122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Paper ID #12499

Transforming a Computer Graphics Department from Traditional Education Methods to a Polytechnic Approach

Dr. Patrick E. Connolly, Purdue University, West Lafayette

Dr. Patrick Connolly is a professor and interim department head of the Department of Computer Graphics Technology in the College of Technology at Purdue University. He has extensive experience in the aerospace design and CAD/CAE software industries, and has been serving in higher education for almost twenty years. Dr. Connolly has a BS degree in Design and Graphics Technology and an MS in Computer Integrated Manufacturing from Brigham Young University, and a PhD in Educational Technology from Purdue University. His research interests include spatial ability development, virtual and augmented reality applications, product data and lifecycle management, and innovative classroom methodologies.

Dr. Esteban Garcia Bravo, Purdue University
Dr. Gary R. Bertoline, Purdue University, West Lafayette

Dr. Gary R. Bertoline is the Dean of the College of Technology and a Distinguished Professor of Computer Graphics Technology and Computer & Information Technology at Purdue University. He earned his PhD at The Ohio State University and was on the faculty in the College of Engineering for 3 years before coming to Purdue University in 1990. From 1995 through 2002, Gary served as Department Head of Computer Graphics Technology at Purdue University. He also served 5-years as the Associate Dean for Graduate Programs in the College of Technology before becoming dean of the college

Prof. Raymond Patrick Hassan, Purdue University

Transforming a Computer Graphics Department from Traditional Education Methods to a Polytechnic Approach

Abstract

The computer graphics department at a major research institution in the United States of America is undergoing a radical transformation involving the transition of teaching methods, classroom structure, instructor roles, and student autonomy. There are many challenges impacting this transformation, including resource allocations of time, space, and faculty/student ratio demands, how to manage both 'legacy' programs for existing students concurrently with the polytechnic program for incoming students, and how to scale up the successful polytechnic model implemented in small cohorts to a much larger group.

Additionally, the polytechnic approach focuses on skill competencies rather than the traditional course credit tracking for student achievement. A competency-based methodology utilizes demonstrated learning by the student and can be challenging due to a more open and student-driven process that allows for multiple paths for achievement. The polytechnic approach to learning emphasizes learning by researching and doing, risk taking, and the blending of liberal arts into technical subject matter and education. The faculty members involved in polytechnic instruction are active as mentors to the students, providing guidance as the students strategically plan out their own educational paths. This approach intrinsically motivates students and provides graduates that better meet the needs of industry.

This paper documents the process followed to transition from a traditional instructional unit to a polytechnic focused department, reports on the challenges encountered and overcome, provides initial results and feedback, and discusses potential plans for the future. A discussion on the concept of a polytechnic institution, its definition, and transformative nature is included to clarify the reasons behind this radical and somewhat unsettling approach to education reformation.

Introduction

Academic institutions of higher learning are facing many difficult challenges, including declining enrollment trends, complaints about costs vs. value, curricular stagnation, and inability to adapt quickly to changing environments facing graduating students. Many researchers and authors claim that the traditional educational methods and structure espoused by universities is outdated and potentially restrictive to learners. [1, 2] The College of Technology at Purdue University is dealing with these challenges also, and has chosen to address them through the use of a holistic transformation of our educational methodologies, underlying principles, and focus. The College created the Purdue Polytechnic Institute to redefine undergraduate education and provide a novel learning experience to our students. [3] Within the College of Technology, the Department of Computer Graphics Technology has elected to dedicate our efforts at reinventing our department to align with these polytechnic values. The radical changes associated with these

values include a transition of teaching approaches, and more fundamentally, teaching philosophies, classroom structure, instructor roles, and student autonomy.

The Polytechnic Foundation

Although there is no single definition for what constitutes a polytechnic approach or institution, it is generally accepted that key components of a polytechnic entity may include crucial characteristics of student mentoring, problem-based instruction, integration and collaboration of subject matter, entrepreneurship, and intrinsic student motivation. Sorensen [4] claims that

> Polytechnics are comprehensive universities offering professional, career-focused programs in the arts, social and related behavioral sciences, engineering, education, and natural sciences and technology that engage students in active learning, theory and research essential to the future of society, business and industry.

Olin College has created an engineering program based on the polytechnic approach. Specific criteria that Olin incorporated into their structure included a curriculum that was designed to be flexible and responsive to changing world needs, a focus on innovation, problem solving, inquiry, research, and entrepreneurship, and contact with students not limited to in-the-classroom experiences. [5] These combined foci of solid foundational knowledge, entrepreneurial thinking, and creativity and innovation help clarify the key elements that were chosen to build the Purdue polytechnic model in the College of Technology.

The Polytechnic Effort in the College of Technology

The 50-year old College of Technology was created with the mission of educating practitioners in emerging technologies and technology managers, to complement other colleges at Purdue University in fulfilling the Land Grant mission. The PPI will be a renewal and extension of the essence of what the College of Technology was created to be while at the same time improving Purdue's standing as a national university. According to Robinson, [6] the role of education is three-fold: develop individual talents and sensibilities (**individual**), deepen understanding of the world (**cultural**), and provide skills to earn a living (**economic**). It is essential to keep an eye on all three and promote them equally. Understanding how the three interconnect is key to transforming the education system of the 21st century. Any new educational system must address all three facets at the same time. This requires that we debunk old myths and artificial boundaries that underlie the current system. We will focus on integrated learning and learning in context. In particular, students will practice the full cycle of innovation desirability-feasibility-viability[7] throughout their studies.

Higher education has traditionally excelled at graduating STEM professionals with depth of content knowledge. While this is an important workforce attribute, business leaders find new graduates are not well equipped with the 21st century workplace competencies needed in today's business environments. It is the combination of the depth of knowledge and the breadth of

general, transferrable skills, defined as "deeper learning" that is needed to drive US innovation.[8] Wealth-driving business sectors are demanding workplace competencies such as analytical reasoning, effective communication, self-direction, and the ability to work in virtual and multi-cultural teams from new hires.

By design, PPI directly contributes to building an innovative workforce by incorporating teaching and learning methods that support "deeper learning" and the development of 21st century workforce competencies (Figure 1). Through purposeful university-industry partnerships our graduates will be technology fluent, self-driven learners. Supported by curriculum that allows for research, exploration, work-based learning, and teamwork we are creating innovators that have already been challenged to solve the ill-structured, real-world problems that industry faces.

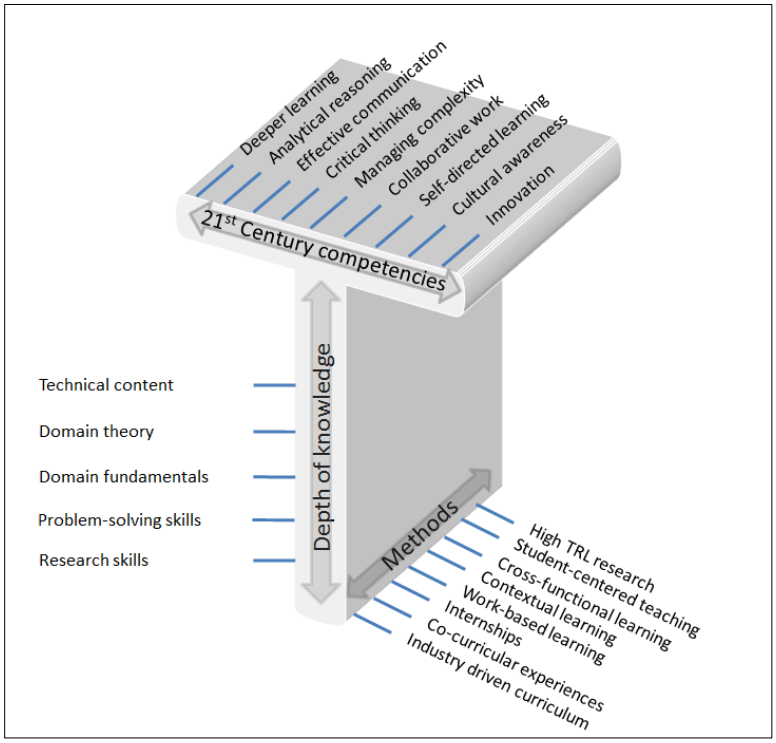

Figure 1 "T"- Shaped Professional (Image created by N. Hartman, C. Bozic, & G. Bertoline)

Creating the "T" shaped professional requires that all programs espouse both philosophical and practical characteristics of the Polytechnic Initiative at multiple programmatic levels.

In 2013, the College of Technology at Purdue University committed itself to developing a polytechnic approach to radically transform the undergraduate learning experience. The basic tenets of this effort include many of the components described in general above, such as entrepreneurial thinking, collaborative teaching environments that combine faculty from different disciplines into a holistic learning experience, and emphasizing student and faculty creativity in problem-solving experiences. However, the polytechnic effort in the College of

Technology also focuses on creating a culture of success and community, student/faculty mentoring, incorporating of industry and alumni partners, student involvement and input into the learning process, and student leadership development.[9]

A dedicated entity called the Purdue Polytechnic Institute (PPI), later renamed the Purdue Polytechnic Incubator, was created to provide an experimental 'sandbox' to test and refine polytechnic approaches and to help drive the reformation of the technology learning experience. During the fall semester of 2014, the PPI began with its first cohort of freshmen students, self-selected from departments across the College of Technology. The PPI experience incorporated combined studio and seminar experiences that provided collaborative learning opportunities in technology, programming, English, and communications, with an emphasis on project-based problems. One of the novel approaches taken by the PPI was the elimination of course-based objectives, and the adoption of competency-based goals in their place. The faculty members who participated in the PPI were released from other teaching loads and were designated as 'PPI Fellows' to highlight the considerable commitment of time and effort involved in this undertaking.

In parallel with the PPI incubator effort, the College of Technology also initiated an 'Accelerator' effort to encourage existing departments and programs in the College to begin transitioning to more polytechnic-like approaches. The adoption of both Incubator and Accelerator approaches provided a synergistic effort that required the involvement of nearly all faculty, staff, and administration of the College of Technology, and effectively hastened the transition of the College on multiple 'fronts' simultaneously. The effort to transform the Department of Computer Graphics Technology was initiated from the Accelerator efforts, but the Department was also targeted for this transition based on the creativity and forward-thinking nature of the department members.

The Polytechnic Transformation of the Department of Computer Graphics Technology

During the fall semester of 2014, the Department of Computer Graphics Technology was invited by the Dean of the College of Technology to apply to become polytechnic certified, with a goal of implementing some aspect of a polytechnic program by the fall of 2015. This action would require the department to measure itself against a list of criteria and to propose how those requirements were going to be met. These criteria included the following:

- All faculty and staff in the department will complete requisite training in polytechnic teaching and administrative development (administered by college and university programs)
- A plan will be established for faculty development and sustainability
- A polytechnic-based learning experience will be developed that will transform the existing undergraduate curricula, and will include the following components:
    - Freshman Technology Experience

    - Discipline Specific Technology Skills Program
    - Faculty-Student Connections Program
    - Technology Global Experience
    - Extracurricular Certifications
    - Internship, Co-op, or required field experience
    - Capstone Experience
    - Technology Backbone
    - Competency-based Option
    - Student-created Plans of Study
    - Integration of Math, Sciences, and Humanities
    - Business, Leadership, and Entrepreneurship
- Submittal of a plan for periodic review of all undergraduate programs every three years, to include the following:
    - Enrollment trends
    - Student Success
    - Placement and Starting Salaries
    - Diversity of the Students
    - Advisory Board Review
    - Student Surveys

It became obvious that in order for this transformation to succeed, the faculty and staff members of the department would need to be fully committed to the polytechnic principles and methods. Additionally, it became apparent very quickly that the department could not transition to meet all these criteria en masse, but that a staged approach would be required. After the faculty and staff agreed that the department collectively wanted to pursue this polytechnic status, a proposal was written to identify plans to meet the criteria. This proposal established the initial steps to be taken by the department, but was recognized as a 'living document' that would be continuously revisited and revised as progress was made in the various areas of focus.

After submitting the proposal, the next step in the process of transforming the department was to strategically break down the requirements into specific tasks and topics. The faculty and staff training, development, and sustainability criteria, as well as the periodic review requirement were allocated to the department head for planning and oversight. It was decided that the polytechnic-based learning components would be best addressed with a small team approach. These topic areas were identified as primary, secondary, or tertiary level targets based on several factors, including current department status, logical progression of initiatives already in effect, documented priorities of department and college administration, and (very importantly) faculty and staff interest:

Primary Priority Components

- Freshman Experience

- Faculty-Student Connections Program
- Capstone Experience
- Competency-based Option
- Integration of Humanities
- Entrepreneurship

Secondary Priority Concerns

- Extracurricular Certifications
- Technology Global Experience
- Internship, Co-op, or Required Field Experience
- Integration of Math and Sciences
- Business and Leadership

Tertiary Priority Concerns

- Discipline Specific Technology Skills Program
- Technology Backbone
- Student-created Plans of Study

Additionally, two other primary priority-level focus areas were identified: IMPACT/Problem Based Learning Space Planning and Undergraduate Student Recruiting. The faculty and staff members in the department were then invited to self-select onto teams for each of the identified components. Each team was tasked with identifying the following four items in the context of that challenge area:

- What needs to be Done (recommended transition)
- When It Needs to Happen (timeline and milestones)
- How to Do It (steps involved in the transition process)
- Resource Needs (people, capital equipment, training, etc.)

Progress to Date

The department has focused on the eight primary priority items to be implemented for fall 2015. Other items from the secondary and tertiary activities may also be initiated on a piecemeal basis at that time, but our initial focus is on the primary items. The teams for each of these areas are meeting on a regular basis and progress has been made in each area as explained below:

- Freshman Experience

The goals of the freshman experience in the department include retention of new beginning freshmen students as well as the development of intrinsic motivation. The overarching vision of the experience involves providing the students aspects of industry involvement, career

understanding, application of mini-projects to provide exposure, and an intellectually stimulating journey through the first year curriculum. In order to accomplish these goals, mentorship and faculty contact is crucial, which ties strongly to the Faculty-Student Connections aspect below.

The experience will build on two parallel efforts – the College of Technology initiative for a college-level commonality involving the first year foundational technology course, English composition, and communications; and the department level effort to meld the computer graphics introduction classes into studio/seminar experiences with the goal of eventually incorporating psychology and philosophy content.

A pilot study with students during the fall of 2014 of the Purdue Polytechnic Incubator introduced a program dissolving the boundaries of traditional disciplines, namely, humanities and technology. During one semester, a cohort of students was introduced to foundational concepts of English and Communications in the context of digital technologies. The integrated courses were delivered under a studio model and the students were able to explore topics of interest while earning technical knowledge. Students were very satisfied with the ability to work closely with faculty and receive personalized responses to their own self-paced learning.[10] Students felt engaged and interested on the hands-on projects, but there was not a significant evidence of whether this was caused by the merger of disciplines or not.

- Faculty-Student Connections Program

The department strives for relevant mentoring environments for all of its students. As part of this goal, the department will formalize a faculty-student mentorship program. Additionally, the department will leverage the proposed programs' focus on faculty-student and student-student mentoring. This will include peer mentoring and upper class student-younger student mentoring throughout the learning experience. Cohorts of freshman students will be formed (similar to existing learning communities) to provide collaborative and mutual support resources for every student in the department. Finally, the department will expand on the concept of faculty-student mentoring to include student-professional mentoring via interaction with members of the department industrial advisory board.

- Capstone Experience

The department currently has a semester-long senior capstone experience, but plans are in place to change that to a year-long experience. The capstone is crucially important as both the culmination of technical learning and the implementation of acquired skills in a manner that mimics the professional environment. This assists in the preparation of students to be immediate contributors in industry. One important goal is to have these capstone experiences be industry sponsored. Additionally, we would like to ensure that each capstone experience is individually relevant to each CGT student, so emphasis will be placed on project definition and development closely related to each student's area of focus. Finally, several CGT programs are forming plans for curricula that provide multiple capstone experiences on an annual basis. These opportunities

would be industry sponsored ongoing projects that will heavily leverage student-student mentoring and the principle of proximal learning.

- Competency-based Option

The department has already made significant progress in defining competencies for freshman level courses, and in establishing related badges and badging procedures. Competencies have been defined for all of the computer graphics courses, and it is expected that freshmen students master these by the end of the first year in the department. Additionally, competencies and badges have been defined for all courses in the animation major, providing the students with the structure necessary for a full competency based degree option.

The computer graphics students that were enrolled on the fall 2014 cohort from the Purdue Polytechnic Incubator, were early adopters of a pilot competency-based option. The students were successful and actively more engaged with their learning process. Instead of grades, students earned the first semester computer graphics competencies through the successful completion of challenges and projects. Each project went through different iterations, until the student demonstrated mastery of the competency. Given that the sequence of the course could be taken in any order, the instructor provided a map of challenges to complete during the semester. A map of challenges and their relation to a competency is shown in Figure 2. The freshmen students found the designated paths very useful,[11] because as new learners they had difficulties on deciding where to start.

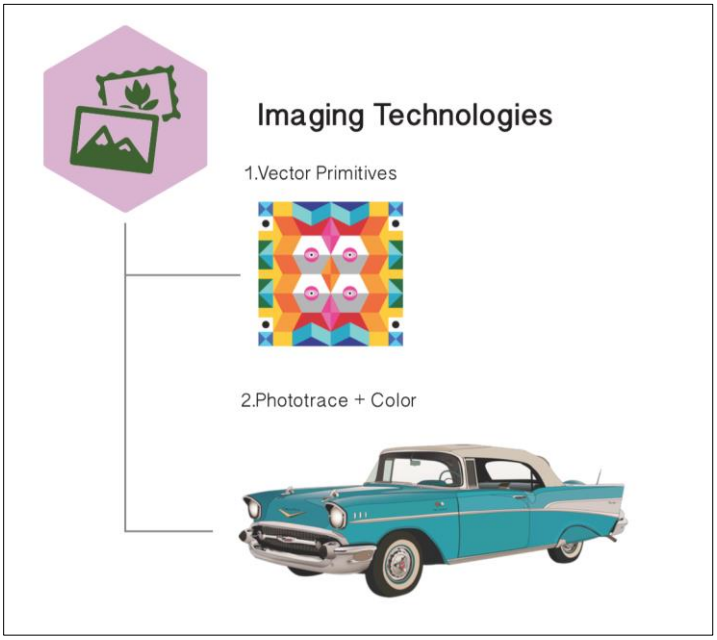

Figure 2. Map of challenges and competencies

Currently badges have been created for the animation major, each with its own unique challenges and related learning outcomes, that lead the students from beginner to expert levels in the various disciplines of computer animation. Purdue's Openpassport platform will be used to assign and manage the badges, and students from the Introduction to Computer Animation course will beta test the application in its first run. Students from this class will initially have access to the lower-level badges, which mostly correspond to the discrete disciplines of specialization within computer animation, namely 3D Polygon Modeling, 3D Surfacing, 3D Lighting, 3D Rigging, 3D Animation, and 3D Effects. Each lower-level badge links to a higher-level badge, creating a badge tree that sometimes branches and converges with other badge trees at the highest level. Most of the badge trees have four levels of mastery, beginning with preliminary, then emerging, advanced, and finally master. Their challenges have been designed with a parabolic gradation of difficulty, with the master level badges indicating a rare and unusual level of student skill, experience, and understanding of a discipline. Also one non-discipline specific badge, the 3D Pre-Pro Team Workhorse badge, has been created to award students who provide outstanding leadership or far exceed expectations in the final team-based project (See Figure 3).

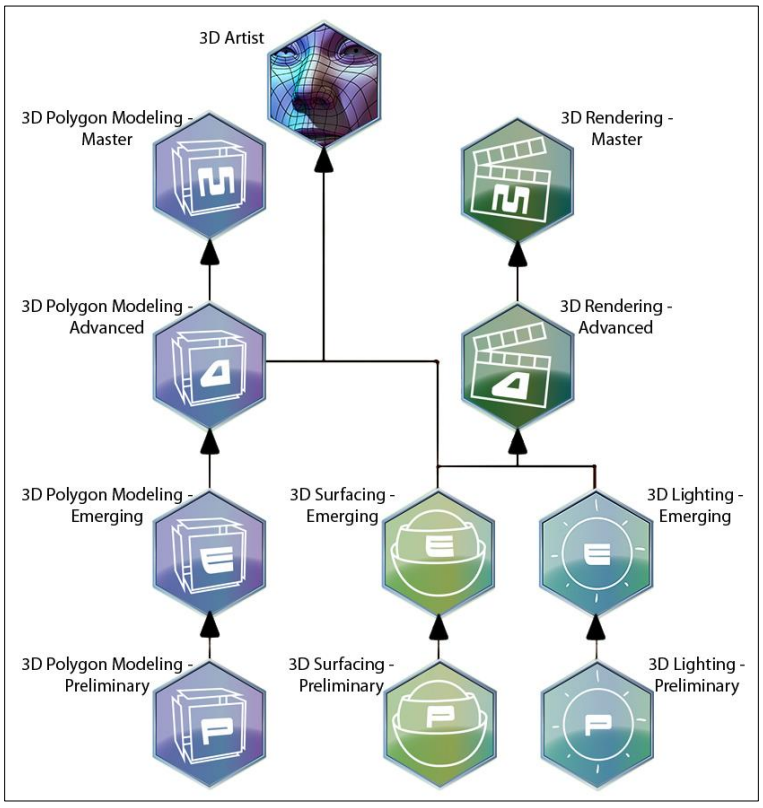

Figure 3. Animation Badge Examples

In the Introduction to Computer Animation course, assignments are given that correspond to badge challenges. Exercises 2 and 3 for example directly correspond to the Prop Model

challenge and the Character Model challenge, respectively, within the 3D Polygon Modeling - Preliminary badge. For a student to earn the badge, both assignments need to be perfect. It would be possible for a student to submit their work, earn a very high grade with only a single imperfection, and still not obtain the badge. For completion of the badge, students must be willing and able to accept critique and fix any problems, even on their best work. The idea is that this process will make their best work better, reinforce their learning, instill ownership of mistakes, and it will simulate one aspect of a working environment.

Continuing with the example of the 3D Polygon Modeling - Preliminary badge, the next badge in line for that skill tree would be the 3D Polygon Modeling - Emerging badge. The preliminary badge is a prerequisite for the emerging badge, and the emerging badge challenges are Rig-Ready Character and 3D Scene. Each challenge for this badge expands on challenges from the preliminary badge, exacting an acutely different level of time, effort, and ultimately skill from the badge seeker. These challenges however do not directly correspond to course assignments, but can still be pursued in the course via the open-ended final team project. The emerging badges would not necessarily be required of any student in the Introduction to Computer Animation course. Instead this badge and the badges above it must leverage student intrinsic motivation to be obtained.

As students progress through the courses in the animation major, they become increasingly engaged in team projects. Animation teams typically require members to have complementary skills. For example a team full of 3D Rigging expertise and no 3D Polygon Modeling expertise will never finish their character models, and their rigging skills will be wasted. It is expected that students will use their badges to identify equally skilled teammates with differently focused specializations. Thus the demand for higher level badges can be driven through both scholastic and social compulsion.

At the highest level, the master badges need not correspond with course work. Master level badges in this progression correspond with jobs, and the advanced and master level challenges either critique the entire body of a student's work or test the student's ability to produce the highest possible quality of work with the shortest possible limit of time. Such challenges strongly resemble portfolio requirements and interview tests that students will face as they begin their career. The process of earning these highest level badges should instill confidence and strong determination. It is expected that students who earn the highest level badges in a discipline should have far less trouble finding jobs.

The future of badging in the Department of Computer Graphics Technology will see interconnecting badge trees from all Computer Graphics Technology majors and course levels. Top level students may be selected to pursue a competency-only path to graduation in their major within Computer Graphics Technology, eschewing grades for refinement and perfection of project, portfolio, and concept.

- Integration of Humanities

At the department level, requirements for mathematics, sciences, and humanities will remain a critical part of the expected curricula. Initially, instruction in mathematics and science will be accomplished through traditional stand-alone courses offered outside the department. However, as this effort matures, it is anticipated that the integration of these subjects will be accomplished through means of team teaching with collaborative faculty from outside departments, as well as by computer graphics faculty with specific skillsets in the topic areas. We anticipate a much quicker integration of humanities into the experience, partially due to the success in this area by the College during the fall of 2014 in the Incubator experience. Although the pilot study did not find an advantage of teaching integrated courses, it was an important step towards the re-envisioning of the existing curriculum. The Purdue Polytechnic Incubator operated as a faculty network that explored best practices on education by deconstructing the models of traditional disciplines. This allowed for re-visioning of the traditional educational model by including co-teaching and group reflections as a core component of the experience. The integration of humanities and technology provided with a rich ground for student development. Rather than focusing only in a mechanistic approach to technology, students were able to draw parallels with their cultural contexts and provide solutions to unstructured problems.

The integration of the disciplines poses a big challenge that requires joint efforts across different colleges on campus. Thanks to the pilot study, many bridges and faculty connections were made, allowing for future development.

- Entrepreneurship

Entrepreneurship is a relevant principle in the professional world of computer graphics, and is therefore a significant component across all majors. This will be extended and increased in new majors that are being proposed in the department. Multiple courses in entrepreneurship are required in most majors in the department, often coupled with extensive project-based learning situated in simulated business environments. Several majors also utilize production studio models that enable students to bring commercial-grade graphics products to real world markets. This approach will allow the studios to become industry outsourcing partners contracted to produce digital assets for commercial enterprises. These efforts are coordinated very closely with industry partners and provide many opportunities for students to work on real world problems while interacting closely with industry sponsors.

- IMPACT/Problem Based Learning Space Planning

One exciting aspect of a transformative polytechnic approach to instruction is the emphasis on student interaction, studio-based and problem/project-based learning methods, and the strategic use of adaptive, configurable learning space. Faculty from the department are leveraging this time of transformation to provide input into the redesign of traditional computer lab space into multi-use, compute-intensive environments. Serendipitously, the opportunity to collaborate in

this space design exercise is also providing opportunities to resolve other problematic issues with computer resource allocation and capability. The faculty members are eagerly anticipating using the new instructional space as a key component of the polytechnic environment.

- Undergraduate Student Recruiting

As the transformation gathers momentum, we have been placing emphasis on recruiting and information dissemination. One of the key goals of the initiative is to provide this new educational experience to as many students as possible, and to leverage these efforts to grow our program offerings and department. As the recruiting team has met, they have committed to improving and increasing the department's Web presence; developing and advertising new majors, minors, and specializations; improving outreach efforts to high school students, parents, and advisors; and leveraging technology tools to showcase the professional fields related to computer graphics. A fortuitous byproduct of these efforts is the enhanced focus this has provided for strategic examination of our current academic programs and future plans.

Conclusion

At this point in time, much has been accomplished in the transformation of the department, yet much more lies before us. Great benefits have already been achieved as a result of reaching consensus on department strategic direction and future goals, as well as agreement on educational approaches and methods that are radically changing how we look at and provide instruction. Even in the planning and early implementation/experimentation stages, we are seeing beneficial impacts on our students. There is also a palpable level of excitement and refocusing among the faculty that has had an energizing effect on the department. Realistically, we realize there will be challenges ahead in implementation, especially in areas impacted by the 'scaling up' of polytechnic efforts and approaches to a large number of students, and in faculty members needing to 're-invent' themselves as effective educators in this new paradigm. However, we believe the potential benefits far outweigh the costs that may be accrued, and see this as a necessary and novel initiative that will establish the future of the department and college.

References

1. Barnett, R. (2013). *Imagining the University: New Studies in Critical Realism and Education*. Taylor and Francis.
2. Wagner, T. (2012). *Creating Innovators: The Making of Young People Who Will Change the World*. Simon and Shuster.
3. Mili, F., & Bertoline, G. (2013). *The PPI Curriculum: Values-driven System-level Design.* https://polytechhub.org/resources/6/download/PPI_Learning_and_Culture_11-23-13.pdf

4. Sorensen, C. W. (2006). Retrieved from http://www.uwstout.edu/about/polytechnic/upload/polypaper.pdf
5. Kerns, D. V. (2001). *Curricular Vision.* Retrieved from http://www.olin.edu/sites/default/files/curricular_vision.pdf
6. Robinson, K. (2011). *Out of Our Minds: Learning to be Creative* (2nd edition). Capstone Publishing.
7. Miller, R. K. (2010). *Beyond Technology: Preparing Engineering Innovators Who Don't See Boundaries.* Retrieved from http://www.olin.edu/sites/default/files/beyond_technology_-_may_2010.pdf.
8. BHEF (2013). Promoting Effective Dialog between Business and Education around the Need for Deeper Learning. Retrieved from http://www.bhef.com/sites/g/files/g829556/f/201303/report_2013_promoting_effective_dialogue.pdf.
9. Bertoline, G. (2013). *A Transformation Plan for the College of Technology*.
10. Purdue Polytechnic Incubator (2014). *Instructor and Student Responses to First-Semester PPI Experience*.
11. Focus Group with Polytech Students. (December 12, 2014). [Focus group]. West Lafayette, IN.