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Implementing Project-based Learning through University Curriculum

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The benefits of engaging students in project-based learning as part of university curriculum are becoming more widely appreciated. As a result, many universities are looking for ways to implement project-based learning on their campuses. Worcester Polytechnic Institute (WPI) has employed a project-based approach to education since 1970, requiring all students to complete at least two large projects as part of their graduation requirements. WPI faculty and leaders believe that project-based learning is transformative for students. As an undergraduate student at WPI, now in my senior year, I have been able to take part in WPI's innovative project-based approach to learning.

As a leader in project-based education, WPI offers a summer conference called the *Institute on Project-based Learning*. University faculty from around the country and internationally attend to learn more about project-based learning and to work with a WPI faculty mentor to develop a plan to implement or improve project-based learning programs on their home campuses. I attended the 2016 conference as a student observer.

WPI's Project-based Approach

The largest projects WPI students complete are the Interactive Qualifying Project (IQP) and Major Qualifying Project (MQP). Both aim to benefit society whilst teaching students to work in teams and solve problems, preparing students to make the most of their knowledge and ideas. The IQP, a nine credit hour project, is typically completed during the junior year and is usually focused at the junction of science and technology. Many students complete their IQP off-campus at one of 40 project sites located in 25 countries. Many projects are sponsored by companies or non-governmental organizations. The MQP, also a nine credit hour project, is typically completed during the senior year and is based on a student's major, similar to a senior thesis or capstone design project. In addition to these two projects, all students complete an inquiry seminar or practicum in the humanities and arts. This project is typically undertaken during the sophomore year and varies from theatrical performances to research projects in public health. A fourth project-based course is the Great Problems Seminar (GPS), offered to first year students as an optional semester-long course that includes a group project in the second half of the semester. (WPI uses a quarter system, so most courses are seven weeks long rather than a full semester.)

As a senior at WPI, I have completed a Great Problems Seminar on Food Sustainability, the Humanities and Arts Inquiry Seminar by writing a white paper on public policy to combat opiate addiction, and the Interactive Qualifying Project. My IQP was completed abroad in Moscow and was sponsored by Deloitte CIS. The project determined the criteria that graduating students from top universities in Russia use when choosing a company to work for upon graduation. The project investigated how Russian students look for jobs and

why they prefer to work in certain companies over other seemingly similar companies.

What Does Successful Project-based Learning Look Like in a University Setting?

According to Randy Bass, Vice Provost for Education and Professor of English at Georgetown University, there are four design principles for successful project-based learning in a university setting (Bass, 2016):

- learner-centered;
- networked;
- integrative;
- adaptive.

The learner-centered principle entails educating the whole person, addressing knowledge, skills, mindsets, and values (Bass, 2016). This principle strives to cultivate a balanced person, with intellectual, affective, imaginative, and reflective capacities. It should empower students and cultivate broader holistic outcomes, rather than just a traditional term paper or similar final product.

The networked principle draws on student experiences, including online learning communities which connect students across the world, helping them to virtually participate in experiential learning. This principle works to connect students (and the university campus more broadly) to the world through project-based learning.

The integrative principle entails using electronic portfolios (a fundamentally social platform) and encourages reflection.

The adaptive principle entails turning universities into learning organizations by using project-based learning as the engine for institutional learning.

> Three Kind of Knowledge

Project-based learning ideally lies at the intersection of three kinds of knowledge: knowledge of a domain, knowledge of the world, and knowledge of self (Bass, 2016). This intersection is where transformation and whole student development happen.

Project Team Dynamics, Formation, Development, and Mentoring

At the 2016 *Institute on Project-based Learning* conference, held at WPI, there was a session which focused on creating effective teams for project-based learning, Charles Morse, the Associate Dean for Student Development and Director of Counseling at WPI, and Holly Ault, an Associate Professor of Mechanical Engineering and Co-director of the Melbourne Project Center at WPI, presented the characteristics of highly effective and ineffective teams with input and discussion from conference attendees.

Some of the characteristics of highly effective teams (Ault and Morse, 2016) include:

- clear goals;
- good communication;
- active listening;
- leadership;
- members understand their roles and the roles of others;

- members support each other;
- mutual respect;
- openness and willingness to see diverse perspectives;
- shared responsibility;
- sense of equity within the group members;
- each member is willing to prioritize the team when scheduling;
- trust.

Some of the characteristics of ineffective teams (Ault and Morse, 2016) include:

- one member over functions (takes complete control);
- one or more members under function (don't contribute their share);
- power struggles between members (e.g., too many leaders);
- over- or underestimating the scope of the project;
- setting inappropriate goals;
- lack of good communication;
- blame and tension between members;
- disparity in expectations by different members of the group;
- lack of engagement, motivation, or ownership of the project;
- distractions from personal life that carry into the team;
- logistics or scheduling issues.

Project Team Selection

The Myers-Briggs Personality Types (Myers & Briggs Foundation, 2016) can help faculty to better understand how a group will likely function together. It can also help a team to better understand why group members contribute to a team in certain ways (Morse, 2016). My IQP group, which consisted of four WPI students, took the Myers-Briggs test before going to Russia. We discussed our widely varying personality types in terms of how we preferred to work. We found this helpful and I believe that this understanding of each teammate's personality type was critical to us avoiding a lot of conflict.

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For example, two of my teammates were strong "Perceivers" while the other teammate and I were strong "Judgers." Perceivers tend to be more flexible with rules and deadlines while Judgers are more rigid. This potentially caused conflict on my team when we were given a specific time to meet someone or arrive for a meal or meeting because the two Perceivers didn't mind arriving ten minutes after the agreed upon time, while the two Judgers wanted to arrive ten minutes early. Because we had taken and discussed the Myers-Briggs test, we better understood the cause of the conflict and were able to resolve it (most of the time) by agreeing to a short window around the scheduled time to arrive at.

Students should be organized into teams in a way that results in each team having a diverse set of skills (Ault and Morse, 2016). Some professors suggest considering academic ability when assigning teams – grouping a 'strong,' 'average,' and 'weak' student together. Other professors prefer to allow students to self-select their project teams, often with some guidelines that result in a diverse set of skills. Some professors

follow carefully honed guidelines when organizing project teams. For example:

- each student should have a different major;
- each team should include at least one student with experience in a specific language, computer program, and/or course;
- each group should have a variety of Myers-Briggs types;
- each group should have at least one male and one female.

Other guidelines used when assigning groups are often logistical considerations to take into account potential scheduling conflicts and student project interest (i.e., partnering students who would like to work on similar topics).

Project Team Formation and Development

At the WPI 2016 conference, Charles Morse, WPI's Associate Dean for Student Development and Director of Counseling, gave a presentation on project team formation and development. He presented on the four stages of group development (Morse, 2016):

- **Forming**: enhancing group cohesion;
- **Storming**: predictable sources of tension;
- **Norming**: "group think," team building, transforming into a productive team;
- **Performing**: group works well together, incorporating differences, to produce the desired outcomes.

In project team development, it is important to normalize the idea that there will be tension at some points (especially during the "storming" stage). It is critical for the project team

to try to address its issues and resolve tensions before the professor steps in. The professor should support the group as it figures out how to resolve its issues, but the professor should not attempt to fix the project team's issues on his or her own. Properly mentored, students struggling with tension as a project team will grow in their conflict management skills, becoming stronger team members. A team contract is often effective in helping to mitigate tensions within the team as they arise. By having each student team write and sign a contract at the beginning of the project (i.e., during the "forming" stage) that details how problems will be handled later on, students have guidelines they can follow to handle problems as they arise. In addition, hurt feelings and further tension that could arise by discussing issues are less likely because team members know what the group expectations are and the consequences of not meeting those expectations. While project teams should be encouraged to struggle a bit in resolving their own problems, it is important that professors allow and encourage teams to communicate with them about the team dynamics issues they are experiencing and how they are going about resolving them, asking for help if they can't resolve them themselves.

Tension often arises as a result of conflict avoidance. This is often a major factor within dysfunctional teams. Issues that are present within a team at the start of a project, that are "swept under the rug" instead of being dealt with, often reappear later in the project, especially as deadlines begin to loom closer and stress levels rise.

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Intervening with Under-functioning Teams

At the WPI 2016 conference, a model for faculty intervention was presented by Charles Morse, Associate Dean for Student Development and Director of Counseling at WPI. Many conference participants listed under-functioning teams as a major problem they had when incorporating project-based learning into the curriculum. Morse stressed the importance of taking a whole-team approach to intervening. His suggested model, which he uses with under-functioning project groups at WPI, first involves meeting individually with each team member for ten to fifteen minutes. The purpose of this meeting is to clarify the observations, concerns, and desires of each team member and to hear each team member's recommendations for improving team functioning. A follow-up meeting (generally thirty to sixty minutes long) is then scheduled for the entire project team to come together and discuss the areas of tension the group is facing and to develop a mutually agreed upon plan for moving ahead. The faculty member in this meeting aims to steer the conversation to a discussion of the issues the students brought up in the individual consultations. However, the faculty member should not act as the leader of the meeting. Rather, the students should steer the meeting, discussing with each other in a safe environment the problems they are having. Then they should devise an action plan which mitigates those issues with help from the faculty member as needed.

Project-based Learning as a First Year and General Education Strategy

In universities, it is normal for there to be a course or program which teaches first year students academic skills that can be widely applied, such as using the library resources, improving research and writing skills, learning to use the technology available on campus, improving teamwork skills, and more (Pfeifer and Rosbach, 2016). According to Geoff Pfeifer, an Assistant Teaching Professor in Humanities and Arts at WPI, and Derren Rosbach, an Assistant Teaching Professor in Civil and Environmental Engineering at WPI, who co-teach a first-year project-based course, this strategy helps move students from knowledge consumers (listening to a professor lecture) to knowledge producers (going out and finding information, then bringing it back to share with the class).

The learning objectives for this program are teamwork, research, writing, presenting, approaching problems, cultural awareness, and values.

WPI has found that team teaching is an effective approach to this kind of interdisciplinary course. WPI often pairs a professor from the sciences or engineering with a professor from the humanities. The differences in background and perspectives help generate discussion and varying viewpoints. To support the professors in these roles, WPI holds a summer institute where the professors hone their teaching strategies for the first-year seminar. WPI's first-year seminars are called Great Problems Seminars or GPS. They are optional courses that focus on one of the great problems facing the world today, such as food sustainability, clean water, public health or equality in education in a project-focused setting. There are approximately 50 students in each course, with each

class further split into project groups of three to five students each.

WPI has found that doing smaller, less intensive group projects in the first half of the semester in first year, before assigning the final group project, helps students to improve their skills so they are better prepared for the large project in second semester.

First-year students vary widely in skill sets, so the professors who teach these seminars use several project facilitation approaches. Some student teams enjoy the freedom to choose their own project that is within the scope of the class, with guidance from the professor on setting appropriate project outcome goals and milestones. Other student teams prefer to choose from a list of project options that the professor has provided. Still others prefer to be assigned a project to complete. However, when student teams select their own projects, they are immediately invested in the project because it is something they are interested in.

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There are a variety of self-selecting team methods that professors at WPI use. Some have students deliver pitches that focus on their final project idea. Following this, students who are interested in working on a similar project join together to form a team. Other professors have students decide who they would like to work with (based on their past experiences working with a variety of their peers earlier in the semester). Then the group works together to come up with a project

idea. There is often an overlap in how these two methods are employed.

Professors have found that having an even split of individual and group assignments in the curriculum helps them to discern the participation contributions of individual students which promotes individual accountability. In addition, team contracts help teams hold each member accountable for producing quality contributions to projects.

To promote peer-to-peer feedback, professors teaching in the WPI program have used several methods to make critiquing each other's contributions less awkward for students. One effective method involves giving notecards to randomly chosen students in the audience during project team presentations. The students with notecards give feedback to the speaker(s), emphasizing the aspects of the presentation that were strong, as well as those aspects that could be improved for future presentations. A second method that several professors in attendance at the WPI 2016 conference have successfully used is peer writing evaluation, in which each student is given another student's paper (with the student's name and other identifying information removed) to provide feedback on. This method seems to improve the overall quality of writing in the class as a whole as 'weaker' writers see the products of other students and are therefore motivated to work harder and/or seek help to improve their writing.

Rather than grading solely based on the final outcome of the project (be it a report, poster presentation, or slideshow, etc.), professors also grade the steps taken along the way. Failure is expected to occur at some points in project-based learning. This approach rewards ongoing diligence, adaptability, and growth throughout the life of the project, pushing student focus toward the process followed, rather than the final grade received, and encouraging a steady effort rather than a rushed

last-minute attempt to make the outcome match the original project goal.

What Do Students in Project-based Learning Programs Think Professors and Educators Should Do to Make Project Experiences Valuable?

On the first night of the WPI 2016 conference, a panel of three WPI students described their project-based learning experiences and answered questions from the audience. The first student was Jack Murphy ('17), a senior in Chemical Engineering who plans to complete a fifth year Master's degree program in Fire Protection Engineering at WPI. He talked about the ways he has been able to incorporate his personal interest in fire protection into WPI's required projects.

The second student to speak was Roman Gutierrez, who graduated from WPI with a Bachelor's degree in Biomedical Engineering in 2015 and a Master's degree in Management in 2016. For one of his projects at WPI, he created a device that surgeons can use when doing CCL tear surgery on dogs. The device tells the surgeon where to drill and suture, improving the chances for success in what is a difficult surgery. A provisional patent has been filed for the device. According to Gutierrez, "knowing that our projects had an impact on the world was one of my favorite things" about the WPI experience.

The third student, Katie Picchione ('16), is a Mechanical Engineering and Society, Technology, and Policy double major. As a freshman at WPI, she participated in an energy-

themed project, titled *Evaluating Biogas as an Option to Heat an Urban Greenhouse*. The project was completed by a team of WPI students for a local urban greenhouse that wanted to create natural gas out of rotting food in order to power their greenhouse. Picchione stated that this "was a hands-on project experience that set the tone for my IQP and MQP [required junior and senior year projects] and other projects I've done as part of my coursework at WPI."

When these three students were asked what they thought professors and educators should know about making project experiences valuable for students, they had several suggestions:

- Encourage student reflection during and after the project. Have students reflect on their personal and academic growth by asking questions that focus on how the project affected them (Gutierrez, 2016);
- Give students an appropriate amount of guidance based on maturity and ability. Freshman students may need specific due dates, goals, and guidance throughout the project; while senior students can set their own goals and will need less guidance to complete the project (Murphy, 2016);
- Encourage students to engage in project-based learning both as a team and individually. While project-based learning tends to lend itself to a team-based context, individual projects are also valuable and teach students about their own strengths and weaknesses (Picchionne, 2016);
- Give students the freedom to work out group issues themselves (such as one member not contributing to the group), rather than stepping in before the group has attempted to solve the problem on their own (Gutierrez, 2016).

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About the Author

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Discussion Questions

1. As an undergraduate student in university, did you participate in any substantially sized projects? If so, how did such projects benefit you? If you did not participate in university projects, do you think your university experience would have been enhanced had you participated in one or more projects? If so, how?

2. When working in teams, have you ever experienced problems with group dynamics? If so, how did you address such problems and did the group and/or leader pursue the right solution(s) given the group dynamic challenges presented?

3. In your opinion, what prevents more universities from integrating project-based learning into the curriculum from first year undergraduate on? How could these barriers be overcome?