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Engagement in Practice: Engineering at a Monastery - Integrating Course Content with Community Engagement by Building a Better Maple Sap Evaporator

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I am a monk of Saint Vincent Archabbey, Br. Lawrence, and in addition to seminary studies I work in our college as a lab assistant to the physics department. After finishing seminary I will go on to graduate studies in physics so as to teach in the college. Two years ago some monks and students came together to make maple syrup by tapping local maple trees. In the second year we constructed our own evaporator and this year we are working with an engineering course to design a sap preheater system to improve the evaporator's efficiency.

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Monasteries have long been associated with the notion of communal self-sufficiency. Throughout much of history, this was brought about by necessity – a large portion of the staple foods and other necessary provisions were the result of the combined labor of the monastic community's members. This often included raw materials such as grains and fresh produce as well as processed goods such as fabric, preserved foods, and beer. Catholic, Benedictine communities in particular are noted for adherence to the ideal of *ora et labora* – prayer and work. In the past century or so, it has become more cost-effective to purchase, rather than produce these necessities. However, many monasteries maintain production of specialty goods such as jams, soaps, flour, and coffee as a way to maintain a sense of community through labor, and to help support the work of the monastery through their sale.

It is in this spirit that monks at Saint Vincent Monastery recently began a community effort to collect sap from the maple trees on its campus (which it shares with Saint Vincent College) and process that sap into maple syrup. In the spring, assisted by students in an environmental science lab, monks tap maple trees on campus, attaching collection buckets to each. These buckets are emptied daily for 3-4 weeks, and the collected sap is frozen until the entire batch is ready to be processed. In order to become maple syrup, around 97% of the water is removed by evaporation. To improve the efficiency of this process, the monks have constructed a draft-driven evaporator which allows the sap to boil in shallow pans atop a wood fire. Although the syrup-making effort was only begun in 2015, it has brought together people from many different parts of the college, monastery, and greater community. Students assist with the tapping of trees and the collection of the sap, and through a nature reserve associated with the college, community outreach is provided in the form of demonstrations and tastings. Additionally, community members are invited to tap their own trees and contribute the sap to the syrup making efforts.

Community engagement programs in higher education have grown significantly in popularity in recent years[1]. Practitioners of successful programs report numerous benefits the students, including a more engaging learning experience, practice working on projects of real relevance, improved performance in traditional measures of learning, increased proficiency in relevant "soft skills" such as communication, and an increased sense of civic involvement[2]. The community partner also benefits from the experience, through both the fruits of the student work and the increased exposure to the partner's mission[3].

In the fall of 2016, a collaboration was begun between Br. Lawrence Machia (the monk who spearheads the maple syrup production effort) and the Engineering Science program of Saint Vincent College. The goals of this collaboration are as follows:

1. Strengthen the connection between the relatively new Engineering Science program and the greater campus community, including the monastic community.
2. Provide engineering students with an opportunity to apply their technical knowledge to a real project, located on campus.

3. Reinforce to students the idea of engineering as a service towards the betterment of one's community.
4. Increase the efficiency of the maple-syrup making process based on analyses and improvements designed by engineering students.

The collaboration centers around the evaporator that had been built by Br. Lawrence for concentrating sap into syrup, and an upper-level course in heat and mass transport that may be taken as an elective by Engineering Science students. Nearly every topic covered by the transport course could be directly applied in some way to the evaporator. For instance, heat is transferred from the fire to the sap boiling pans through radiation, convection, and conduction, and the operation of the evaporator includes aspects of phase changes, heat exchanger design, and transient heat transfer. Vanasupa and Schlemer[4] characterized community engagement programs according to the level of overlap with course content, and whether the scope of the program was to provide a service for (transactional) or to build a relationship with the community partner. According to their model, this collaboration – which is at this point in time transactional – would be classified as *service learning.*

The accessibility and simplicity of the evaporator design make it an excellent subject for the basis of analysis and design in the context of project-based learning (PBL). When properly implemented, PBL can greatly increase the sense of engagement among students, while also improving retention of course concepts and the development of related soft skills[5]. Incorporation of PBL techniques has been successfully demonstrated for a wide variety of projects and settings in thermal and fluid engineering courses, including the design of a brewery[6], HVAC equipment[7], and thermal insulation devices[8]. In addition, the inclusion of "real-world" clients has been shown to have positive impacts on student engagement in course projects[9].

The course had been taught in a traditional lecture format in the previous year (Fall 2015). The intent for 2016 was to restructure the course to include:

- A project-based learning component relating to the evaporator
- Out-of-class activities to test the evaporator's operating conditions and measure relevant parameters such as temperatures, temperature gradients, and draft velocity
- Theoretical applications of heat transfer to the evaporator alongside lecture materials – replacing some of the calculation examples taken out of the textbook.

For their project, the students, in collaboration with Br. Lawrence, would identify an aspect of the evaporator that might be improved. They would then analyze the evaporator using principles of heat transfer and design a proposed improvement. In the original conception of this collaboration, students would then build the improvement and test its implementation. However, in the actual implementation these expectations were scaled back to the analysis and design of an improvement.

We entered this collaboration expecting numerous mutual benefits. For the engineering program, the partnership offered first and foremost an opportunity to engage with a segment of the Saint Vincent community with whom we typically share little overlap. As a program that is still fairly new, this collaboration offered a way to increase our visibility on campus and perhaps in the greater community, since the improvements to the evaporator would become part of the story of syrup making at Saint Vincent College. A more visible program would lead to increased interest from local students, and perhaps higher enrollments in subsequent years. Secondly, it would offer our students a chance to work on a real-world engineering design problem that would make a lasting impact on the community. Along with the transport course, the potential would exist for students to complete their capstone design project by continuing their work on the evaporator. For the syrup-making program, the main benefit would be an evaporator with improved efficiency and/or safety, making the syrup production process easier and more flexible. They would also gain some insight into how the engineering field views the world, and potentially increase their technical and scientific literacy. This could help to improve other aspects of production not specifically addressed by the student project, or may carry over into other aspects of their lives. Finally, they would build relationships with the engineering students and faculty, which may pave the way for future collaborations with engineering on other campus- or community-based projects.

Implementation of the restructured course

When initially taught in 2015, the transport course consisted of traditional lectures for most class sessions, with a few classes devoted to problem solving, using modifications of textbook problems. A small portion of the grade was devoted to a project wherein students chose an application relating to course topics to research and submitted a report and mathematical analysis. While the experience with this project was positive, it was also rather academic, and did not allow students a chance to feel they were working on something "real".

The 2016 implementation modified the course in several ways. The list of topics covered was altered to reflect those topics most directly relevant to the evaporator. Most notably, transient conduction, analogous mass transfer, and computational methods were dropped, and boiling was added. Other topics were expanded (convection) or de-emphasized compared to the 2015 course. Initially, it was anticipated that the format of the course would move away from lecture and more towards directed analysis of the evaporator. However the course ended up enrolling a single student[*], who expressed a strong preference for lecture-style class meetings. Out of respect for this preference, the lectures were retained.

The 2016 course therefore consisted of lectures interspersed with applications of the current topics to the evaporator. The evaporator project was introduced at the beginning of the semester, and progress milestones were assigned as follows:

- Week one – Br. Lawrence joins the class to introduce maple syrup making and the evaporator
- First two weeks: student to meet with Br. Lawrence and examine evaporator

[*] The low enrollment was a result of the size of the institution (around 1600 undergraduates) and the youth of the Engineering Science degree. There were few students eligible to register for the course in 2016, but as the first incoming classes matriculate upwards, enrollment in the elective course is anticipated to increase to 5-10 students.

- End of week four: student to propose an improvement to design and outline a project schedule
- Weeks 4-8: student to test evaporator operation using infrared thermometer readings and (if possible) anemometers to measure the hot combustion gas flowrate.
- Week 15: Project submission due and project presentation

Results and Observations

In consultation with Br. Lawrence, the student chose to analyze a proposed addition to the evaporator consisting of a set of cooling pipes below the pan supports, serving dual purposes. Water flowing through these pipes would absorb heat from the combustion chamber, protecting the metal pan supports from warping due to extreme temperatures. The heated water would then be passed through a copper coil submerged in a large container containing partially-melted sap, in order to accelerate the melting process, which was a major bottleneck in production.

From the student perspective, the project was not entirely successful. The final product that was presented consisted of an analysis of the energy transferred to the water in the proposed pipes through convection and radiation, and a comparison of this rate to the amount of energy required to melt a 5-gallon bucket of frozen sap. However, the analysis included only a single flowrate of the cooling water, and did not include the design of any component. Looking back, we have identified several reasons for this limited success, based on self-reflection and solicited feedback from the student at the end of the class.

- <u>*The student did not receive enough guidance from the instructor regarding the progress of the project*</u>. Specific check-ins regarding the project were not scheduled, and were therefore informal and sparse. This resulted in the project not progressing as quickly as would be necessary to properly complete a full design and analysis. In a written feedback survey administered at the end of the term, the student indicated feeling like they were "*navigating this project blind*". In part, this may be due to the decision to keep the lecture format for the course, as a more open course structure would have facilitated closer interaction between the instructor and the student. Furthermore, the lecture format limited each class meeting to the topic at hand for the day – whether it was relevant to the design project or not. Thus, some necessary topics for the analysis were not even introduced until late in the semester (radiation).
- <u>*The scope of the project was too large for one student alone*</u>. The student indicated feeling "*overwhelmed*" by the project, on top of their other obligations and the perceived difficulty of the course topics already. The project was designed with an enrollment of 3-5 students in mind, which would have eased the workload on an individual student. This issue is expected to self-correct going forward, as the population of upper-level engineering students grows.
- <u>*The choice of evaporator improvement was delayed far beyond its initial deadline*</u>. This is a combination of the poor instructor guidance detailed earlier, as well as some indecision on the part of Br. Lawrence regarding the direction he would like to see the project go. The actual project design (cooling water pipes) was not even proposed until late in the semester, by which time the amount of analysis that could be performed was lessened.

Because much of the work on the project was delayed until the last weeks of the course, the analysis was rushed and was not fully submitted to the instructor for scrutiny and feedback before the results were presented to Br. Lawrence and a few other interested parties. This resulted in an erroneous conclusion by the student, which was pointed out during the question phase. Afterwards, the student wrote that they "*felt humiliated*" by the experience, and began to question what they had even gained from the project and the course as a whole. Since the feedback was solicited shortly after the presentation, this strongly negative experience may have colored the student's overall perceptions of the worth of the project. When asked to comment on continuing to incorporate a similar project in future versions of the course, they recommended against including the project as a major course component in the future, based on the experience from their presentation. However, they also advised that if the project is retained in future versions of the course, to greatly increase instructor guidance, particularly at the project outset. Not all of the feedback was negative. The student indicated that working on the project helped to enhance their understanding of the material, and that "*it was nice to feel like I was designing something [real]*".

From the perspective of the instructor, there were positive outcomes as well, that the student may not have been in position to appreciate. Although its conclusions were flawed, the mathematical analysis submitted by student was accurate and led to many good insights in subsequent discussion. Also, despite the student's comments questioning their learning, their performance in the course was in line with the instructor's expectations based on prior academic performance, and they demonstrated good understanding and application of course principles on homework and exams. In essence, the *learning* aspect of PBL was successful, even if the *project* aspect fell short. Finally, the student's experience was a good lesson in the messiness of working with outside parties, and the need for frequent communication and clearly stated expectations (even if the instructor contributed to the problem). However, the student's concerns with the outcome of the project are shared by the instructor as well, and are indeed areas that will need to be significantly improved.

From the community engagement perspective, the result of the project was more satisfactory, but could still be greatly improved. Although the improvement was not completely designed, much of the more difficult analysis was completed, which showed that the proposed system was potentially worthwhile. In addition, Br. Lawrence was able to learn some basic heat transfer concepts that were relevant to the evaporator, which may shape future plans and modifications to the maple-making process. In particular, he was quite interested to learn that increasing the flowrate in his proposed cooling-water system would – counterintuitively – decrease the effectiveness of the attached sap melter. The collaboration also increased the awareness of the maple program among the engineering community, and vice versa. The student who completed the project stated that because they were a commuter "*it's normally difficult to feel engaged in the Saint Vincent community*", but that by working with a monk who is connected to the monastic part of the community, they felt they made a significant contribution to the campus culture.

Although the first year of this collaboration did not live up to the lofty hopes for the improvement of the evaporator itself, there are still many reasons to continue the effort in future years. The community engagement aspect of the collaboration was overall quite positive. Right now, there are plans to re-house the evaporator in a nature center on campus which will increase the visibility of the maple production program and will allow the role of engineers in the design of the evaporator to become more widely known. This also presents an excellent opportunity for engineering students to offer their design skills, as the evaporator will need to be rebuilt when it is moved. The project-based learning aspect of the collaboration was not as successful. Much of the problem can be traced back to the inexperience of the instructor, as it was their first attempt at utilizing PBL in a major way. Based on this first year, a number of changes are planned for the future. The students will be given much more guidance, including a specific timeline with intermediate progress reports/presentations and deliverables clearly indicated. This will include more in-class discussion of the progress, which will also allow the instructor to provide more advice and assistance regarding the analysis and design. Class sessions will shift away from lectures as originally planned, to allow more in-class involvement of the instructor, although lectures will still have their place. In addition, students will be required to present their *full* final results to the instructor in advance, before presenting to the greater community. Some of the difficulty of this first year will be ameliorated simply by the fact that enrollment is expected to increase, so that a student team, instead of an individual, will take on the challenge and will thus have a more balanced workload. With these intended changes, we believe that the success of this collaboration will increase greatly in upcoming years.

[1] C. B. Zoltowski and W. Lafayette, "Immersive Community Engagement Experience," *ASEE Conf. Proc.*, 2014.

[2] R. G. Bringle and J. A. Hatcher, "Implementing Service Learning in Higher Education," *J. Higher Educ.*, vol. 67, no. 2, pp. 221–239, 1996.

[3] M. J. D. Thompson and B. K. Jesiek, "Motivation of Community Partners and Advisors to Participate in Community Engagement Engineering Programs," *ASEE Conf. Proc.*, 2014.

[4] L. Vanasupa and L. Schlemer, "Relational versus transactional community engagement : An experience of the benefits and costs," *ASEE Conf. Proc.*, 2014.

[5] M. J. Prince and R. M. Felder, "Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases," *J. Eng. Educ.*, vol. 95, no. 2, pp. 123–138, 2006.

[6] J. J. Elmer and N. Comolli, "Unifying Multiple Concepts with a Single Semester-Long Project: A Brewery Design Project for Heat Transfer Courses," *Proc. Spring 2015 Middle Atl. Sect. Conf. Am. Soc. Eng. Educ.*, pp. 459–472, 2015.

[7] S. Krishnan and M. R. Nalim, "Project-Based Learning in Introductory Thermodynamics," *ASEE Conf. Proc.*, p. 14.986.1-14.986.11, 2009.

[8] M. Sozen, "A Design-and-Build Project for Heat Transfer Course," *ASEE Conf. Proc.*, 2016.

[9] M. S. Zarske, M. Dana, E. Schnee, and A. R. Bielefeldt, "The Impacts of Real Clients in Project-Based Service-Learning Courses," *ASEE Conf. Proc.*, p. 23.1213.1-23.1213.19, 2013.