RESEARCH

Community-Engaged Projects in Operations Research

BARBARA M. ANTHONY
Southwestern University

KATHRYN M. REAGAN
ThoughtWorks and Southwestern University

Abstract

Community-engaged learning is not very common in technical fields, but including relevant projects in courses can make it feasible and successful. We present an implementation of an operations research course at a liberal arts college. Working with one of four nonprofit community partners to optimize aspects of their organization, students gained insight into relevant, real-world applications of the field of operations research. By considering many aspects of their solution when presenting it to community partners, students were exposed to some issues facing local nonprofit organizations. We discuss the specific implementation of this course, including both positive learning outcomes and challenging factors.

Introduction

Operations research, a "discipline that deals with the application of advanced analytical methods to help make better decisions" (INFORMS 2017), is used by many organizations. Southwestern University, a small liberal arts college, offers an operations research course cross-listed as business, computer science, and mathematics, which broadens opportunities for students to take computer

science courses (Anthony 2012). While civic engagement is popular in colleges, its incorporation into the classroom is less prevalent in STEM disciplines (Butin 2006). Though some computer science courses incorporate community-engaged learning, it frequently occurs in a senior capstone experience (Bloomfield et al. 2014). An interdisciplinary course taken before the senior year can provide more realistic experiences in working with people from different backgrounds. Project-based courses are not uncommon in operations research; colleges are sometimes even paid by outside corporations for such projects (Martonosi 2012).

The operations research course's popularity and increasing support on campus for community-engaged learning worked synergistically to have projects proposed by local community partners (nonprofit organizations) in 2014. The Southwestern University Office of Civic Engagement (OCE) helped facilitate these projects by aiding in the solicitation of partners, providing continuing education to the faculty member, and providing a student Community-Engaged Learning Teaching Assistant (CELTA), whose duties included serving as a liaison between student groups and community partners. The CELTA was a computer science major who had previously taken courses with the instructor and had worked for the OCE for multiple semesters. Together, the instructor and CELTA investigated the value that students found in the project experience, in terms of both more traditional goals of community-engaged learning and the content typical of an operations research course. In the four projects, students partnered with a hippotherapy organization, a local chamber of commerce, and two units on campus.

Methods, Projects, and Partners

Students engaged in a semester-long team project partnering with local nonprofit organizations to solve a problem in need of optimization. Four student teams, working both in class and on their own time, submitted a proposal, a poster with preliminary results, and a final report including an executive summary and full technical details. They also made a final presentation to classmates, the professor, and their community partners. The course is typically a student's first introduction to operations research. Thus, students are learning the basics of the field while simultaneously applying the ideas presented in the course to their project with the community partner. Both quantitative and qualitative data were collected from students about their experiences, with approval from the university's Institutional Review Board. Students were asked identical questions about their attitudes toward community service in general, taken from Bringle's (2004) *The Measure of Service Learning: Research Scales to Assess Student Experiences*, before project groups were assigned and at the end of the semester, while final project reports were being prepared. All answers were given on a 1–7 Likert scale of likelihood (extremely unlikely to extremely likely) or agreement (strongly disagree to strongly agree). The qualitative data was collected from multiple sources, including meetings with the instructor and CELTA, peer and self evaluations, final exam questions, and course evaluations.

Two of the community partners came from area nonprofit organizations: Ride On Center for Kids (R.O.C.K.), a hippotherapy organization, and the Greater Leander (Texas) Chamber of Commerce. The other two partners were internal to the university: the Center for Academic Success and Records (CASAR) and the directors of the new incarnation of Paideia, an interdisciplinary curriculum program unique to Southwestern.

R.O.C.K. "provides equine-assisted therapies and activities to children, adults, and veterans with physical, cognitive, and emotional disabilities" (R.O.C.K.). R.O.C.K. aims to serve as many clients as possible while using limited resources (including staff, arena time, and horses) appropriately. Clients' needs determine whether the therapy sessions are individual or small groups. Students formulated appropriate linear programs for modeling the constraints and objectives, and analyzed the solutions under various assumptions (such as the number of hours a horse can be used each day or week). They recommended that R.O.C.K. alter operating hours to better utilize resources while still serving the same number of clients and prioritize the acquisition of additional horses.

The Leander Chamber of Commerce (LCC) has four membership plans, with different prices and benefits. As a nonprofit, they want to be sustainable while providing value to their members. Students first used linear programming techniques to determine optimal pricing for each of the plans while keeping the same benefits, under the limiting assumption that members would stay on the same plan. They then used knapsack problem techniques

to determine the ideal combinations of benefits in the plan that provide the most perceived value to the members for a given cost. As costs and perceived values change and new benefits are considered, LCC can use provided software tools to update offerings.

Currently at Southwestern, academic advisor/advisee assignments are made manually, a time-consuming and suboptimal process. Students worked with the Center for Academic Success and Records to convert their process into a flowchart, assigning measures for compatibility based on stated academic interest and predictors of transitional challenges. The assignment can now be considered as a transportation problem, maximizing the compatibility indicators of the entire incoming class while limiting the number of advisees assigned to any one advisor. The team used a Java program to parse data about students, fed that information to a tool called glpsol within the Gnu Linear Programming Kit (GLPK), to solve the transportation problem, and again used Java to present the output cleanly.

Beginning in Fall 2014, as part of a reconfigured Paideia program, all students are part of an interdisciplinary cluster, making connections across disciplines through a subset of required courses. There are numerous tradeoffs to be considered, for faculty, students, and the university as a whole, when considering the ideal number of clusters, courses, and faculty per cluster. Students developed an Excel tool to model these relationships that will be used by present and future Paideia directors in their decision making. Their recommendation of three new clusters per year provided an ideal balance of number of courses available to students and faculty in the cluster, while allowing for changes in class size in future years.

The creation of groups in a course project often poses an interesting dilemma. Each group had at least one person from each of the three predominant majors represented in the course: computer science, math, and business or economics. For the projects where it was anticipated that higher-level programming languages would be used (as opposed to Excel), multiple computer science majors were assigned. Students were required to complete a questionnaire with questions including their preferences among the projects, their willingness or ability to work with an off-campus partner, and published personality questions in a STEM text (Burger 2008). The instructor and CELTA then assigned groups, based on those responses and their prior experiences in the classroom.

Research on Student Experiences

In the following table, we report some of the statements that most students agreed or strongly agreed with. We also note that most disagreed with the claim "without community service, today's disadvantaged citizens have no hope."

Responses to the final survey were largely similar to the preliminary survey with regard to the number of students who felt an outcome was likely or agreed with a statement, but when quantified as described above, many of the averages for each question fell. (Given the small sample size, 21 students, we look more at general trends than actual numbers.) The other statements in Table 1 changed by at most 0.1 points.

The differences in the average responses are small. Students answering less enthusiastically (e.g., "somewhat likely" instead of "likely" or "agree" instead of "strongly agree") may have felt no differently in the final survey and simply had a hard time discretizing their response. Alternatively, a slight decrease in enthusiasm in final responses may be indicative of end-of-semester fatigue. As students typically did not interact directly with clients of the nonprofit partners, they might not have been able to see the outcomes and benefits of their projects. They

TABLE 1. Selected statements most students agreed with in the preliminary survey, and the percentage of students who responded with agree or strongly agree (6 or 7 on the Likert scale). For all of these statements, the number of students who answered slightly agree (5 on the Likert scale) was at least an additional 10 percent.

Likeliness of experiencing personal satisfaction knowing they are helping others during this service project. 86%
College student volunteers can help improve the local community. 81%
Improving communities is important to maintaining a quality society. 71%
There are people in our own community who need help. 86%
It is important to help people in general. 86%

TABLE 2. Average responses to statements in the preliminary survey and final survey.

	Preliminary Survey	Final Survey
Likeliness of experiencing personal satisfaction.	6.2	5.9
Our community needs good volunteers.	6.0	5.8
College student volunteers can help improve the local community.	6.1	5.7
Improving communities is important to maintaining a quality society.	6.0	5.8

might have also recognized that many clients served by their partners are not socio-economically disadvantaged and perhaps not people whom they would see as "in need."

Since team dynamics can play an important role in the success (or lack thereof) in any group project, students periodically evaluated the contributions of their group members. They rated each group member on a scale of 0 to 4, including themselves, indicating whether they were a team player, the amount of effort put forth, whether they were dependable, their intellectual contribution, and their overall contribution. Student were told that specifics would not be shared with the group members, but the instructor would be speaking with anyone who did not seem to be contributing adequately, in an effort to allow them to improve their performance. Additionally, evaluations would be considered in calculating each student's participation grade, but except in extreme cases, would not affect the project grades. The provided instructions and reminder that it is highly unlikely that everyone is excellent at everything seemed to lead students to give considered answers. In addition, they wrote a single sentence for each group member (including themselves) about their overall impression of said member's performance. These comments typically suggested most group members were pulling their weight. Sometimes their disciplinary backgrounds meant they were a stronger contributor in one area than another. For example, a student who had more accounting experience might be especially skilled at reading financial statements and explaining their contents to others who have more programming experience. This exercise, along with in-class discussions, seemed to help mitigate some of the tensions that occasionally arose with the differences between majors/backgrounds.

The final exam included questions eliciting the benefits and drawbacks of having a group project with a community partner. A few students felt the group project prevented them from learning additional course material because of the time devoted to working on the project. However, most enjoyed delving into a large and real problem. One student noted that "it exposed us to another learning method," another said through the projects students "saw applications of theory which reinforced the ideas learned in lectures," and a third indicated that "'What can I do with this class/theory?' actually gets answered." (In accordance with the IRB consent forms, student quotes are not being attributed to specific individuals.) While many people often think of the benefits of operations research first in terms of money (whether increasing profit or cutting costs), the projects helped students focus on other things that can be optimized, as illustrated in this response: "The group projects gave much more of a feel of the complexities of optimizing real world situations, particularly when profit is not the most important quantity to an organization." Other students talked about the benefits of the project being in the "real world," and of working in teams similar to their anticipated future work environments. A student summed up much of the motivation for doing the group project with community partners in the observation that "reading case studies or doing fictitious projects does not provide the same sense of urgency and rewards as doing a project for someone who can actually benefit from it." The student comments echo many of the benefits purported in literature about community-engaged teaching, including deeper understanding of course material and the ability to transfer knowledge (Furco 2010).

Most drawbacks students reported were logistical in nature, either with their group members or community partners. Frequent concerns were difficulty scheduling meetings (with or without the community partner) and having access to information. One indicated that "people bringing different backgrounds was a benefit in tackling

our project, but it was hard to balance the work and make sure everyone pulled equal weight," which led to concerns about receiving a group grade for the project (cumulatively, twenty-five percent of the final course grade). Another stated that community partners "did not fully understand the benefits and applications an OR student can provide" and had nebulous expectations, whether expecting too much or too little. Only a few students indicated a concern that the project resulted in "less time learning concepts with the professor," and most viewed the experiential learning as likely to be retained longer. Most students indicated a desire to keep this component of the course.

Just as the small sample size limits statistical analysis, the frequency of the course offering (typically once every two or three years) and the varying nature of the projects and partners limit meaningful longitudinal studies. One wonders whether such projects increase student engagement and satisfaction, possibly with positive impacts upon retention and graduation. Anecdotally, all non-visiting students in the course have in fact graduated from Southwestern, but given that the students were typically juniors or seniors, that is unsurprising. Likewise, with the variety of majors enrolled and the differences in the projects, other assessments of impacts on overall academic performance are limited. However, in the future it may be possible to determine whether there is a correlation between students' performance on exams and the specific skills and techniques used in their projects.

Discussion: CELTA, Community Partner, and Instructor Reflections

Each team met with the CELTA three times. The first meetings were primarily introductory in nature. Each group had held its first meetings with community partners and was involved in initial planning stages. The two groups working with on-campus partners both had a strong start, with detailed plans in place to find their solutions. Likely because of the connection to campus and the professor's connection to these projects, the expectations were communicated more clearly than those tied to the projects that were based off campus. In contrast, the off-campus partners had more of a vision to be interpreted than a concrete plan to be executed. Though students are often more comfortable with precise directions, the real-world experience of uncertainty and ambiguity is quite valuable.

In the second round of CELTA meetings, group members were still excited but now had some concern about partially completed projects and looming deadlines. The groups had all made substantial progress and were working on posters to be presented at a campus symposium. Three of the four groups were now experiencing more of the challenges of a real-world project, where the scope or goals can change over time. The Academic Advising group felt that some of the partner's requests were growing beyond the original requirements, but had difficulty scheduling face-to-face meetings to discuss the limitations. The Paideia group had the fewest communication obstacles, likely because the primary contact is a professor in the math department. As such, many group members already had a working relationship with her, and would often drop by her office for immediate feedback.

At this point, groups had already considered the obvious stakeholders, but were now asked to reflect further on the non-obvious stakeholders affected by their project, which can be equally important when modeling problems. The Academic Advising group had identified students and professors as the obvious stakeholders, with counseling services and parents as non-obvious stakeholders; both are concerned with students' overall well-being and stress levels, which can be impacted by advising. The Paideia group noted students as the obvious stakeholders, and considered professors as non-obvious stakeholders, due to teaching load and leave considerations. The projects with off-campus partners, not surprisingly, had different stakeholders, with interesting implications. The member working with R.O.C.K. identified the horses as a non-obvious stakeholder. While meeting the needs of obvious stakeholders (the clients, and if they are minors, their parents), it is important to ensure that the horses do not get overworked. Accordingly, group members had to familiarize themselves with seemingly restrictive regulations that R.O.C.K. adheres to concerning the number of hours a horse should work per day and needed to incorporate those into their problem formulation and

solution. For the LCC, member organizations are obvious stakeholders, and group members identified residents of Leander as non-obvious stakeholders, since each new resident of Leander receives a directory of businesses that are chamber members, and said membership confers certain credibility. In all groups, students realized that projects can have far broader impacts than initially considered.

The final round of CELTA meetings occurred toward the end of the project, while groups were finalizing their linear programs and solutions and writing their final paper. The completed project portfolio was provided to the instructor and the community partner, and each group gave a final presentation to the entire class, inviting their community partners to attend. While not all partners were able to attend, the possibility that the partner would be present ensured that students had to thoroughly motivate the assumptions made for the project and explain why they were reasonable. All groups already had experience presenting as a team from the campus symposium. Additionally, the poster presentations had increased student enthusiasm when they realized how interested their peers and faculty were in their projects. This was especially true for the groups working with on-campus community partners; students and faculty were able to ask specific questions because they were already familiar with Paideia and the Academic Advising process, which alerted members of these groups to issues with their solution that they might not have previously considered. Many group members talked about broader implications of their projects. A Paideia group representative considered optimizing Paideia to be part of the legacy he leaves behind upon graduation. The R.O.C.K. representative appreciated that the project had relevant business applications, and was excited to be able to apply the knowledge learned in the real world. Overall, group members expressed the opinion that it was a positive, albeit challenging, experience.

During the semester, morale was often correlated with the level of engagement of the community partner; groups that maintained good communication with their partner felt more positive about their projects. Communication challenges occurred with both on- and off-campus partners. While the instructor reassured students that projects could earn good grades despite incomplete partner information (with students making reasonable assumptions based on the information they did have), students naturally wanted to deliver products that met their and their community partner's expectations. Groups that believed their partner would implement the proposed solutions were more satisfied with the experience; yet implementation was not always feasible for the partner. Not surprisingly, when a community partner is more invested in a project, a group often does better work. Accordingly, in future offerings the instructor will have more up-front discussions with both the students and the partners about how to facilitate such communication and commitment.

All community partners gave positive feedback about the work completed by the students. The LCC president has benefitted from the tools (e.g. Excel spreadsheets that are easily updatable without any operations research background), the analysis from students, and recommendations from the group about plan offerings and costs. Likewise, R.O.C.K. appreciated the information and made plans to present it to their board. However, like many nonprofit organizations staffed primarily by part-time employees and volunteers, R.O.C.K. experiences frequent staff turnover; the main project contact left the organization shortly after the project was completed, so follow-up has been limited. Likewise, a new director for the Paideia program was selected from the faculty shortly before the class project was completed; she has since used the spreadsheet and tools created and has given positive feedback.

The tools for assigning advisors to advisees require ongoing updates and maintenance by people with sufficient Java knowledge to reflect annual changes such as the number of advisees an advisor currently has. In addition, since the students who need to be assigned are new each year, there is some data processing involved in converting the information students provide on a web form into the format needed for the Java programs and GLPK. Full implementation has not yet happened for various reasons unrelated to the course, but there is support from CASAR staff for eventual usage, and the instructor is willing to do the updates.

One final exam comment was positive overall about the project, but the student wished that the group had "had more time to do more." This issue of the semester-long lifetime of the project is an issue the instructor

continues to struggle with. While the deliverable at the end of the semester is expected to be useful to the community partner, often some continued involvement with the partner after implementation would be ideal. Some students may be able to continue the partnership as an independent study, allowing the community partners to have the model refined as they realize limitations, whether due to assumptions the students had to make or to factors that were not readily known in the original problem.

We believe that these projects are in fact rightfully viewed as partnerships, with students acting in a consulting role for the organizations. While there are inherent dangers in community-engaged learning programs that try to "fix" what is "wrong" with a community (Cooks 2004), the partners themselves responded to offerings of these optimization services, and they chose the problem or issue. And of course they also remain in control of how the resulting information is used. Though the instructor and students did have a role in deciding which projects were selected—which does confer a degree of power (Mitchell 2008)—choices were largely based on suitability of the problem for the course (i.e. an optimization problem, not a website redesign). The concern about developing tools without providing people and resources to maintain them long-term, paralleling the concerns of do-gooders who impose their will on others, is worth acknowledging (Illich 1968). We are up-front with the community partners about the time span and limitations, aim to provide useful tools that are easily modifiable, and typically use software (frequently Excel) that their organization already uses.

Partners greatly valued the community-engaged learning relationships with the university, but, consistent with the literature, logistics (student schedules) and communication issues are not easy to overcome (Vernon and Ward 1999). While partners were invested to some degree in the projects, the projects were not their highest priority (nor were they expected to be). The instructor can be more proactive in future years about outlining the expected time commitments and flexibility needed to both the partners when selecting projects and the students when they register for the course. Having tangible results from the 2014 offering may make it easier to solicit future projects, and partners may be more invested when they have a fuller understanding of expected benefits.

Conclusion

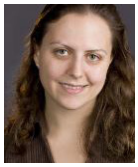
This Operations Research course was a productive and positive experience for students and community partners alike. Students benefitted from the hands-on project that required them to apply their knowledge outside of the typical classroom, and gained experience working and solving problems in a large group. The Community-Engaged Learning Teaching Assistant and instructor witnessed student learning in and out of the classroom, and they were able to educate students about community-engaged learning in general while further motivating course content. Finally, the community partners each received a solution to a problem from skilled students, which further strengthened the partnership between Southwestern University and the Georgetown community.

The instructor is committed to continue offering this course with nonprofit partners. Since ideally each project ends with a "solved" problem, partners will often differ from year to year, unlike many community-engaged learning courses which are able to work with the same partners for extended periods of time. Yet organizations may have new problems in mind that are in need of optimization, and can be partners in future offerings. Including presentations from community partners early in the semester could be beneficial, since passion about a project often leads to stronger teamwork, dedication, and enthusiasm about the experience. Though there will always be logistical challenges in courses of this nature, offering a community-engaged learning component in an operations research course is a worthwhile endeavor that results in beneficial learning outcomes and hands-on experience for students, and in tangible products for the partners.

Acknowledgments

Thanks to Dr. Sarah Brackmann, Director of Community-Engaged Learning at Southwestern University, and to the community partners and their primary contacts: Bridget Brandt (LCC), Jerry Fye (R.O.C.K.), Dr. Alison Marr (Paideia), and Kim Morter (Center for Academic Success and Records).

About the Authors



Barbara M. Anthony, (anthonyb@southwestern.edu), the instructor for the operations research course, is an Associate Professor of Computer Science at Southwestern University in Georgetown, Texas. She received her PhD in Algorithms, Combinatorics, and Optimization from Carnegie Mellon University in 2008. She is active in the computer science education community, with a particular interest in introducing students from underrepresented groups to the discipline, and finds ways to bring her theoretical computer science interests into multiple courses.

Kathryn M. Reagan, (kathryn.m.reagan@gmail.com), the CELTA for the operations research course, is a class of 2016 graduate of Southwestern University in computer science. She is currently a consultant software developer for ThoughtWorks. Her passions lie in social and economic justice and computer science education, and she loves finding ways to work within the intersection of those passions.

References

Anthony, B. 2012. "Operations Research: Broadening Computer Science in a Liberal Arts College." Proceedings of the 43rd ACM Technical Symposium on Computer Science Education (SIGCSE '12): 463–468.

Bloomfield, A., M. Sherriff, and K. Williams. 2014. "A Service Learning Practicum Capstone." Proceedings of the 45th ACM Technical Symposium on Computer Science Education (SIGCSE '14): 265–270.

Bringle, R., and M. Phillips. 2004. The Measure of Service Learning: Research Scales to Assess Student Experiences. Washington, DC: American Psychological Association.

Burger, E. 2008. Extending the Frontiers of Mathematics: Inquiries into Proof and Augmentation. Hoboken, N.J.: Wiley.

Butin, D. 2006. "The Limits of Service-Learning in Higher Education." The Review of Higher Education 29 (4): 473–498.

Cooks, L., E. Scharrer, and M.C. Paredes. 2004. "Toward a Social Approach to Learning in Community Service Learning." Michigan Journal of Community Service Learning 10 (2): 44–56.

Furco, A. 2010. "The Engaged Campus: Toward a Comprehensive Approach to Public Engagement." British Journal of Educational Studies 58 (4): 375–390.

Illich, I. 1968. "To Hell with Good Intentions." Address, Conference on Inter-American Student Projects (CIASP), Cuernavaca, Mexico, April 20, 1968.

Institute for Operations Research and the Management Sciences [INFORMS]. 2017. "What is Operations Research?" https://informs.org/About-INFORMS/What-is-Operations-Research (accessed May 27, 2017).

Martonosi, S. 2012. "Project-Based ORMS Education." In Wiley Encyclopedia of Operations Research and Management Science, J. Cochran, ed. Hoboken, N.J.: John Wiley & Sons.

Mitchell, T.D. 2008. "Traditional vs. Critical Service-Learning: Engaging the Literature to Differentiate Two Models." Michigan Journal of Community Service Learning 14 (2): 50–65.

R.O.C.K. (Ride On Center for Kids). www.rockride.org (accessed May 27, 2017).

Vernon, A., and K. Ward. 1999. "Campus and Community Partnerships: Assessing Impacts and Strengthening Connections." Michigan Journal of Community Service Learning 6: 30–37.