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## Creating a High Impact Learning Environment for Engineering Technology Students

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### ABSTRACT

This paper discusses an initiative called Product Innovation and Development (PID) that was launched at Texas A&M University. The goal of PID is to create a high impact learning environment that focuses on innovative product development. Undergraduate students are hired to develop innovative new products. The student teams generate ideas for new products, conduct market analysis, design and manufacture the product, sell the products, and provide technical support to the customers. It is intended that the PID projects generate revenue and become self-sustainable in the future. To maximize the impact, project materials are being used in various courses to enhance the curriculum. Project examples are presented to illustrate the PID process. Student learning is evaluated through surveys distributed to different groups of students who received potential benefits from PID.

**Key words:** Product development, Bloom's taxonomy, Philosophy of engineering education

### INTRODUCTION

A typical engineering technology curriculum in a higher-education institution in the United States contains common body of knowledge (CBK) courses followed by technical courses in a specific major. In most programs, students do not have an opportunity to work on real-world projects that involve every aspect of the product development process until the capstone/senior design courses in their senior year. Due to the lack of experience with real-world projects, many students majoring



in engineering technology have trouble understanding the gap between the material they learn in class and their expectations of engineering [27, 39]. This could contribute to the high attrition rate among engineering technology majors.

To improve student learning and lower the attrition rate, Texas A&M University invested heavily in seven activities [34]. These are:

1. Enhance the students' preparation for the workplace and society through high impact learning;
2. Develop integrated interdisciplinary experiences for students;
3. Enhance the core curriculum outcomes and elements through technology and distance education;
4. Enhance the opportunities for colleges to allocate credit by exam or credit for demonstration of competencies;
5. Enhance the outreach to PK-12 and community colleges in order to improve college readiness;
6. Enhance faculty development in high impact, non-traditional, deep learning pedagogies;
7. Enhance support for graduate students.

The majority of the funding was directed to Activity 1, where the main objectives are to enhance students' preparation for the workplace through high impact learning and advising for progress toward degrees. After realizing the importance of a high impact learning environment for providing engineering technology students with product development experience in the real-world setting, the Department of Engineering Technology and Industrial Distribution (ETID) submitted an Activity 1 proposal to the Provost's office and received funding for three years from 2012-2015 [38]. The establishment of the Product Innovation and Development (PID) initiative, funded by Activity 1, was presented in [38]. This paper presents the completed work, evaluation results, and analysis. Section II discusses Bloom's taxonomy of student learning, high impact learning, and the PID initiative. Section III contains examples of PID projects. The impact of PID on curriculum is discussed in Section IV. The evaluation of student learning is presented in Section V. Section VI contains the conclusions and further discussion.

### HIGH IMPACT LEARNING AND PID

Bloom *et al.* introduced the concept of taxonomy for student learning [2, 4-6, 8]. They categorized student learning into six levels, from basic to advanced: Remembering, Understanding, Applying, Analyzing, Evaluating, and Creating. Remembering is being able to recall relevant knowledge from long term memory. Understanding is being able to make sense of what one has learned. Applying



is being able to use knowledge learned in new ways. Analyzing is being able to break the concept learned into parts and understand how each part is related to the rest. Evaluating is being able to make judgements based on a set of guidelines. Creating is being able to put the learned knowledge together in an innovative way.

While remembering and understanding the materials taught in class are crucial first steps in learning, it is critical that students have opportunities to apply, analyze, evaluate and eventually create their own design. These latter steps offer the student a chance to learn more in-depth and make an engineering technology major more attractive. While successful implementation of Bloom's taxonomy can be found in engineering majors [15], traditional teaching methods used in engineering programs have their limitations in higher learning levels in the categories of apply, analyze, evaluate, and create [34]. Many courses in engineering curricula are too theoretical and do not provide enough real-world perspective. Educators are aware of this problem and proposed many new pedagogical approaches, such as problem-based learning [1, 29], project-based learning [22], collaborative learning [21], process oriented guided inquiry learning (POGIL) [23], and peer-led team learning (PLTL) [14], to improve the situation.

To promote higher level student learning, Kuh proposed high impact practices (HIPs) work [18] in 2008. HIPs include first-year seminars and experiences, common intellectual experiences, learning communities, writing-intensive courses, collaborative assignments and projects, undergraduate research, diversity and global learning, service learning/community-based learning, co-operative education/internships, and capstone courses and projects. Since 2008, many researchers conducted research in this area [8, 13, 16, 19, 20, 26] with promising results.

There are similarities between high impact learning practices and project-based learning; for instance, both emphasize experiential learning [22]. However, high impact learning is broader in the sense that it is not limited to traditional courses. Some of the HIPs, such as common intellectual experiences, learning communities, collaborative assignments and projects, and undergraduate research, can be effectively applied to engineering programs to provide intensive learning experiences for students. In addition to learning, there are other benefits from HIPs, such as retention rate improvement.

While HIPs have proven effective in improving student learning in various aspects [8, 13, 16], specific majors still face implementation challenges. One of such challenges is funding the implementation of HIPs. This is more so the case when the HIPs are not part of the curriculum. The Department of ETID received a seed fund from Texas A&M University to start the PID initiative to create a high impact learning environment. The challenge is for PID to become self-sustainable.

Four ETID faculty members formed a committee to look for a way to implement some of the HIPs. After an initial evaluation, the team decided that a focus area must be selected to create a



high impact learning environment. The selected focus area must be appropriate for the unique ETID structure, the student body, faculty, and the available resources, as well.

### **ETID programs, faculty, and students**

ETID is one of the fourteen departments in the College of Engineering at Texas A&M University. The department had three programs: Manufacturing & Mechanical Engineering Technology (MMET), Electronics System Engineering Technology (ESET), and Industrial Distribution (ID). A new program, Multidisciplinary Engineering Technology (MXET), has been created recently. The focus of the department is undergraduate education: there are four undergraduate programs, one master program, and no doctoral program. ETID offers courses in electronic, mechanical, manufacturing, mechatronic, and industrial distribution subjects. The courses offered by ETID are similar to courses offered by the Mechanical Engineering, Electrical Engineering, and Industrial Engineering departments, but with more emphasis on hands-on learning. Before the creation of the MXET program, due to the nature of the programs, there was almost no interaction among the three programs within ETID. The department was like a small college consisting of three sub-departments.

The majority of ETID faculty members have doctoral degrees in engineering or management science, and many of them have industrial experience. Many faculty members have connections with industry and are interested in conducting applied research sponsored by industry.

The department has about 1500 undergraduate students. Most of them are more interested in hands-on experience than in theoretical work. The vast majority of ETID graduates find jobs in industry. They typically work as application engineers, field engineers, test engineers, operations, and technical sales.

### **Selection of the focus area for HIPs**

Because of the close ties ETID has with industry, the department is constantly seeking feedback from industry to enhance the curricula. One such feedback from all three programs' industrial advisory boards was that the students' knowledge and skill in product development must be strengthened. For companies to stay competitive it is necessary to have a rigorous product development process and the employees must know how to follow the process [25, 31, 32]. After reviewing the feedback from industry and the current curriculum, ESET faculty realized that there was a significant gap between what students learn in school and what they would face in an industry setting [27, 37, 39]. To reduce this gap, the ESET program revamped the curriculum to shift the focus to system and product development [27]. New courses in product development were created and the program name was changed from Electronic Engineering Technology and Telecommunication Engineering Technology to ESET. The MMET program also made similar changes with more product development related courses.



The faculty committee responsible for creating high impact learning environment reviewed the literature in the product development process [3, 7, 10-12, 24, 25, 31, 32, 35, 36]. They found that early exposure to the product development process and tools was effective in introducing the product development process [6, 33, 36, 37]. Familiarity with product development processes is also critically important for entrepreneurship, a major interest area for engineering technology students [7, 9, 17, 28]. In particular, the successful incorporation of entrepreneurship and product development in engineering technology curriculum by Birmingham *et al.* [7] was an inspiration for the faculty committee. After reviewing literature and considering the multi-disciplinary nature of the department, the faculty committee made a decision to focus on multi-disciplinary product innovation and development for creating a high impact learning environment for students. The HIP activities were determined to have the following characteristics: student-centered, multi-disciplinary, high impact in breadth and depth, innovative product development, and long term self-sustainable. This effort was named as the Product Innovation and Development (PID) Initiative.

#### **PID mission, organization, and process**

The mission of PID was established first:

*The mission of the PID Initiative is to provide a high impact and experiential learning environment for students to develop skills and interests in product innovation inspired by real-world market needs. The goal is to educate Texas A&M University students to be capable of leading successful product and service innovations.*

The organization of the PID Initiative is as follows:

*Steering Committee:* consisting of the ETID program directors. The steering committee provides general guidance in the direction of the PID initiative and determines the short-term needs for financial support before PID becomes self-sustainable.

*Working committee:* consisting of four ETID faculty members, and each program has at least one representative. The committee chair is rotated each year among the faculty member representing each program.

*Faculty advisors:* consisting of faculty members with technical expertise and interests that match the specific PID projects. The faculty advisors are not permanent roles, instead, they are selected yearly based on the PID projects.

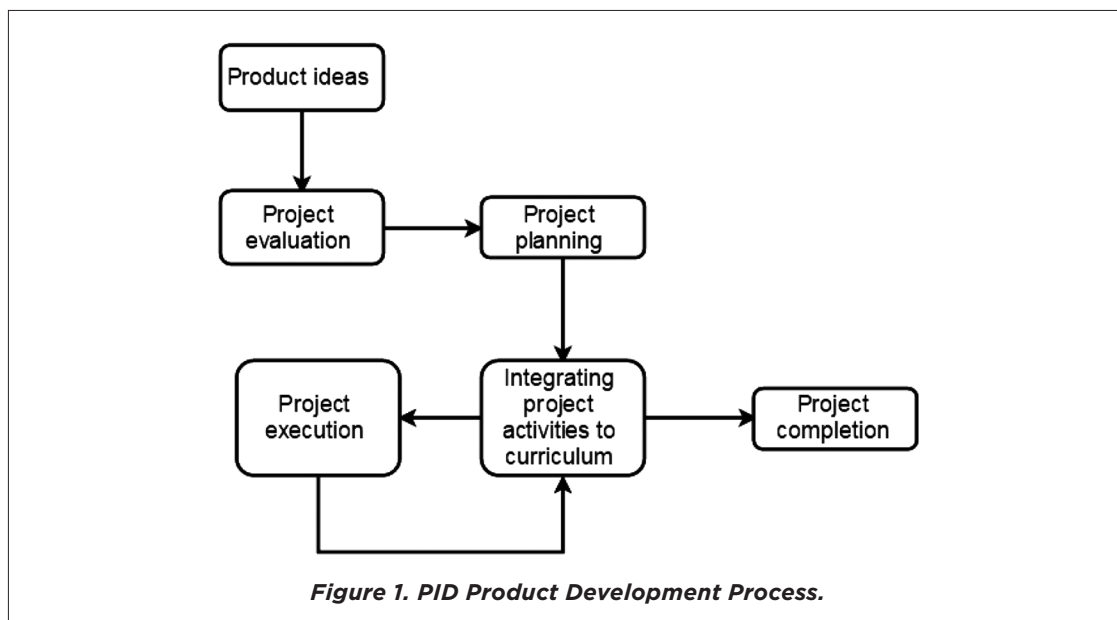


## Creating a High Impact Learning Environment for Engineering Technology Students

*Student researchers:* consisting of undergraduate students within College of Engineering who are paid to work on PID projects. In addition, they work closely with instructors of relevant ETID courses to design curriculum modules for educational purposes using the materials and experiences from the PID projects. They do not receive course credits for participating in PID projects.

There are two main focus areas in PID. One is the product innovation effort by students; the other is the educational modules developed by the PID students. These modules are used in relevant ETID courses. The impact is two-fold: in depth for the student researchers involved in the PID project and in breadth for other students who benefit from the educational modules developed by PID student researchers. The PID process is shown in Figure 1.

The starting point of the PID process is the creation of product ideas, which can be from students, faculty members, industry sponsors, idea competition ran by PID, and other funded external research projects. Interested students and faculty advisors then must evaluate the product ideas. A student team will be formed and a faculty advisor assigned to the team. Student researchers then conduct business analysis, including market analysis, cost analysis, sales forecast, profit estimation, breakeven point analysis, estimation of initial investment needed, and estimation of return of investment. The feasibility report will then be submitted to the PID committee for final approval of establishment of a PID project. If the project is approved, the students will plan for the product development and



**Figure 1. PID Product Development Process.**



potential curriculum application. The design of the product will be carried out in parallel with the curriculum development efforts until the completion of the project.

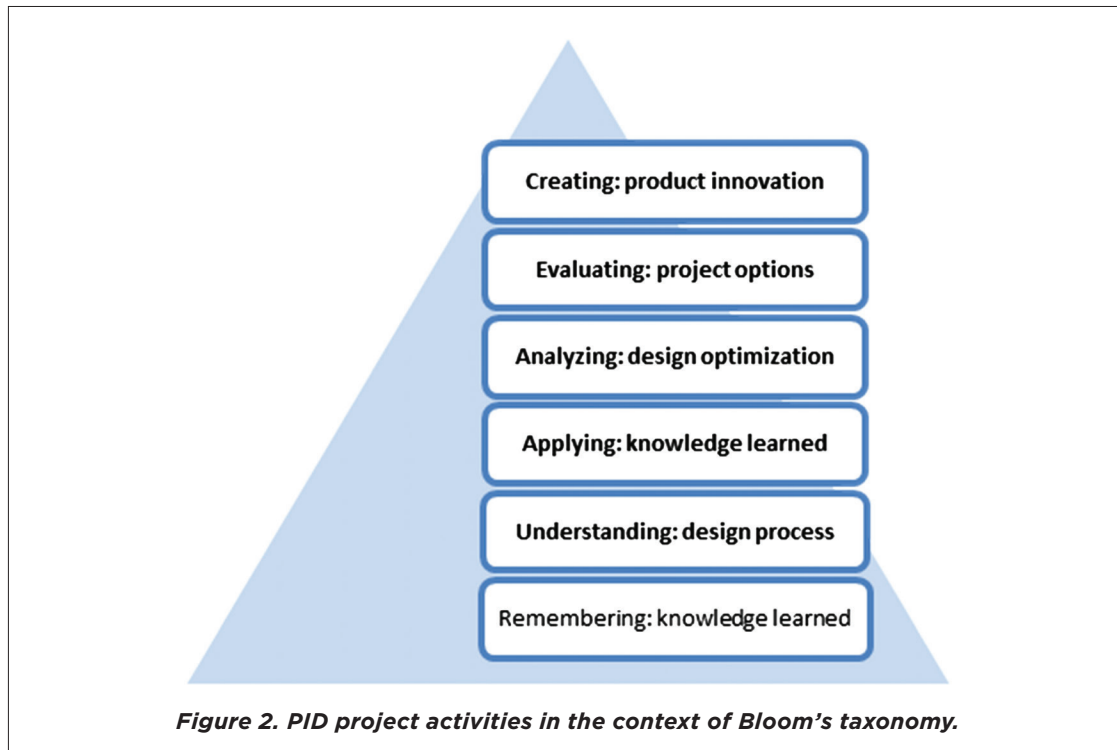
Although PID is not-for-profit, the expectation is that, in the long run, some successful PID projects will generate sufficient revenue to cover the cost and make PID self-sustainable. Therefore, PID student researchers must focus on both the financial aspect and the high impact learning aspect since PID needs the revenue to fund additional student researchers and new PID projects. This way, students working on PID projects get the full benefit of understanding how a business works. Financially, a PID project can be sponsored by faculty members, industry partners, and other external research project sponsors. As discussed earlier, resources needed for HIPs is one of the main challenges in implementation. To achieve self-sustainability, student researchers must execute PID projects as real-world business projects. This requirement brings the business and technical design together with multi-disciplinary efforts by the PID student teams. This is also an effective way to include the Industrial Distribution students who play a major role in the business aspect of PID projects. Not only do students from all three programs get to work together in project teams, but faculty members from different programs also collaborate more, which was lacking before the PID initiative.

### **Unique Features of PID Initiative**

As discussed earlier, HIPs have been implemented in many higher educational institutions. The PID Initiative has the following unique features:

- The high impact learning is student-centered. Faculty members serving as advisors play secondary roles.
- The high impact learning can be in a course or outside of ETID courses. What the PID student researchers do is outside of the ETID curricula. The educational modules they created are used in ETID courses and provide learning opportunities for students taking these courses.
- PID student researchers do not receive any course credits. They get paid for their work.
- The PID projects are managed like a business. There are two distinct objectives: generating profit and making a positive impact on the curriculum.
- PID student researchers learn every aspect of product development process.
- The PID Initiative must be self-sustainable in the long run. If a project is not profitable in the long run, it will exit the PID project portfolio.
- Most of the projects will be multi-disciplinary, typically including students from ESET, MMET, and ID programs.

In the context of Bloom's taxonomy for learning, PID projects involve the top five levels as indicated by the bold face font in Figure 2.



In the design process of PID projects, student researchers must make sense of what they learned in the technical courses they took from the ETID curricula; this is the understanding part of the Bloom's taxonomy. Similarly, they have the opportunity to apply the knowledge they learned before in new ways during the design process. To optimize their design, which is necessary in order to maximize profit, students must have the ability to break the knowledge they learned into parts and understand how each part is related to the other parts. Evaluating occurs when the students and faculty advisors evaluate the feasibility of the project. It is also used when considering different options during the design phase of PID projects. Creating is thoroughly practiced because all PID projects involve product innovation. In summary, the top five levels of Bloom's taxonomy of learning are included in the PID projects.

The seniority of students hired to work on PID projects can vary from freshmen to seniors, which provides the opportunity for first-year experience for some freshmen. The PID teams provide opportunities for common intellectual experiences, learning communities, collaborative assignments and projects, and undergraduate research as well. The educational modules developed can be used in course projects and capstone projects. Therefore, many HIPs are available in PID projects, where a high impact learning environment is created.



**Evaluation criteria**

Since the main objective of PID initiative is to enhance student learning, the evaluation of PID projects will focus on the educational aspect of the projects. To this end, the following metrics are established:

- Number of students impacted by the PID Initiative projects (breadth);
- Number of student researchers hired to work on PID projects (depth);
- Number of courses impacted by the PID projects;
- Percentage of profitable PID projects;
- Overall balance of PID projects.

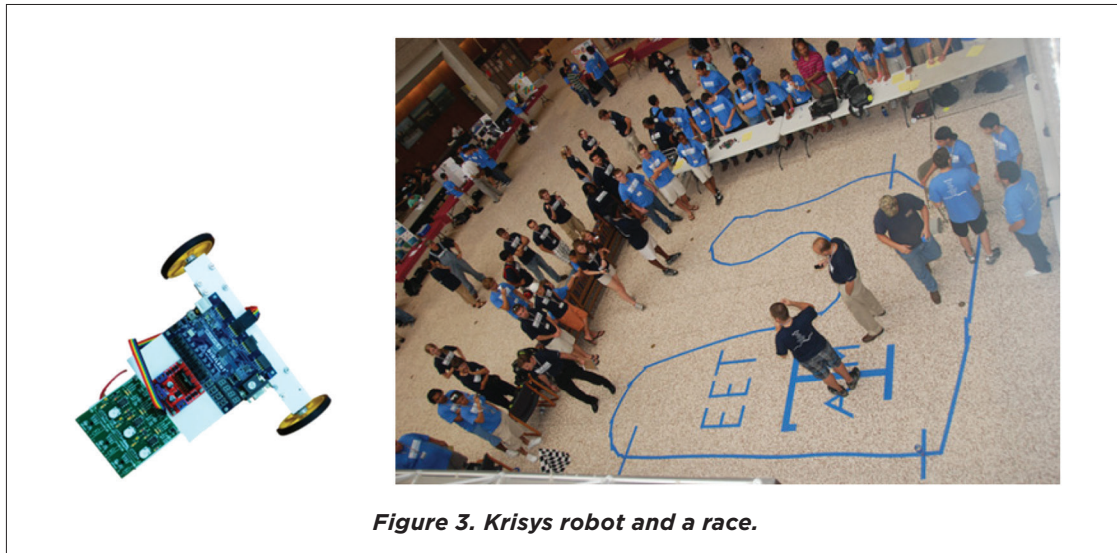
**PID PROJECTS**

Since the establishment of the PID, four projects have been successfully completed. The first one is an educational robot kit intended for outreach for high school students. The second one is development of a coaster set for former ETID students. The third one is a research project looking at the next generation of industrial vending machines, sponsored by industry. The fourth one is a research project sponsored by a faculty member to develop a smart stick for vision-impaired people. The fifth project, which is near its completion, is the development of an electronic clock for former ETID students. There were several other projects that were evaluated or started, but were not completed.

**Krisys Robot Kit**

Krisys robot is an autonomous vehicle used in a course project in Digital Electronics (ESET 219) and ETID outreach activities (Figure 3). Students take the part kit provided to them and follow instructions to populate the printed circuit board, assemble the robot, and program the micro-controller so that the robot can follow a trace on the floor with an AC current flowing through it. This process involves use of electronics, hardware, and embedded software coding. Krisys has also been used as an outreach tool in various summer camps run by the College of Engineering. Four student researchers were hired to develop a commercial product out of the Krisys robot. This project is different from other PID projects in that an initial technical design was available even before the project was started. The focus for the student team was to optimize the design with the main objective of reducing the cost and the lead time for the robot kits.

Student researchers searched for similar commercial products online to gather information about pricing and features of robots kits. They then conducted surveys in the summer workshops where Krisys robot was used. One hundred and twenty five survey results were collected from the



**Figure 3. Krisys robot and a race.**

summer camps, in total. The survey results were analyzed and a price target was determined based on the analysis.

To reduce the cost, the team investigated costs of in three categories: parts, labor, and technical support. The electronic circuit design was optimized to lower the part cost. A website was created with many supporting documents, including the step-by-step instructions for populating the PCB and programming the micro-controller. YouTube videos were produced and linked to the website so that the needs for in-person customer support were greatly reduced. The team also analyzed the relationship among the lead time, inventory, and cost. They came up with an optimal solution that significantly reduced the lead time with a small investment in inventory.

The student team used the project material to create a Lean Six Sigma project for ESET 329. This project was so successful that it became a Lean Six Sigma case study in a textbook [40]. A House of Quality for this project was created in a Product Development course (ESET 333) to gather the Voice of Customer and derive the product requirements. Krisys was also used in a Sales Engineering course (IDIS 330) as a case study for market analysis. The PID team implemented many recommendations made by students in these three courses to improve the Krisys robot kit operation. Through this process, more than three hundred students received educational benefits from this project. The students develop appreciation of the practical aspects of their learning. The four student researchers gained valuable real-world experience running a business. More importantly, their work had a significant impact on the learning of other students. The project was presented in Engineering Showcase organized by the college of engineering at Texas A&M University in 2013. The Krisys team also presented the project in an ETID research seminar in 2013.



Within a few months, the Krisys robot project reached a breakeven point. After that, a small profit was made, which provided support to other PID projects. The Krisys robot project was a complete success.

#### **ETID coaster**

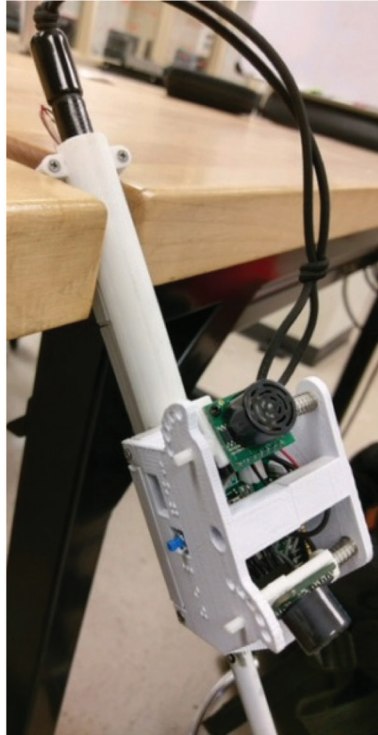
In an MMET course (MMET 380), students are tasked in laboratories to make small parts using machine tools. In another course (MMET 281), students work on compression molding in a polymer processing laboratory exercise. These parts used to be disposed of after the completion of the laboratories. A PID project was established to modify the laboratories so that useful products can be developed from these courses. Student researchers developed procedures to produce molds and coasters for machining and polymer processing labs. Instead of arbitrary parts, students in these labs make coasters, as shown in Figure 4. The coasters set, consisting of four coasters, a die, and a wooden display, are given to the donors of the ETID Department as a gift. It can also be purchased by others. A total of more than three hundred students were impacted by this project. The ETID coaster team used a business model different from that of the Kyisis project. The sales volume was lower than the Krisys robot, but the profit margin is higher. The coaster set has become a popular souvenir among former students. The coaster project was also a complete success.

#### **Smart stick for visually-impaired individuals**

Visually-impaired individuals face great challenges in their daily life. A PID project was proposed by faculty members and two capstone teams. This PID project explored yet another PID model,



*Figure 4. ETID coaster.*



*Figure 5. The smart stick prototype.*

which is to use PID to conduct feasibility study of large projects. Faculty members work with the PID project team to develop a prototype that can enhance the probability of receiving external funding from NSF, NIH, and other agencies. The goal of the smart stick project is to develop a low-cost smart walking stick that the visually-impaired can use to get around Texas A&M campus. RFID tags powered by solar panels are proposed to be installed in each building on campus. The smart stick reads the information out loud to the user to provide information about their location. Another capstone team worked on a navigation system inside a building for use by visually-impaired individuals. Prototypes were successfully developed by the two capstone teams. A working prototype is shown in Figure 5. Based on the initial feasibility study, a faculty member submitted a proposal for external funding. The smart stick project was also a complete success.

### **Vending machine**

Three faculty members submitted a proposal to an industrial sponsor to develop the next generation industrial vending machines. The weight of the machine needs to be reduced significantly. A large computer is replaced by a small micro-controller, which keeps count of the dispensed items



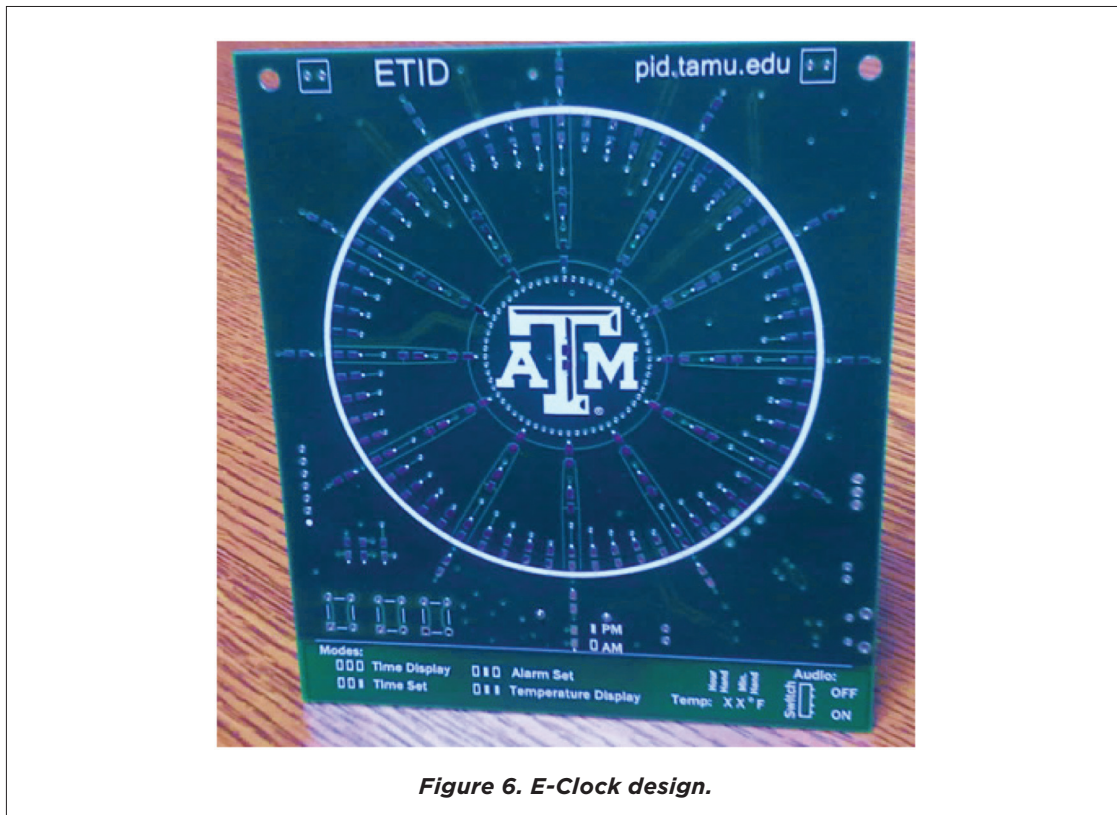
and sends the information through various wireless connection methods such as WIFI, cellular service, and ZigBee in combination with wired communication to internet. RFID fobs together with a motion detector allow individual users to operate the vending machine. The regular fluorescent light bulbs are replaced by LED lights. A light sensor is installed inside the vending machine so that the brightness of the LED light can be controlled based on the ambient light. Many of these efforts are made to reduce energy consumption. Four capstone project teams worked on the [vending machine](#) to support this externally funded research project. This project exemplifies how externally funded research can be combined with educational effort such as high impact learning practices. This project was also a complete success.

### **E-Clock**

A PID student team and a capstone team worked on a project to develop an electronic clock (E-Clock). Similar to the ETID coaster, this product is mainly intended to be a gift to the donors of the department of ETID. The clock keeps track of time by lighting up the appropriate LEDs on a printed circuit board. It has an alarm that, once triggered, will play the Aggie War Hymn. It also has a temperature sensor and temperature display mode. An on-board light sensor can detect the ambient light so that the LED brightness can be adjusted according to the ambient light. This product involves electronic hardware design, embedded software development, sensor technology, digital filter design, and audio amplification. The product has been designed, as shown in Figure 6, and is currently going through final testing and validation.

## **IMPACT ON STUDENT LEARNING**

The first impact from PID initiative is the in-depth impact on the learning of the PID student researchers. For student researchers who worked on PID projects, the project and the PID initiative provided them with opportunities of more in-depth learning. They were exposed to many of the HIPs in the learning environment created by the PID initiative. They create innovative products, optimize their design, put together different information they learned from various courses, and worked as teams consisting of students with different levels of experience. In addition to the technical skills, they learned more about the product development process and many business aspects, which they usually do not get to see in ETID courses. One of the important lessons the students learned is that the success of a product relies largely on marketing, sales, and other business aspects. The PID student teams typically consist of students from ESET, MMET, and ID programs working together as a cohort to follow a new product development process. The student teams from multi-disciplinary



**Figure 6. E-Clock design.**

backgrounds working on a common goal develop a holistic way of thinking. The students face many challenges and oftentimes struggle to design, make, and sell their products. Every time they overcome a hurdle, they end up learning something new that may benefit them in their lifetime. The PID high impact learning environment is clearly different from a traditional classroom, where the knowledge acquired is most likely to be used for tests and assignments and rarely beyond the end of the semester. The PID student researchers are more likely to achieve higher level of accomplishment and retention because of the challenges they faced and overcame [30]. So far, the retention rate for PID students is 100%. It is expected that the PID projects create more competent students that are ready to face real-world challenges not only as engineers, but as the entrepreneurs and managers of the next generation.

The second impact from PID initiative is on other ETID students through the curriculum modules developed by the PID student researchers based on their experience from PID projects. One of the criteria for evaluating PID projects is how much of an impact it will have on ETID curricula. This criterion ensures that the impact of PID project has breadth in addition to depth. Each project team always identifies opportunities to make a connection between their project and ETID courses. The



courses can be what they have taken or are taking currently. They also receive guidance from their faculty advisors in terms of which courses to look at.

The five completed or nearly completed PID projects created many opportunities for curriculum enhancement. Examples, lab exercises, and case studies were created and used in ETID courses.

Overall, twenty one PID student researchers were hired to work on PID projects with four completions and one near completion. PID sponsored eight capstone teams. Ten ETID courses and more than seven hundred students were impacted by the PID projects through curriculum development. Results from student surveys indicated positive impact from using the curriculum modules developed by PID students. Guest lectures were given by an ESET faculty member involved in PID project to an MMET course (MMET 463) to promote interdisciplinary interactions. Surveys for the guest lectures were very positive.

### EVALUATION OF IMPACT FROM PID

Selected student groups were surveyed for evaluation of the impact from PID. The first survey was for PID student researchers. The second survey was for ESET 329, where a PID project was used in a course project and case study. The third survey was for students who attended the guest lecture in which PID project material was used.

#### PID Student Researchers Survey

The following questions were asked to students who worked on PID projects:

Circle one of the numbers from 1-5 for each question (1: strongly disagree, 2: disagree, 3: neutral, 4: agree, 5: strongly agree, NA: not applicable). Write additional comments if you have any.

1. Were you able to use any knowledge that you learned at TAMU during your work for PID projects that you have been involved in?    1 2 3 4 5 NA
2. Did the PID projects reinforce the knowledge you learned at TAMU?    1 2 3 4 5 NA
3. Is there anything that you think is important that you did not learn from TAMU courses, but you learned by working on PID projects?    1 2 3 4 5 NA
4. Are you more prepared for jobs after graduation after working on PID projects?    1 2 3 4 5 NA
5. Are you more familiar with selecting parts, getting quotes, finding lead time, negotiating prices, creating purchase orders, and other aspects of dealing with vendors?    1 2 3 4 5 NA
6. Are you more familiar with the business aspects of the product development process?  
1 2 3 4 5 NA



7. Are you more confident in designing a product? 1 2 3 4 5 NA
8. Are you more confident in managing the inventories? 1 2 3 4 5 NA
9. Are you more confident in providing customer support? 1 2 3 4 5 NA
10. Are you more confident in dealing with customers? 1 2 3 4 5 NA
11. Are you more confident in printed circuit board design including schematic capturing and board layout? 1 2 3 4 5 NA
12. Are you more confident in embedded software development? 1 2 3 4 5 NA
13. Did you learn anything about project management from working on PID projects? 1 2 3 4 5 NA
14. Did you learn anything about teamwork from working on PID projects? 1 2 3 4 5 NA
15. Did you learn anything about testing and requirement verification from working on PID projects? 1 2 3 4 5 NA

There were 21 student responses to the survey. The statistics are summarized in the following table. Note that not every team dealt with customers, embedded software, or printed circuit boards, as indicated by lower response numbers in these categories. The average response for each problem was 4.23 or higher, indicating that the student researchers enjoyed the high impact learning environment created by the PID initiative. In addition to the numerical rating, students also gave comments to some of the questions. For example, for questions 3, many students commented that they learned to help customers, manage inventories, and negotiate with vendors while working on PID projects.

### Survey in ESET 329

IN ESET 329, three projects were presented as case studies. The Krisys robot was from a PID project. The other two were non-PID research projects. The following survey was conducted among students taking ESET 329 in Spring, Fall semesters of 2013, and Spring semester of 2017. Students were asked to rate the three Lean Six Sigma case study projects.

(provide a score for each question, 1: strongly disagree, 5: strongly agree)

1. Do you think the Six Sigma project examples presented in class are helpful in understanding the DMAIC process and in completing your project?  
Motor PWM project \_\_\_\_\_  
Krisys robot project \_\_\_\_\_  
PCB heating project \_\_\_\_\_

A total of 112 students participated in the survey for the evaluation of the motor PWM project and Krisys robot project. The PCB heating project was added in the Fall semester of 2013, with a





**Table 1. Statistics of PID Student Researcher Survey.**

Question	Average Rating	Standard Deviation	# of Responses
1	5.00	0.00	21
2	4.62	0.50	21
3	4.57	0.51	21
4	4.67	0.48	21
5	4.71	0.47	14
6	5.00	0.00	21
7	4.30	0.67	10
8	4.23	0.73	13
9	4.33	0.65	12
10	4.25	0.75	12
11	4.78	0.44	9
12	4.60	0.52	10
13	4.90	0.44	21
14	4.90	0.44	21
15	4.27	0.47	11

total of 68 students participated in the survey. The average and standard deviation of each project are calculated in Table 2.

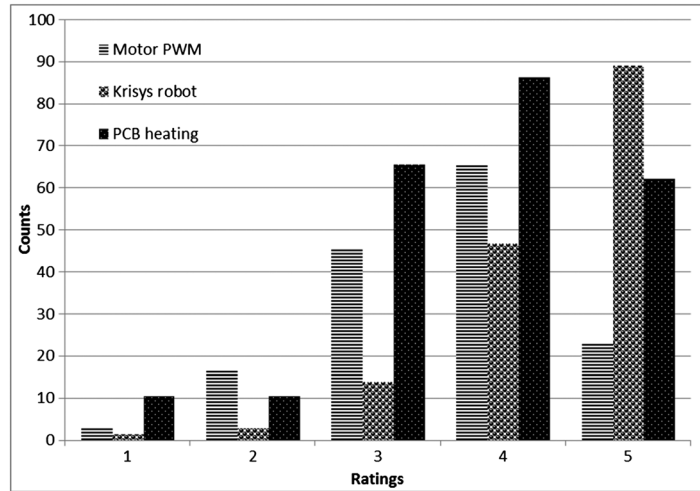
At 95% confidence level, the confidence intervals for the three projects are calculated as:

- Motor PWM: (3.41, 3.76)
- Krisys robot: (4.28, 4.58)
- PCB heating: (3.52, 4.01)

Hence, one can conclude that the Krisys robot project was evaluated higher than the other two by the students.

**Table 2. Statistics of ESET 329 Survey.**

Project	Average	Standard deviation	# of responses
Motor PWM	3.59	0.94	112
Krisys robot	4.43	0.80	112
PCB heating	3.76	1.04	68



**Figure 7. Histogram for the three projects.**

The histogram for the three projects is plotted in Figure 7. The vertical axis represents the percentage of students who selected 1, 2, 3, 4, and 5 respectively. It can be seen from Table 1 and Figure 6 that the Krisys project ranks higher than the other projects. Some students commented that the motor PWM project was too advanced and had more academic flavor because it used differential equations. Others commented on the PCB heating project that they did not have enough knowledge in heat transfer analysis. The survey shows that the Krisys robot project developed by PID student researchers was well-received by students in ESET 329.

#### **Survey for interdisciplinary guest lectures**

As a part of the PID initiative, an ESET faculty member gave a guest lecture to MMET students using the materials developed in PID projects. To evaluate the cross-disciplinary effort, the following survey was conducted.

**Table 3. Statistics of MMET 463 Survey.**

Question	Average Ranking	Standard Deviation
1	4.1	0.71
2	3.85	0.67
3	4.03	0.59



Please provide your feedback by giving a rating from 1-5 (1 being the worst and 5 being the best) or writing brief comments for the following

1. Is the presentation appropriate for MMET 463? \_\_\_\_
2. Do you like to see more of this kind of interdisciplinary exchanges among the three programs within ETID? \_\_\_\_
3. Give an overall evaluation of the guest lecture \_\_\_\_

There were twenty three responses. The statistics of the result is summarized in Table 3. The result is positive, but not as strong as the other surveys.

Compared with the other survey results (Surveys in ESET 329 and MMET 463), the average scores from PID student researchers were higher with less variation. Since they received more in-depth impact from HIPs, this result is not surprising.

### **CONCLUSIONS**

The department of ETID tried to create a high impact learning environment by hiring students to develop innovative products. A PID process was established for creating, selecting, and executing projects that are profitable. Students working on PID projects practice many of the high impact learning activities such as first-year experiences, common intellectual experiences, learning communities, collaborative assignments and projects, undergraduate research, and capstone projects. Not only did they gain experience from real-world product development, they also made contributions to curriculum enhancement so that many more students received the benefits as well. Twenty one students were hired to work on PID projects, five of which were successfully completed. Ten ETID courses and more than six hundred students were positively impacted by PID projects. Three surveys were conducted with positive overall responses.

During today's tough economic times, being able to create a high impact learning environment without significant institutional financial support in the long run is a challenge to educators [26]. For students, in particular the ones with financial needs, it is attractive to get paid while learning. There is no universal way to implement HIPs, so to be successful it must be tailored to the specific programs. This paper presents a success story, which may encourage others to do the same.

In addition to the creation of high impact learning environments, PID also brought other benefits. These include an ETID research seminar presentation by a PID team, participation in Engineering Showcase in College of Engineering, cross-disciplinary research collaboration among faculty members from different programs within ETID, and a presentation in an educational conference [38].



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