schedules is tremendously beneficial.

Nearly as important as establishing the need for flexibility is establishing channels of communication so no one is left out of the loop. With research partners in two universities and on two continents, good communication is critical. Determining a schedule for update meetings and status reports early in the process can help to ensure that everyone involved is informed regarding the progress of the research. In order to ensure that company goals are met, a representative from Evonik Degussa was included on the research committee.

Another key item considered during the organization of this project was determining where and how this research fits in with current research being done at Auburn University. Since this research was conceived outside the university, organizing funding for the project could have been a challenge. In this case, the research is wholly funded by Evonik Degussa. It may at first glance seem surprising that a company would be willing to fund such an endeavor solely to benefit an employee. Since this research was going to be conducted by Evonik Degussa regardless, however, including it as part of a Ph.D. dissertation adds tremendous value. Since the industry researcher and the student are one and the same in this case, the potential for creative discoveries is greatly improved. With this arrangement, the student is motivated not only by career goals, but by the chance to achieve the highest degree in the field. For others considering a similar path who work for companies without such a well-developed research history, however, grant money may also be a potential source for funding.

Regardless of the source, it is important to accurately forecast the total cost of the project. By spending the time to estimate the total cost over the life of the project, the issue of running out of money before all the academic requirements are met can be avoided. Some lessons learned from the budgeting process of this project are listed in Figure 2.

Finally, since this research must fit in with the normal job function of the student, it is important to organize how hours during the work day will be allocated between the research project and other job functions. This research project has been organized as an Evonik Degussa engineering project with a fixed budget to account for research hours spent during the work week. The original budget was based on allowing approximately 30% of the week to work on the research project. Depending on the phase of the project, however, more or less time was spent as required.

Lessons Learned: Budget

- Accurately determine the expected duration of the research project. The dissertation will include additional elements beyond the industrial portion of the research, so it is important to include these when estimating the project duration.
- Decide how university tuition and fees will be paid. Since the research was not conceived at the university, funds for tuition waivers or stipends may not be available.
- Determine who will be responsible for travel costs for both the student and academic advisor. Additional costs for attending technical conferences and seminars may also need to be included.

Figure 2. *Some lessons learned regarding the budgeting process.*

Despite the time allowed during the work week, a significant amount of the student's own time is required. In this regard, the effort is similar to the effort required for a traditional Ph.D. Although the time commitment is significant, a student with several years in industry can draw on this experience with regard to both problem solving and time management in general.

One potential problem is drawing the line between what part of the research is focused on meeting the goals of the company and what part is solely focused on meeting academic requirements. Clearly, activities such as completing coursework requirements are solely academic. Since the development of a Ph.D. candidate requires time to be spent exploring various avenues of research, it can be difficult to determine what work is being done to meet the company goals and what work is being done to meet the additional requirements for academic rigor demanded by the university. Therefore it is important to establish research goals and milestones up front so progress can be easily measured.

In summary, it is important to realize that balancing work, school, and sanity is not always easy. Any student considering this path must have advanced time-management skills. In other words, personal organization is as important as the

Lessons Learned: Conflict

- Definition of pre-existing intellectual property: It is important to establish what each side already knows with regard to the proposed research.
- Ownership of any patents that arise from the research: Patent ownership can be a huge source of conflict; negotiating an ownership and royalty agreement up front may help to avoid this potential conflict.
- Publication of research findings. Since the research may contain business-sensitive information it is important to determine what can and cannot be published and who will make this decision.

Figure 3. *Some lessons learned regarding identifying potential sources of conflict.*

organization of the project. Without good organization, it is easy to feel overwhelmed by the demands of school and career. Understanding of these demands from supervisors at work and from the academic advisor can help make this burden manageable.

POTENTIAL SOURCES OF CONFLICT

Even with the most well-organized projects, conflict between the partners will arise. To help minimize this potential conflict, it is important to consider where conflict might arise and take preemptive action to avoid it. One primary source of potential conflict is over the ownership of intellectual property generated as a result of the research. In the case of this project, a thorough research contract has been entered into between Evonik Degussa and the two universities. In the process of negotiating these contracts, it became clear that there were two competing interests regarding intellectual property: The university does not want to "give away" its innovations, and the company does not want to pay royalties to use its own technology. Clearly, addressing intellectual property (IP) issues before they become conflicts is wise. In the case of this research project, the scope was divided between academic objectives and industrial objectives to help settle any intellectual property conflicts that may arise. By dividing up the anticipated intellectual property before it is generated, serious conflict can be avoided. In addition, all department faculty members were included in the IP agreement. This allowed frank and open discussions regarding the research without compromising confidential research results.

Another potential source of conflict is the duration of the research project. Because the Ph.D. student must be allowed time to develop creative solutions to problems and explore alternate avenues of research, the pace of the project may be slower than the pace to which industry is accustomed. To avoid a possible conflict, it is important to outline a schedule up front, including milestones and a general timeline. In the case of this research project, a three-year timeline was proposed to meet the industrial and academic requirements. This timeline was acceptable to Evonik Degussa, and reasonable for a Ph.D. student already holding a master's degree. Some lessons learned regarding identifying potential sources of conflict are listed in Figure 3.

Conflict is a normal part of business, and this collaborative research project is no exception. Even though conflict can not be avoided entirely, brainstorming to look for possible sources of conflict and addressing them from the onset can help to streamline the process. Although there is no universal right way to address potential conflicts, it is well worth the time to look for and discuss them before any money or time is invested on collaborative research.

PUBLICATIONS AND DISSEMINATION OF RESULTS

A primary part of the academic experience is publication in technical journals and presentation at conferences. As natural as this process is in academia, it is often discouraged in industry for reasons of protecting business-sensitive information. These two conflicting interests can also cause problems for the industrial Ph.D. student. For this research project, the importance of publications and technical presentations was discussed before any work began. The agreement reached allowed publication and presentation of general research findings, while specific data was withheld. This agreement was an acceptable compromise for all sides. As a result of this agreement, the total scholarly output from this research so far includes four peer-reviewed publications and 10 technical presentations at national and international conferences.

COURSEWORK REQUIREMENTS AND RESEARCH PROGRESS

Since the requirements for the Doctor of Philosophy degree include coursework as well as research, being located so far from campus presents challenges for a prospective student. Obviously, driving more than 200 miles just to attend class is not practical. Fortunately in this case, all graduate courses in engineering at Auburn University are available through distance education. The distance education option is really a necessity for a nontraditional student. Another avenue to explore is transfer credit. Since many universities allow at least some transfer credit, it may be possible to take some courses at a nearby university to avoid having to take all classes via distance education. Auburn University allows up to 12 hours of transfer credit to count toward the 30 hours of graded coursework required. In addition to the 30 hours of traditional graded coursework, Auburn University requires a further 30 hours of ungraded coursework as well. This requirement was met by research and dissertation as well as directed study credit.

Lessons Learned: Final Notes

- Negotiate as much as possible up front.
- Brainstorm early and often to anticipate potential roadblocks.
- Secure management commitment up front.
- Be prepared for surprises along the way!

Figure 4. *Some final lessons learned regarding the nontraditional Ph.D. process.*

Not only does the geographic distance create challenges for completing coursework, it can also be an obstacle for the normal interaction between a student and advisor that is so critical to the student's development. To help bridge this gap, it is critical that both the student and the advisor be comfortable using long-distance collaboration tools such as e-mail, video conferencing, instant messaging, and Web-based meeting tools. If used effectively, these tools can create an open forum for communication and discussion.

Despite advances in technology, the use of long-distance collaboration tools can never completely take the place of face-to-face conversations. Because of this, regular visits to Auburn by the student and to Evonik Degussa by the advisor are important. Initially, three or four face-to-face meetings were scheduled to discuss project planning, resolve intellectual property issues, and determine the overall direction of the research. Once the research work began, two or three meetings per semester were planned to review the progress with the other research committee members at Auburn University. Meetings were held both at Auburn and on the Evonik Degussa plant site. As the research progressed, fewer face-to-face meetings were required while more extensive use was made of long-distance collaboration tools.

PARTICIPATION IN A RESEARCH GROUP

In order to truly develop as a Ph.D. candidate, participation in a research group is also important. From the academic side, this research is folded into the research group of the academic advisor. This was a tremendous advantage of the partnership with Auburn University. Since the research project fit well with other research already being done at Auburn, there has been ample opportunity to learn from, and contribute to, other research in this area. Because of this it is important to spend time interacting with the other students in the research group, not just the advisor, during scheduled visits to campus. Interacting with other students can enhance creativity due to an exchange of ideas from others working on similar projects. In addition to campus visits, participation in technical conferences and seminars with other members of the research group is a good way to achieve this interaction.

CONCLUSIONS AND FINAL THOUGHTS

Integrating industrially relevant research topics into an academic setting is an important goal for providing balance to a chemical engineering department. Through collaboration with an industrial partner on an academically interesting and industrially important research topic, this goal can be achieved. Although this project is unique for all parties involved, the results of the collaboration have so far been successful. This experience can serve as a model for other manufacturing companies looking to bring an academic perspective to a research project, and for universities looking to bring an industry focus to chemical engineering education. Although many of the points raised in this contribution may appear obvious when they are put in print, making such a project work in practice is no trivial matter.

In conclusion, this unique and nontraditional research project has been a tremendous learning opportunity for both the student and the advisor. Although sometimes challenging, the success of this project has been the result of hard work, careful planning, and good communication along the way. Based on this experience, some final lessons learned are listed in Figure 4.

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