The Product Innovation Cellar: A Resource to Support Product Development in Engineering Technology

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Abstract

Recently, the Electronic Systems Engineering Technology (ESET) program at Texas A&M University has undergone a major curriculum revision. The program, once focused on producing graduates for the general electronics and telecommunications industries, now has a strong emphasis on electronic product and system development. As the faculty moves forward with this initiative, extensive effort has also been put into creating real-world product development experiences that augment the theory presented in the lectures. In fact, the curriculum culminates in a major experiential learning course sequence where students form pseudo-startup companies, brainstorm ideas for products, find funding for their ideas, and then design/implement/test a functional prototype of their product. As one can imagine, in order for students to be successful in this endeavor, they need to have access to a substantial number of resources. To this end, the faculty in ESET developed the idea for the Product Innovation Cellar (PIC) in Fall of 2010. Over the course of two years, the necessary funding was acquired and then the new facility was designed and built. Today, the PIC provides our students with a 3400 sq ft state-of-the-art facility that offers them the resources to be successful including:

- A reconfigurable development area with workbenches and lockable storage.
- A collaboration room that supports customer interactions.
- Separate prototyping areas for electronics, mechanical systems and software development.
- A part store that carries inventory for prototyping electronic and mechanical systems.
- A small breakroom.

The PIC is now a functional facility that has supported numerous capstone projects, course projects, as well as multiple offerings of the program's course on product development. This paper will present a detailed description of the PIC and discuss the many issues involved in supporting such a facility including funding, maintenance and sustainability. The paper will also present the lessons learned to date.

Introduction

As with many Electronic Engineering Technology programs across the nation, the Electronics and Telecommunications Engineering Technology programs at Texas A&M University began to experience enrollment declines in the early 2000's. As this trend

continued, the Telecommunications program dropped to an enrollment of approximately 20 students while the Electronics program reached steady state near 100 students. To address this, the faculty started looking for solutions in late 2008. Over a period of approximately three years, they merged the electronics and telecommunications programs into a single degree named Electronic Systems Engineering Technology and completely redesigned the existing curriculum.

This new program was rebranded to have a focus in electronics-based product and system development.[1] One reason for this was that product development was an excellent fit for the companies that hired the current graduates as well as for the types of positions that the current graduates were taking. But equally as important, the product development emphasis was being used successful at other institutions [2,3,4] and made for an easy way to differentiate the engineering technology program from traditional electrical engineering. To this end, the faculty worked together through several retreats to redevelop the curriculum and to include both business and engineering product development elements across the curriculum. In particular, the faculty added project-based product development experiences across the curriculum [5] as well as a dedicated course on Product Development [6] taught by industry experts from both large and small companies. In addition, starting in 2008, the capstone course sequence was changed to have a real-world, experiential-learning product development experience. The capstone course sequence now requires students to:

- Form a team of three to four students and take on the persona of a new startup venture
- Find an idea for an electronics-based product or system that meets a required level of technical merit
- Find a corporate, faculty, or angel investor
- Design and plan the development a functioning prototype for their idea
- Implement their idea by creating a professional and functioning prototype

The new program focus and name has proven to be a valuable asset for recruiting. The new program's enrollment now grows at a rate of 10 to 20 percent per year and currently has more than 170 students.

One can imagine that in order to have the types of project experiences proposed here, facilities are needed that provide students with the environment and tools necessary to be successful. While the program already had multiple educational laboratories that were accessible to the students, most of these were focused on specific subject matter (i.e., analog electronics, digital electronics, telecommunications, motors and power,…) and were heavily utilized for specific courses in the curriculum. Thus, the faculty began to look externally to see how other institutions, such as Rice and the University of Dayton, were solving this problem.[7,8] With multiple ideas in mind, the faculty set to designing and implementing the Product Innovation Cellar, or the PIC as it is now known.

This paper starts by giving the reader a brief overview of the Electronic Systems Engineering Technology (ESET) program and introduces the Product Innovation Cellar

concept. The timeline and efforts to acquire funding are then discussed as well as a general description of the facility. Finally, the methods for maintaining/sustaining the PIC and lessons learned are presented.

The Electronic Systems Engineering Technology Program

In Fall of 2012, the merger of the old electronics and telecommunications engineering technology programs became finalized and Texas A&M University recognized the new streamlined program. Then, in Fall of 2013, the program officially became the Electronic Systems Engineering Technology (ESET) program. These changes resulted in multiple advantages. First, the graduates of the new ESET program now receive a diploma with their full degree name on it. Previously, students received a diploma with the degree name Engineering Technology. Their specialization was only indicated as an option on their transcript. Second, the program name is easier to differentiate from the traditional electrical engineering degree also offered at Texas A&M. In fact, the value proposition of offering an experiential learning-based degree that prepares students for careers in electronics-based product development has proven to resonate well with both transfer and freshman students. Finally, the new emphasis meshes well with the faculty's interest in introducing students to entrepreneurship. Currently, products being developed by student teams are occasionally acquired by industry for commercialization and have even resulted in graduate-led startup companies.

The new ESET curriculum has three primary technical tracks. These include analog/digital electronics, communications, and embedded systems hardware/software. In addition, the curriculum has several system-level courses including instrumentation, controls, as well as two technical electives where the students have the opportunity to integrate their technical knowledge through project-based learning. Finally, a product development emphasis is included through several courses such as electronics test, engineering statistics and six sigma, product development, and the capstone course sequence. These courses are focused on bringing both engineering and business-based product development concepts into the curriculum.

Finally, as part of the ESET curriculum many courses now have open-ended projects that require students to work in teams and implement electronics-based solutions. In addition, the capstone course sequence requires student take an idea for an electronics-based product to a professionally designed and packaged prototype. Early in the curriculum development process, the faculty recognized the need for a new "laboratory" environment to support this new educational paradigm. Unlike typical electronics engineering technology laboratories that are dedicated to teaching one specific set of topics during set lab times, the ESET students needed access to a dedicated environment where they could collaborate in an open environment and that could supply the tools and mentorship necessary for them to be successful. The new Product Innovation Cellar discussed below is exactly this resource.

Product Innovation Cellar Concept

To support the new product and systems development focus of the ESET Program, the faculty wrote a proposal for differential tuition funds to renovate an area in the basement of Thompson Hall. Being in the basement, the obvious name for the new facility had to be the Product Innovation Cellar. The "cellar", shown in Figure 1, branding was well received by both ESET students and faculty and provides the ambiance of the Hewlett and Packard "garage" or two good ol' boys going down to the basement and tinkering until they develop a new invention.

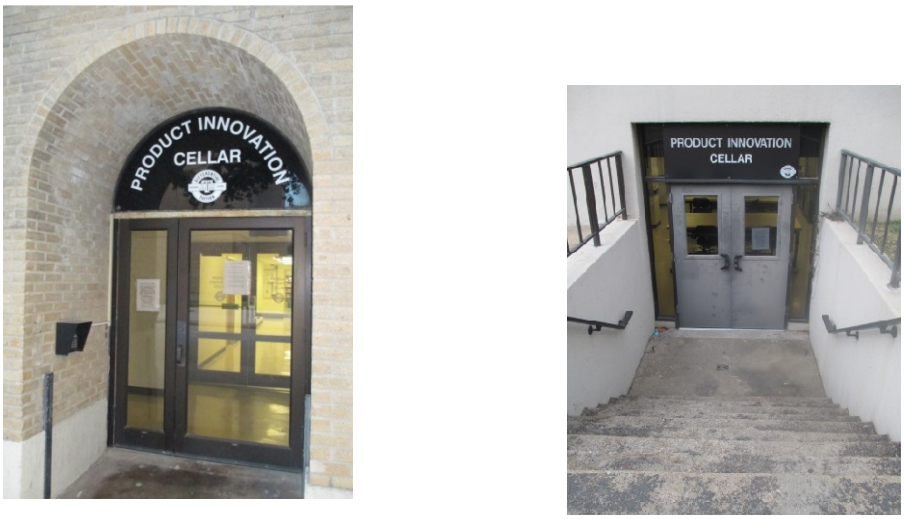

Figure 1 – The entrances to the Product Innovation Cellar (PIC).

Once the name was created, a mission statement was needed to tell others about what the PIC is and how it would add value to the University. The current mission statement is:

To support and encourage innovative multidisciplinary product development and entrepreneurial activities for Electronic Systems Engineering Technology students and faculty

The overall concept of operation is that the PIC is available to authorized teams on a 24/7 basis. Prior to receiving access authorization, each student agrees to two fundamental operational principles:

- Always conduct themselves as an adult and professional engineer.
- Always leave every resource better than they found it.

After more than a year of operation, the facility has remained in excellent condition based solely on the students conforming to these two expectations. Part of this success is the level of ownership that the students have assumed and the value they place on having this unique resource within their educational program. In addition to supporting student teams that behave as startup companies in transitioning a problem to working prototype, the PIC is also a focal point for perspective new student tours and introducing public and private sector guests to the ESET Program and its Capstone and applied research capabilities.

Timeline and Funding

In 2010, prior to the merger of the programs, the faculty realized the need for a facility that would allow students to collaborate outside of normal laboratory space and hours. In addition, it was clear that the course and capstone projects had outgrown the capabilities of the tools available within the program. Thus, the faculty worked as a team to conceptualize a new facility that could meet the growing needs of the student body. From this process, the PIC was conceptualized. With an idea in mind, two faculty members worked to develop a preliminary design and budget.

Prior to beginning the design process, the faculty members visited design facilities recently stood up at peer academic institutions. These included the Oshman Engineering Design Kitchen at Rice University and the Innovation Center at the University of Dayton. Through this process, best practices were gather and used as input to the design process. Other inputs included the identified needs by the faculty and included:

- an open and reconfigurable area where students could interact as teams, teams could also interact with each other, large presentations could be made, and occasional lectures could be given
- mechanical and electronic fabrication facilities
- a collaboration room where student teams could interact with industry and faculty both in person as well as remotely
- a parts "store" where students could purchase supplies needed for development purposes

Finally, the ESET facilities were examined to identify space for the new facility. As is typical at most institutions of higher learning, the ESET program, and more importantly the Department of Engineering Technology and Industrial Distribution was space constrained. Through creative reconfiguration, the design team identified approximately 3400 sq ft of contiguous space that included the original capstone design lab, an educational lab that supported digital design, and an ESET faculty member's research lab. By moving the faculty member to a new research space and doubling up the digital design lab with an existing freshman lab facility, the design team was able to acquire the necessary floor space needed for the PIC.

Using the space and information discussed above, the design team created a floor plan (Figure 2), equipment list, and preliminary budget. As originally conceived, the PIC required approximately $300k for completion. Several options were originally pursued for funding including external donor support, industry named laboratory support and internal university support. Fortuitously, the College of Engineering had just instituted a new differential tuition policy and was soliciting the first call for proposals. Through this call, the design team received $200k to begin development of the PIC in Fall of 2011. This funding was sufficient to support all building renovations as well as the purchase of all needed furniture and some of the equipment.

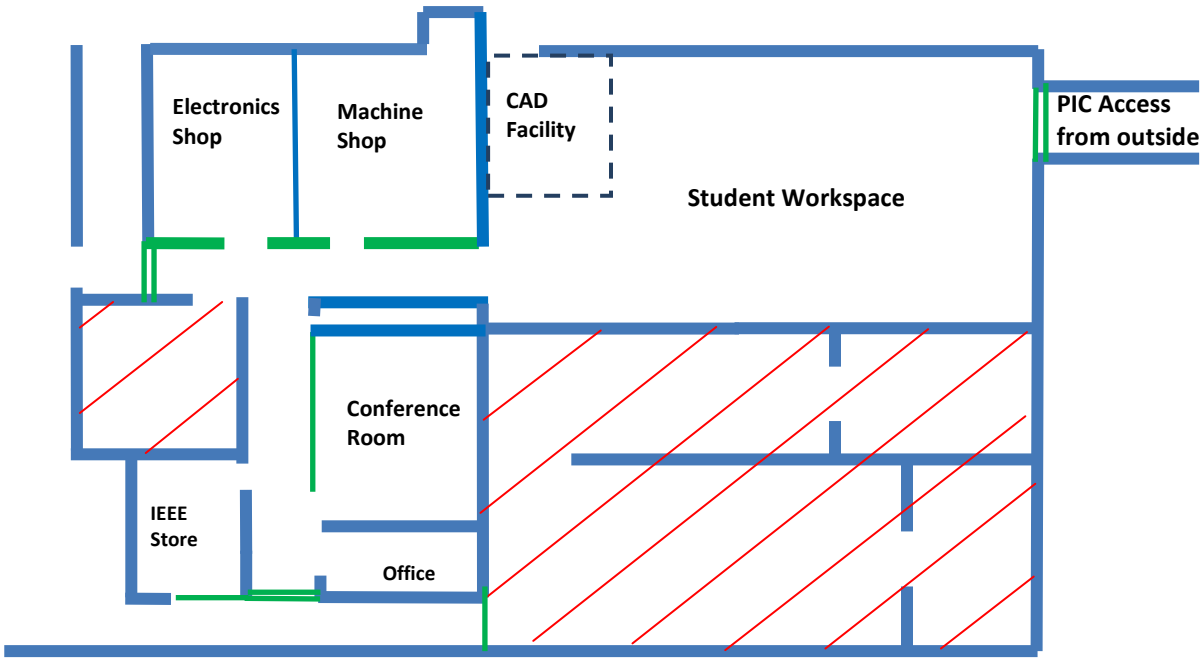

Figure 2 – Conceptual design for the PIC. Double green lines indicated doors and single green lines indicated glass walls.

With support in hand, the design team began soliciting bids for the construction and furniture. One issue that was almost immediately encountered was a requirement to set aside twenty-five percent of the renovation budget for Americans with Disabilities Act (ADA) compliant construction. Because the building that would house the PIC was extremely old, the construction company required the entire amount for compliance renovations. Fortunately, a request to have the Provost cover these additional costs was granted. Thus, the initial funding was sufficient to start the project. The balance of the needed funds ($100k) was eventually covered through an internal program, again funded by the Provost, to fund activities that promoted innovation across the University.

The actual renovations were started in Fall of 2012. Over a period of four months, the construction was completed, the furniture delivered and initial equipment purchased. Starting in January of 2013, the PIC was first opened to support undergraduates in ESET. Initially, the PIC supported specific capstone design projects and the laboratory for the Product Development course. Now, over the last year most of the equipment originally envisioned has been purchased. To date, the facility has supported approximately fifteen capstone projects, multiple course projects in ESET courses, the teaching of the program's product development course, and a new University-level course in product innovation and startup company methodologies.

Facility Description

The PIC is a 3400 sq ft facility housing five functional areas and three support areas. Since the facility was opened in January 2013, approximately fifteen student teams have used the PIC in achieving their design and development goals.

The five functional areas include the open development area, the design suite, the mechanical fab, the electronics and testing fab, and the industry collaboration room. The development area shown in Figure 3 is open space that is highly reconfigurable as to work tables and whiteboards. Each workspace easily accommodates a four person team. When testing, demonstration or other activities require more than the 4'x4' workbench, multiple benches can be readily combined to form large work areas. The intent of the development area is cross-disciplinary interaction and sharing between teams. The open area also promotes group problem solving. In addition, locking/rolling cabinets are available to give teams secure storage while they are resident in the PIC.

Figure 3 - PIC Development Area.

The design suite shown in Figure 4 supports electronic hardware design, mechanical design and software design activities. The computers in the design suite are loaded with professional-level design software that complements and extends the entry-level version of software that exists on student laptops. For electronic PCB design, schematic capture/simulation//testing/PCB layout software includes NI's Multisim/Ultiboard, EagleCAD and Altium. For mechanical design, the PIC design suite boasts SolidWorks, ProE, and Autodesk. The embedded software development systems include Microchip, TI, and Freescale microcontroller environments.

Figure 4 – PIC Design Suite

Because teams using the PIC do not stop at the design phase, the PIC provides the ability to transform mechanical designs into real physical hardware overnight. Using the mechanical fab depicted in Figure 5, the teams can produce mechanical assemblies and customized enclosure in short period of time. Reducing the turn-around time and costs on the mechanical aspects of the project improves the probably of success. The mechanical fab currently includes a 3D printer (plastic), a 75W laser etcher/cutter, a 3-axis CNC router and over $3400 in associated hand and power tools. Literally overnight, the team can transition a design into a viable and testable part. For safety reasons, this is the only area that is not 24/7 accessible and students must use a "buddy system" when in the mechanical fab.

Figure 5 – Mechanical Fabrication Facility

Analogous to the mechanical fab, the PIC includes an electronics fabrication, assembly, and test area shown in Figure 6. The electronics fab area of the PIC facilitates the

transition from hardware design to two-sided PCB manufacture. Additionally, templates can be generated, solder paste applied, parts can be placed using a manual pick and place machine, and then the PCB can be baked using a PCB oven located in the electronics fab. High-end test equipment benches are also available for the students to verify and validate their designs with a populated PCB.

Figure 6 – Electronic Fabrication Facility

Most projects are now sponsored by the public and private sectors. Unlike most universities, Texas A&M is not located near major commercial/industrial areas. To support high-quality interaction between the PIC development teams and their customers/sponsors, the PIC also includes an Industry Collaboration Room as shown in Figure 7. This resource provides the teams with high-resolution, internet video conferencing capability where the camera system can be controlled by the remote user to pan/tilt/zoom as needed to interact with the teams as they make presentations or conduct demonstrations. Having a SmartBoard and large screen monitor with associated wireless technology for mouse, keyboard, microphone, speaker, etc. make this a valuable, useful and professional asset for interaction and communications. The room is also used for the teams to deliver weekly status reports to their stakeholders.

Figure 7 – Industry Collaboration Room

These five functional areas are augmented by three support areas: 1) break room, 2) parts store, and 3) supervisors office. Because the PIC is accessible 24/7 by authorized team members, the facility includes a break room. This area provides a refrigerator, microwave, coffee maker and other appliances that can be used by students to store and prepare food and beverages. Food can only be consumed in this area, and students must clean the area after each use. As this is of real value to students, they have been very responsible in its use and in ensuring it is left better than they found it.

The part store is operated by the IEEE-TECH student professional society and includes a service window to an external hallway where electronic parts and kits can be sold to students. In addition, the parts store has another door that is inside the PIC. Authorized teams can access the parts store from this entrance. The ESET Program is currently working with a number of vendors to establish bins for parts, modules, and development kits. These resources would be free to the PIC authorized teams. The PIC would maintain a log of what parts were used by what teams and the bins would be replenished on a quarterly basis.

The final support area is the supervisor's office. The ESET Program uses this office for graduate or student workers who will spend time in the PIC and assist teams in the use of the equipment. The entire facility is also monitored by cameras which periodically record pictures of the five functional areas.

Maintenance and Sustainability

The PIC was created by renovating an underutilized space in the basement of Thompson Hall and furnishing and equipping it using differential tuition funds that are paid by the Texas A&M students in the ESET Program. However, on-going operational costs necessary to maintain and sustain the facility long term will need to be funding from other sources. The ESET Program is using a number of different funding sources to accomplish these goals. Of these, funds that were received from a proposal made to the National Collegiate Innovation and Innovators Association were leveraged to create a small endowment that provides continual funds at the initial stages of operation.

Another method that worked well is the assistance of student teams in maintaining the PIC. Student teams have been given responsibility for a piece of equipment or fabrication asset. The team then prepares user guides and operational instructions on the proper operation of the equipment. The team also acts as a technical reference for other teams so that all of the equipment is operated and maintained correctly. This knowledge and responsibility is then passed down from team to team in subsequent years.

A major source of operational support for the PIC now comes from the Capstone Project grants that are provided by the industry sponsors. These funds allow the purchase of raw materials such as the 3D printer plastic stock. Other operational costs such as cutting tools, test equipment leads, etc. are also provided through these funds.

As mentioned previously, a new source of support will be the bench stock bins being set up by a number of companies that see the value in having students working on the development of real prototypes use their products. Finally, the ESET faculty is working diligently to create a naming opportunity that would secure a new, major endowment for the PIC. Having such an endowment would result in the PIC being named for the donor. These funds would provide for long-term operation of the PIC and the ability to fund a wider range of projects. Projects such as quality of life or supporting the first responder community could be undertaken through the support generated by the endowment.

Lessons Learned (Morgan/Porter)

Though the PIC has only been in operation for approximately one year, several lessons have already been learned. These include:

- Undergraduate Intellectual Property: As part of the work done in the Capstone course sequence, various methods have been tried concerning student intellectual property. Originally, all students were asked to voluntarily sign an agreement that would allow their contributions to be handled by the University's Office of Technology Commercialization. The idea behind this was so that students, faculty advisors and graduate student assistants could be listed as co-inventors and share in any royalty streams that might be generated in the Capstone process. This, however, proved to be a cumbersome process that, in general, did not produce any significant wins. Since then, the process has changed. Now every student team must only demonstrate that they have reached an intellectual property agreement with all of their stakeholders (faculty advisors, team members, industry, and others). Quite often, this agreement is simply that the student team owns all of their intellectual property. However, periodically industry and faculty stakeholders choose to work with the team to share the IP, especially when the ideas belong to someone other than the student team. One thing to note is that many of the faculty involved with student teams choose to assist (sometimes creating intellectual property) them altruistically, without any desire to have IP ownership.

- Inadequate space: When the PIC was first envisioned, the 3400 sq ft seemed more than sufficient. However, over the past year the usage has grown substantially. With the facility supporting capstone as well as four separate courses, in is clear that the amount of space may soon be insufficient to support all of the necessary activities. In particular, with the College of Engineering's 25 x 25 initiative enrollment may soon outpace the size of the facility. Fortunately, there is some opportunity for future growth. The PIC currently sits adjacent to a little utilized classroom and as such there may be room for expansion in the near future.
- Value of publicity: Soon after the PIC officially opened, an article was written by the College of Engineering. Based on this article, this faculty from across the University as well as various companies showed an interest in working with faculty and students to use the PICs resources. In fact, a student incubator on the A&M campus, Startup Aggieland, and a new incubator being stood up within the region have demonstrated an interest in working with the PIC to support entrepreneurs who need help developing technology
- Importance of good planning: The design team that designed the PIC put substantial effort in developing detailed construction plans, furniture/equipment purchases, and project budgeting. While this initial planning phase took a substantial amount of time, the investment was invaluable. It was through a detailed, documented plan that the faculty was able to convince the College and the University to invest in the project. In addition, once construction started there were no significant issues that impeded the build-out of the PIC.
- Value as a recruiting resource: A serendipitous value that the PIC provides to the ESET Program is it has become an outstanding recruiting tool. Texas A&M University receives a large number of students and their parents during activities like Aggieland Saturday. Being able to take these visitors on a tour of the PIC and show them the type of projects they will be doing during their senior year in ESET is a far better recruitment tool. Both the students and parents can visualize the content and value of the education through the resources that are contained in the PIC and scope of customer problems that are addressed through the Capstone and applied research projects undertaken by ESET undergraduate students.
- Forum for education and knowledge sharing: The PIC also provides a venue for education and knowledge sharing. Private and public sector guests and visitors like "hanging out" in the PIC and interacting with the design and development teams. Whether in small groups in the Collaboration Room or larger groups in the Development Area, impromptu and planned experiential learning opportunities have become the norm.
- Usefulness as a college prototype: Shortly after the program began the development and construction of the PIC, the College of Engineering began looking at a large scale facility that could support freshman engineering courses and multidisciplinary projects. Due to the success of the PIC, the college's design team used the PIC and its design as a starting point for the new Engineering Innovation Center (EIC). Through this

methodology, the College was able to benefit from lessons learned and accelerate the design of the EIC.

- Limitations of no technician: Originally, the PIC was envisioned to be a self-sustaining entity, supported by ESET faculty and students. However, over the past year, it has become clear that while the concept is functional, it could greatly benefit from a dedicated technician. Currently, the use of equipment is supported by training videos. While this works, a live technician could reduce the overall learning curve for faculty and students, as well as provide a single point of contact when equipment issues arise.

Conclusions

To support the ESET Program's emphasis in product and system development, the Product Innovation Cellar (PIC) has proven invaluable. With the curriculum's strong focus on experiential learning, the use of project-based learning and immersive, real-world experiences is critical. The PIC has enabled these activities by providing the students with the environment and tools to be successful. Just in the past year, the PIC has supported approximately fifteen capstone design projects, three separate course projects, and the teaching of a course in Product Development.

In addition, the PIC has demonstrated its usefulness in promoting multidisciplinary activities, a key ingredient in the College of Engineering's and University's mission. First, the PIC has supported the interaction between faculty and students between multiple engineering programs. For example, one of the current ESET capstone projects is an industry sponsored project that has brought together students from both the Electronic Systems and the Mechanical/Manufacturing programs. Second, the PIC also supports an ongoing interaction between faculty and students across multiple colleges. A new University course in product innovation and startup company methodologies is being taught by faculty from engineering, business, and architecture. The PIC supports the laboratory component for this course.

Finally, the PIC has proven to be an excellent recruiting tool for both industry and students. Based on a tour of the PIC, several new companies have begun sponsoring student capstone projects. Similarly, through tours of the facility, new and prospective students have demonstrated an interest in electronics-based product development and expressed a desire to pursue their college degree with the ESET program.

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