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Project-Based Learning and Collaboration among STEM, Arts, Business, and the Community: Launch Lab Case Study

Prof. Jason Zapka, Youngstown State University

Jason Zapka is an Assistant Professor of Electrical Engineering Technology at Youngstown State University.

Prof. John Martin, Youngstown State University

John Martin is an Associate Professor of Mechanical Engineering Technology at Youngstown State University.

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Abstract

STEM students' mastery of the knowledge, skills, and abilities within the silo of their academic discipline does not necessarily correlate to their early career success. Students who have become accustomed to providing the "one right answer," solving a problem using the "one correct approach," and collaborating only with peers in their major, may struggle to apply themselves after graduation. Unlike in school, in the workforce, performance will require context for how one's work fits within the complex multi-faceted project-based goals of their organization. Furthermore, technical employees must be able to effectively communicate and collaborate with diverse experts from other disciplines, such as business and the arts. Therefore, students given the opportunity to learn through project-based learning (PBL), an integrated education that includes the arts with STEM (STEAM), as well as interdisciplinary group-dependent work, will be more successful.

Launch Lab was founded at Youngstown State University (YSU) to create enhanced project-based, multi-disciplinary learning opportunities for students while also delivering value to both the university its community. Launch lab operates an additive manufacturing makerspace that provides several students part-time jobs and services to students and faculty. Membership, participation, and funding for the Launch Lab are shared among the colleges of Business, Arts, and STEM. Each year, dozens of students participate in diverse real-world projects which have included helping a local company to design replacement parts for antique furniture restoration, applying additive manufacturing to produce metal-cast coat hooks with the university logo for use on campus, and designing an outdoor engineering display. Some students receive course credit for participation while some receive part-time wages. Project teams are comprised of STEM, Art, and Business students and faculty, and sometimes community members.

Providing students interdisciplinary, project-based learning opportunities in a university setting is rewarding, yet it can be challenging. In this paper the authors describe how YSU's Launch Lab was formed and structured. In addition, there will be discussion regarding factors that enable ongoing success and advice on overcoming inevitable challenges will be provided. Topics will include university support, leadership, funding, faculty engagement, community networking, student recruitment, project selection criteria, and student assessment. The collaborative student project work has benefited students by increasing both their problem solving and communication skills. One of the overarching issues is the continuous need for a catalyst in order to initiate the interdisciplinary work each term. In the future, the stimulus for these projects needs to be both sustainable and somewhat automatic if real growth is to take hold. The consensus of those involved feel that the Launch Lab organization is an important and valuable model for how a university can ensure the long-term career success of its students.

Background

Well-designed educational experiences involving interdisciplinary collaboration and application of knowledge to real-world challenges benefit both students and faculty as well as their educational institutions, local communities, and society [1]. The effectiveness of collaborative learning has been studied for some time, and researchers continue to find that it leads to

enhanced critical thinking [2], [3], [4]. In addition, experiential learning has been shown to increase both creative and innovative learning [5]. Interdisciplinary learning approaches have also been studied and show similar effects, including increased metacognitive skills and critical thinking [6].

Project-based learning (PBL) is a student-centered, socially interactive learning method that requires students to pursue a shared real-world goal with other participants through ongoing communication and knowledge sharing [7]. PBL helps students build higher-order thinking skills and engages them in their own learning process as they try to solve ill-defined challenges that cannot be solved by one person- they require the synthesis of skills and knowledge of the group collectively [8]. For example, Guyotte quoted a student who articulated how she perceived the benefits of PBL, "this class was more like an experience than a class, and that's how I feel college should be." [1]. PBL has been shown to be a beneficial approach to motivate learning in diverse fields including both the Arts and in Science, Technology, Engineering, and Mathematics (STEM) classrooms [8].

In recent years, pedagogical scholars are increasingly suggesting that students and society benefit from collaboration between STEM and the Arts [9], [10], [11]. The importance of creating a synergy between majors that focus on creativity and criticality, merging engineering design with the fine arts, has been emphasized [12]. The term STEAM (from STEM with Arts) is now used to characterize programs with this integration [11]. A report from 2010 by ASEE recommends that undergraduate engineering education should include training in communication, working in teams, and collaborating with non-engineers in real-world contexts [9].

Despite the growing body of literature that demonstrates the benefits of PBL and STEAM in educational settings, this remains an underutilized approach because there are numerous inherent barriers to success that must be overcome. Collaboration among persons with diverse mindsets, approaches, and definitions of success, can be challenging. There are often misconceptions and misunderstandings that arise when persons trained in STEM and those trained in the arts work together [11], [13], [14]. One common misconception that must be overcome for success is the belief that art students are creative, whereas, STEM students are not [11]. In addition, some STEAM initiatives under-value and do not engage the art participants fully, considering them to be there to simply decorate the design, rather than viewing them as equal, integral members capable of contributing to all aspects of the design and development [13]. There are also inherent differences in how art and STEM programs typically assess student success; therefore, it is critical to co-develop a rubric comprised of holistic criteria encompassing all aspects of the STEAM experience [15].

Combining project-based learning (PBL) techniques in a collaborative, interdisciplinary STEAM educational setting creates realistic experiential learning opportunities for the students involved. This type of experience could be designed to be even more rigorous than what the student would experience in many real-world instances, by challenging them to work within teams selected to include members that represent the broadest range of diversity in expertise and thinking styles. While research providing evidence on how this would directly correlate to enhanced success for students in their professional world post-graduation is lacking, it is well within reason to presume that students with skills in collaborating in an interdisciplinary project-based team would have an advantage in the workplace. Students would likely benefit from an improved ability to work with others that do not share their background, an increased tolerance when

dealing with people outside of their field of expertise, and greater skills for communicating and showing patience when working with others who lack understanding. Another perceived benefit is an increased ability to be innovative. Our Launch Lab program strives to implement and build upon the insights garnered from these researchers mentioned above to ensure the long-term career success of our students.

Launch Lab Overview

The origin of YSU's Launch Lab can be traced back to a conversation between an Art and Mechanical Engineering Technology faculty in 2008. Their discussion centered around the collaboration between STEM and Arts faculty to bring students from different disciplines together to work on interdisciplinary projects. Shortly after, the group began to use the name "Co-Lab" for collaborative laboratory. The first project with two students was completed in 2009, and since that time, there have been typically three to four projects completed per semester.

Launch Lab evolved from the former Co-Lab initiative and expanded to include Business faculty and students as well as additional facilities and capabilities from across the university. The purpose of Launch Lab is to provide students more opportunities for PBL and multidisciplinary collaboration while also delivering value to both the university its community. Faculty from within STEM, Art, and Business conceived of and then co-created the current Launch Lab structure. All three departments share leadership responsibilities equally.

The name "Launch Lab" might be imagined as one physical laboratory location, but it is more than that. It is a networked organizational collaborative mindset. Launch lab shares among a nebulous network of people, equipment, and materials that are housed in our labs, faculty members' labs, research labs as well as within other companies. The members share what is needed and house supplies in whatever location is logical for each project at the time. As plans, partners, and project needs change, our equipment and supplies change and move.

One of the priority ongoing projects is the operation of a makerspace laboratory that provides additive manufacturing services to students, faculty, and external customers. A business graduate student oversees the laboratory and other students who staff the facility (Figure 1). The lab is open to all our university students, and printing is free (up to 500g). Trained student staff members operate software and assist clients with their printing needs. Students who use our services most often are those requiring additive manufacturing to build prototypes or models for their capstone projects, entrepreneur business classes, and first-year engineering projects.


Figure 1: Launch Lab maker space with AR/VR systems and 3D printers

Participation in Launch Lab is inclusive and dynamic. The group meets weekly to discuss new and ongoing business. Attendees include students, faculty, staff, and persons from outside our university. Everyone with an interest is welcome to participate in Launch Lab projects and to attend our meetings. A few founding faculty members provide a stable core of membership while most students, faculty, and community members participate when their interests align with the scope of our currently active projects. Typically, members find us through word of mouth when they are searching for help with a technical challenge. Faculty often recruit talented students with skill sets matching new project needs.

Projects are selected based on capabilities, capacity, and current member interest. Anyone within or outside the university is encouraged to propose new project ideas to Launch Lab. Most often, faculty members approach Launch Lab for help expanding the scope of work that is in progress. Students interested in working through Launch Lab can request a mini-grant from us by completing an internal document explaining their project idea. Local organizations and companies may also suggest projects to Launch Lab. The decision to accept or decline each proposal is made by a vote from all core members.

A shared-cost operating budget funded by the three colleges and Provost's office is the primary source of funding. The Deans of the three colleges of STEM, Arts, and Business each contribute an equal amount annually with the Provost matching the funding provided by the Deans. These internal funds are not guaranteed and are subject to re-approval annually. Some projects are supported by other outside grants, while customers using our laboratory for services pay fees for the work performed. Most of the income is used to pay for student lab staff workers. Additional funds provide supplies, bring in speakers, and provide mini-grants for students' projects.

The benefits of participation in Launch Lab vary among the members. Students who work as staff supporting the services lab are paid and receive valuable work experience. Students who work on a project can receive independent study class credit. Faculty who participate are

volunteers who do not receive any direct financial compensation, nor do they get teaching release time for their time with Launch Lab. Although, some faculty may receive grant funding for work that is associated with Launch Lab projects, and some may receive teaching credit if they are the professor leading an independent study student. Community partners and businesses are also aided by providing access to equipment and expertise they may not have internally.

Example Project Results

Throughout Launch Lab's existence, there have been a variety of projects undertaken. Some of the projects have been driven by students' interest in learning more about the Launch Lab experience. Other projects have been the result of requests from student organizations, faculty members, and external parties. Figure 2 displays and the captions explain, images representing the range and scope of past Launch Lab projects. Next, the results of three recent Launch Lab projects will be shared.

Figure 2: (Clockwise from top left) mars rover prototype wheel, video gaming club trophies, robot end-effector, coat hanger, and phone charging station.

First, the engineering student honor society, Tau Beta Pi (TBP), initiated a Launch Lab project to design and install an outdoor display showcasing their organization's symbol, a large metal object (called the bent). The bent at most universities occupies a place of importance and the project goal was to relocate and create a structurally sound and aesthetically pleasing base to support and display their bent. The result was envisioned to be a showpiece both for TBP bent and Launch Lab. A team of students from art, EET, MET, and Civil engineering worked on the TBP bent relocation project. Initially, the team meetings were productive. The team successfully developed a cohesive and achievable concept design on paper (Figure 3A). Each of the members worked together well and contributed ideas from their unique areas of expertise. Unfortunately, early success did not translate into a completed project. A combination of a lack of student skills and inadequate communication between faculty and the students led to disengagement. The team is disbanded, and the design is left untested for feasibility and therefore incomplete. This highlights the need for effectively matching a student's skillset with the project requirements and effective communication throughout the lifecycle of the project.

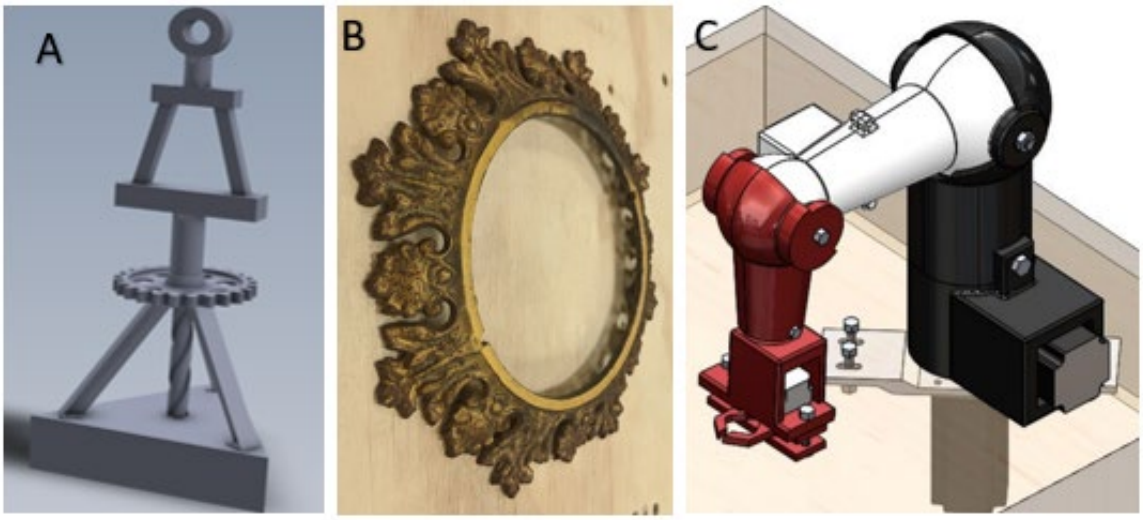

Figure 3: A) Tau Beta Pi Bent relocation project student design, B) Image of prototype 3D printed antique part replica, C) Robotic arm developed by students as an educational tool

In another project, a local business owner was assisted by producing a prototype antique part replacement for a historical restoration initiative. The company was in the process of remodeling a historic building locally and found that the antique light fixtures that were to remain as part of the exit structure we not salvageable. In this project, the outside company initiated the Launch Lab request. They brought one of the few remaining antique parts to our lab, and the team assembled used their expertise and facilities to create a 3D scan of the fixture. The scan was developed into an aluminum prototype resulting in a successful proof of concept piece (Figure 3B). The company has requested cost estimates for the production of the units needed for the completion of the renovation. Students and faculty are currently working on a cost-efficient way to produce the casting. Additionally, Launch Lab is determining the proper method for compensation for this work. Providing expertise and equipment to external customers can be an effective commercialization option. This project has commercial potential beyond this client if it is decided to expand this process to assist other persons involved in restoration projects.

A robotic arm was designed in the third example Launch Lab project (Figure 3C). The idea for this project was brought forward by a faculty member. The project objective was to create a cost-effective, functional robotic arm that would be used in outreach and education to demonstrate robotics at high schools, libraries, and university classrooms. The project was to create an arm controlled by a microprocessor and for it to be programmable so students could add more functionality as they learned about the arm. A student team of art, electrical, and mechanical students were brought together to work on this project. The group discussed the microcontroller, an aesthetic design, and how most components should be 3D printed for the structure. Overall, the project was successful as the arm looked appealing, was able to move and rotate while being controlled by a microprocessor. There were, however, shortcomings to the first project team's resulting prototype. After multiple uses, some of the 3D components broke. The range of motion is limited and could be improved with the use of gearboxes rather than belts. The aesthetics of the current prototype is not yet optimized. The first student team learned a lot and accomplished the production of a working prototype. This project may continue with a future team to further improve the working prototype which should include a business student to analyze costs for the project.

The completion rate of the projects is roughly 80%, but this is including some modifications to the desirable outcomes in order to meet the period for completion. Often the projects will involve making physical artifacts on a low budget, and this can be difficult to accomplish without an assigned dedicated support staff. Currently a project is deemed successful as long as the final product is completed or near completion by the end of the term.

Lessons Learned

Understanding both the strengths and challenges of Launch Lab is necessary to develop the framework for success in the future. Analyzing the work that has been done by Launch Lab and the strides made over the last few years, there have been insights gained that can continue to make this process successful.

First and foremost, this has been a genuinely collaborative activity where each member's opinion and ideas are given consideration. Faculty who participate tend to be cooperative, engaged, and motivated regardless of compensation. By selecting for practical projects that have a reasonable chance for success, student engagement remains high. Additionally, by employing skilled student workers, those interacting with our makerspace are likely to have a positive experience and recommend us to others.

Inevitable challenges that threaten the success of Launch Lab exist. Since there are minimal recognition and compensation incentives for many of the members, Launch Lab projects are often a lower priority relative to a member's other work. Finding the right student(s) for a project continues to be a challenging task. The group sometimes struggles to align the skillsets, interests, and availability of students with the needs of the project outcomes. With such a diverse group, communication remains an area of ongoing difficulty as well. Whether it is between members of a project team, across the various departments, or even externally, miscommunications or infrequent communications are often the critical stumbling block to success. Launch Lab members may benefit from practical training in interdisciplinary communication.

For Launch Lab to continue to be successful, the group must better define success criteria. As suggested by Herro et al., a comprehensive rubric needs to be developed that applies equally and fairly to all disciplines on a project [15]. The group needs to look inward and clearly define how success is to be measured going forward. All stakeholders' points of view need to be discussed and addressed for continued success.

Resources are also a significant concern. Funding is limited and non-guaranteed year to year which can cause some projects to be voted down or narrowed in their scope. Overall, increasing funding and securing financing for multiple years is needed to provide the economic stability necessary for long-term prosperity. Additionally, a method of compensation for faculty members should be established or we risk stunting their impact on the initiatives. Finally, the team must continue to recruit skilled and energetic student employees to ensure a smooth and positive Launch Lab experience.

Launch lab will need to look to share its knowledge and understanding more broadly to grow and expand our reach. The group is considering the development of a general education course available to all students. The course would focus on collaboration and basics of design, team building, and project management. This class would expose students to the concepts of working

with other disciplines and prepare them to participate in Launch Lab projects. Launch Lab may also conduct training seminars and invite speakers on these topics to our university.

The broader and more diverse our network of potential collaborators and partners is, the better. As Launch Lab continues to grow, the team hopes to connect and collaborate with more non-profit organizations and businesses. We could also expand to share these opportunities with younger students from local middle and high schools, perhaps through summer programming. Collaboration with other entities with similar missions as Launch Lab within other universities may be beneficial, as well as strengthening our network with other laboratories. Specifically, in the area of additive manufacturing, Launch Lab may also benefit from broadening its connections to other laboratories with complementary capabilities so that it can direct potential clients among to the group best able to help.

Commercialization of services, products, and ideas that emerge within the Launch Lab community is an untapped opportunity for revenue and benefit to collaborators and the community. Intellectual property concerns have not stifled projects to date; however, this is an area that must be considered and could become an impediment to commercialization. The team envisions working even more closely with local business incubators as commercialization becomes possible for a project.

Recommendations

Based on insights from prior research combined with the authors' own experiences, the following eight recommendations are proposed for universities interested in establishing an entity like Launch Lab:

1. Pilot with a small but diverse group of advocates

New multi-disciplinary team formation can be fragile in the early stages of formation. By starting with a small group of passionate, engaged faculty with natural abilities and skills for multi-disciplinary collaborative work with a shared vision, the likelihood of success is increased. In the beginning, it will be easier to establish an authentically collaborative culture and develop procedures, policies, scope, and norms with a small group of dedicated individuals collaborating closely. It is recommended to add new members slowly to the core founders incrementally over time.

2. Set clear success metrics

Establish metrics for success before, or early in the formation process of, the initiative. Establish a standard grading rubric that encompasses art, business, and STEM to evaluate student learning. The standards developed should incorporate the diverse expectations and skills expected in art, STEM, and business [11], [15].

3. Share leadership equally among collaborating departments

Leadership should be shared among departments. If one department is in charge, then the multi-disciplinary nature of the collaboration could be undermined. The co-leaders should be chosen, or preferably, recruited as volunteers, from those who excel at networking, openness to new ideas, emotional intelligence, and an inclination for mentoring students.

4. Procure multi-year funding

Secure funding that is protected and available for multiple years. The timing from project ideation through to completion often spans years. It can be challenging to commit to complex or longer-term work if funding is subject to sudden changes outside the group's control.

5. Provide financial or release time compensation to faculty

It is recommended that faculty who play an ongoing active role in the team be compensated. Managing external relationships, students, laboratories, communications, and conflicts requires a great deal of time and effort on the part of the volunteer faculty members. Despite enthusiasm and interest, lack of time can erode participation. Faculty could be compensated with teaching release time or supplemental pay.

6. Be inclusive

The creativity of the group and diversity in skillsets and mindsets will be enhanced if the organization is fully open, inclusive, and welcoming of anyone with interest. It is recommended any faculty or student, regardless of background or experience, be invited to participate. Inclusivity should also be extended to ideas. All ideas should be seriously considered.

7. Increase research for university-based PBL STEAM initiatives

The authors recommend that more research be conducted to study the relative effectiveness of various structures, methods, and metrics that are used to establish initiatives like Launch Lab. In the literature, there is significantly more research performed in the secondary school setting than at the university level. More studies are needed to determine the best practices for evidence-based decision making.

8. Establish Standard Intellectual Property Agreements

Finally, the authors feel it would be good practice to have a small number of varying IP agreements for the projects. The length and complexity of these agreements should fit within predefined categories reflecting the nature of the project for which they are to be used for. For instance, a lengthy convoluted legal document should not be used for small student projects, as this will turn a lot of prospective parties away from participating. These agreements should also address FERPA as well, in regards to sharing students project work in the future. Some universities have developed brief FERPA waiver forms for students projects.

Conclusion

In conclusion, there is a growing body of literature that demonstrates the benefits of PBL and STEAM in educational settings. Students at all universities and colleges would be better prepared for their long-term career success if they are given the opportunity to experience multidisciplinary collaboration and engage in PBL and STEAM learning opportunities. Launch Lab at YSU is a unique collaborative of faculty, students, and staff that foster a PBL environment among STEAM members. The authors believe that YSU’s Launch Lab organization is an important and valuable benefit to students, faculty, university, and the community. As other universities look to incorporate these ideas at their campus, they can learn from the successes and

failures of YSU's Launch Lab to develop their own PBL collaborations. With additional resources and institutions working on these goals a more consistent and effective model can be developed and assessed.

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