Developing a working 2-year/4-year research program: experiences from the first year of a collaborative ATE grant.

Dr. Paul B Golter, Washington State University

Paul B. Golter obtained an M.S. and Ph.D. from Washington State University. His research area has been engineering education, specifically around the development and assessment of technologies to bring fluid mechanics and heat transfer laboratory experiences into the classroom. He is currently a Lecturer in Mechanical Engineering at Ohio University.

Prof. Bernard J. Van Wie, Washington State University

Prof. Bernard J. Van Wie received his B.S., M.S. and Ph.D., and did his postdoctoral work at the University of Oklahoma where he also taught as a visiting lecturer. He has been on the Washington State University(WSU) faculty for 34 years and for the past 20 years has focused on innovative pedagogy research and technical research in biotechnology. His 2007-2008 Fulbright exchange to Nigeria set the stage for him to receive the Marian Smith Award which was given annually to the most innovative teacher at WSU, and in 2016 he received the inaugural WSU Innovative Teaching Award based on the development and dissemination of hands-on desktop learning modules and their use in an interactive learning environment.

Prof. Jeffrey Laube, Kenai Peninsula College

Process technology instructor at Kenai Peninsula College since 2009. Worked in the process industry for 20 years before teaching.

Developing a working 2-year/4-year research program: experiences from the first year of a collaborative ATE grant.

Abstract

Joint research projects between two and four year institutions may be fraught with unforeseen pitfalls which contribute to the eventual failure of the collaboration. In this paper, the authors document their experiences in identifying and overcoming differences in culture and expectation that have already been seen in the first few months of a collaborative NSF Advanced Technological Education (ATE) grant that utilizes the joint expertise of process technology instructors at a two-year college and chemical engineering faculty at a four year research university in different Western states. We have identified significant differences in our expectations for what students will do with the same concepts, what portions of a concept are most important to students, and what students will be able to do that demonstrates competency. One key component for success is that the authors have been able to acknowledge and respect each other's differing perspectives and expertise. By understanding the differences in emphasis for our programs, we have been able to adapt materials created for use in teaching engineering students to providing process technology students a low-cost, useful hands-on experience.

Introduction

In terms of content professors teaching engineering at a research university have a theory-heavy focus with emphasis on being able to translate conceptual understanding into mathematical descriptions of a phenomena with the ability to adapt to unique situations. In contrast the process technology program has a more qualitative emphasis in that students do not need to derive the mathematics. Furthermore, the unique situations which engineering professors use to gauge the depth and transferability of a student's understanding are, to process technicians, an indication of a problem in the process. Rather than being able to describe and predict the phenomena, process technology students instead need to be able to correct the process toward normal operation. The differences in these two broad outcomes lead to differences in emphasis and approach to teaching similar topics.

Our ATE project involves adapting novel in-classroom laboratory equipment and activities developed for teaching engineering to teaching process technology. The equipment being adapted consists of very low-cost models of common industrial equipment [1-5]. These are items like heat exchangers and pipes which are common to both process technology and many branches of engineering. The emphases are different however, process technology or PTEC programs are concerned with ensuring that students understand normal behavior and how some of the phenomena can be used to cross-check instrumentation. Engineers are more concerned with design equations. In both types of programs laboratory equipment provides a necessary linkage to physical reality.

PTEC programs provide training for individuals seeking careers as operators in the chemical process industries. As such PTEC programs include training in chemical separation, such as distillation or absorption; heat transfer; reactions; and how such processes are connected, i.e. piping and pumps. For further information on PTEC, please see the web pages of the North

American Process Technology Alliance [6]. Chemical Engineering (ChE) is the corresponding branch of engineering which deals with the same set of topics. Training for both fields uses similar equipment and similar exercises with, as previously noted, different emphases.

Figure 1: Example of a traditional bench-scale ChE or PTEC laboratory apparatus. Picture from http://www.hampden.com/product-details.php?viewid=959

Traditional laboratory equipment in ChE and PTEC ranges from bench-scale, such as the Hampden H-6883 shown in Figure 1, to pilot scale chemical plants. The novel apparatus in use in this ATE project takes advantage of 3-D printing and lean manufacturing principles to develop equipment which costs two orders of magnitude less than traditional equipment. By dramatically reducing the scale of the equipment and making the choice to use low-cost, highly visual measurements, Figure 2, we have developed a set of equipment that fits in a medium sized USPS flat rate shipping box. Between the low cost and the small scale, the apparatus is suitable for classroom use with multiple copies of an apparatus in use by small student groups. The PTEC portion of this collaboration also offers many distance courses. The small scale of the apparatus means that shipping to distance students is possible. Usage at 4-year institutions has shown efficacy in increasing student learning, especially at the higher levels of Bloom's Taxonomy[7, 8]. Student performance on pre-and post- conceptual questions increased by a statistically significant margin ($p < 0.05$) with an effect size greater than 0.7. We expect that similar results can be obtained at a 2-year institution.

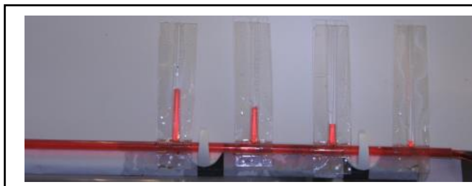

Figure 2: Low cost hydraulic loss apparatus with standpipes for pressure measurement. The fluid in the system is water with food coloring. Length of the system is two feet.

As we have proceeded on this project, one comment from our external evaluator has stood out as something worth investigating as an additional outcome. Our external evaluator has at multiple times over the roughly six months of the project, as of the time of writing this, expressed pleasant surprise at how well we are working together. It is apparently very common, according to her, for collaborations between 2 and 4 year institutions to break down very quickly. The question then is how have we managed to foster this collaboration? What pitfalls or hurdles have we avoided? One possibility is that institutional and program cultures, expectations, and emphasis are different enough that they can be difficult to get past in order to make the collaboration work. In this paper we will discuss some of the differences we have noticed over the first few months of our collaboration and how we have worked past them in order to succeed.

Observed Differences

Those of us from ChE at 4-year institutions had some preconceptions of what a 2-year PTEC program needed. These preconceptions shifted as the collaboration went on and are continually being addressed. Some of these are found in Insert 1. A similar list of preconceptions 2-year faculty had about 4-year programs and faculty may be found in Insert 2. In some cases, these are built on experience. For example, our collaboration member from the 2-year PTEC program spent 10 years as an operator in an ammonia plant. He has, and will happily tell, many stories of engineers messing up plant operations due to not listening to the operators. In one instance the operator knew the suggested changes would force part of the plant to shut down. After getting the engineer to sign something authorizing the change, he called a downstream portion of the plant to warn them that his portion was about to go down. The engineer chose not to pursue the operating change without further investigation. This one instance provides a great example of both the second and fourth preconceptions in Insert 2. It is easy to imagine how this experience could lead to a mistrust of engineers and their decision-making capability.

Insert 1: Preconceptions 4-year faculty had about 2-year programs/faculty

- PTEC courses need little to no math.
- PTEC courses need little to no theory.
- The in-class activities used in ChE courses are suitable for PTEC courses.
- Writing scholarly articles is a primary task for all faculty everywhere.
- Obtaining grant funding is always of benefit for faculty.

Insert 2: Preconceptions 2-year faculty had about 4-year programs/faculty

- Engineers have no practical skills.
- Engineers will never listen to anyone tell them they are wrong.
- Engineers can't do any math involving money (otherwise they would be operators and make more money thanks to overtime).
- Engineers do not consult the operators for advice on projects.

Similarly, one of the 4-year ChE program participants spent four years as a process engineer at a market pulp mill. During his time in industry, he didn't observe much use of math or theory on the part of the operators. As an example, the effluent of the mill needed to be maintained at a near neutral pH. At this point in the pH curve, which is logarithmic, a very small change in acid concentration can result in a significant change in pH. Since the mill was fined for time spent with an out-of-bounds pH, the operators tried to be proactive and respond aggressively to any outage. Unfortunately, they weren't thinking logarithmically and outages were extended as they chased the pH. It took a lot of convincing before they would believe that the control system would correct the problem more quickly than they could by hand. Again, it is easy to imagine how such experiences may color one's perceptions of what operators need to know and are capable of.

In the 4-year engineering program setting, everything, from theory to its application, can eventually be described in terms of higher order math, usually differential equations. From this perspective, it is easy to understand why 4-year faculty might think that PTEC students don't need much, if any, math or theory. We sometimes forget that theory describes phenomena and that this description can be verbal rather than strictly mathematical. We also forget that, if the purpose of mathematics is to describe or utilize normal conditions, it isn't necessary to work with differential equations. A set of simpler mathematical concepts is all that is needed. Once we had this established, we thought about the ChE activities we had designed. These activities are intended to display a phenomenon in a way that can be described using relatively simple math. However, the difference in emphases between the two programs means that the desired learning outcomes for PTEC are different, and the activities needed to be redesigned. For example, with the hydraulic loss apparatus in Figure 2 ChE courses want students to see that the pressure drop is linear with length of the pipe, and roughly second order with respect to velocity. From there they can start discussing friction and roughness. PTEC students are taught that they can use the pressure drop over a known length of pipe to estimate the flow rate and double check their instrumentation. Many of the PTEC students go on to work for companies that are responsible for the Trans-Alaska Pipeline. There may be miles of essentially straight pipe between pressure measurements. For this application, pressure drop across a known length of pipe much larger than the noise in the pressure measurement. ChE piping applications, however, tend to be shorter, with correspondingly smaller pressure drops. It is less practical in those situations to use straight pipe hydraulic losses to estimate flow rate. This example also demonstrates the gap that gives us the perception that engineers can't be practical.

The last two items in Insert 1 are perhaps the most persistent. For tenure track faculty at a 4-year institution grants and scholarly articles are the primary means by which a professor advances his or her career. Granted, there are service and teaching components as well, but research is generally believed to be the primary. One tongue-in-cheek pamphlet on reaching tenure even gave points for various activities: 0.5 points for an article in a low-quality journal, two points for a top tier journal, and points = $ of funding for a grant. It is difficult for tenure track, 4-year faculty to realize that this is not a universal truth in higher education. The most recent example of this impacting our collaboration was during discussion of requesting a supplement. There was no question on the part of 4-year faculty, that a supplement would be a good thing and expand what we could accomplish. The2-year faculty though said "You know, my director is worried about this and how it will affect my workload agreement and whether it will impact the workload for the rest of the department." The priorities are fundamentally different.

Much of our ability to overcome these differences has come from cultivating an attitude of respect for each other regardless of background. It is important to keep in mind that each of us is at the educational peak of our respective fields and has considerable expertise derived from teaching in our fields. Keeping this fact in mind helps remind us that the other person has a reason and probably some experience behind what they are saying. This also gives us space to recognize the limits of our own expertise. It is, after all, easier to defer to an expert than to someone who you are sure knows less than you. The 2-year faculty are experts in training operators for the chemical process industries. Knowing this, it is easier for the 4-year faculty to acknowledge that they don't really know what information these operators need. Similarly, 4-year faculty have tremendous expertise in writing grants and articles. Since this is a much lower priority for 2-year faculty, they defer to the 4-year faculty on this.

Conclusion

One very important part of an effective collaboration between faculty at 2- and 4-year institutions is to remember that the other faculty are equally experts in their field. From the starting point that the members of the other institution are peers one can build a collaboration. The research under the current ATE is still proceeding and we anticipate continuing the collaboration and pursuing further funding on this project. A future avenue of research, that may prove interesting, would be to examine 2- and 4- year collaborations that failed, to identify why. The conclusion above about respecting the expertise of your peers at the other institution represents a plausible hypothesis, but more research needs to be done. Specifically, one would need to determine the root cause of failed collaborations, and contrast that with other successful collaborations.

Acknowledgments

Acknowledge: NSF ATE #1601404, the collaborative grant for institutions new to the ATE which is funding the effort. Terryll Bailey, our External Evaluator who informed us of just how unusual our collaboration success is. NSF DUE #1432674 through which the low-cost miniature equipment used as the basis for the collaboration was built.

References

1. P. Golter, B. Van Wie, and A. Nazempour. The Effectiveness of in-Class, Hands-on Learning Vs. Lecture for Teaching About Shell and Tube Heat Exchangers*, ASEE Annual Conference*, Seattle, WA, 2015.
2. A. Nazempour, P. Golter, C. D. Richards, R. F. Richards, and B. Van Wie. Assessments of Ultra-Low-Cost Venturi Nozzle in Undergraduate Engineering Classes*, ASEE annual Conference*, Seattle WA, 2015.
3. S. W. Njau, B. J. Van Wie, J. K. Burgher, P. B. Golter, R. F. Richards, C. D. Richards, F. S. Meng, O. O. Adesope, N. Hunsu, N. Beheshtipour, P. Dutta, D. B. Thiessen, and A. D. Graviet. Miniature Low-Cost Desktop Learning Modules for Mulit-Disciplinary Engineering Process Applications*, ASEE Annual Conference*, Seattle WA, 2015.
4. C. D. Richards, F. S. Meng, B. Van Wie, P. Golter, and R. F. Richards. Implementation of Very Low-Cost Fluids Experiments to Facilitate Transformation in Undergraduate Engineering Classes*, ASEE Annual Conference*, Seattle WA, 2015.

5. R. F. Richards, F. S. Meng, B. Van Wie, F. L. Spadoni, and A. L. Ivory. Maker: Very Low Cost Experiments Via 3-D Printing and Vacuum Forming, *ASEE Annual Conference*, Seattle WA, 2015.
6. North American Process Technology Alliance, http://www.nataonline.org, 9-16-2014.
7. J. K. Burgher, D. Finkel, O. Adesope, and B. Van Wie, Implementing and Assessing Interactive Physical Models in the Fluid Mechanics Classroom. *International Journal of Engineering Education*, **32**(6), 2016, pp.2501-2016.
8. S. Brown, A. P.-W. Easley, D. B. Montfort, J. C. Adam, B. J. Van Wie, A. Olusola, C. Poor, C. Tobin, and A. Flatt, Effectiveness of an Interactive Learning Environment Utilizing a Physical Model. *Journal of Professional Issues in Engineering Education and Pracice*, **140**(3), 2014.