



High impact activities to improve student learning

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Abstract

With the support of the College of Engineering and the university, the Department of Engineering Technology and Industrial Distribution(ETID) at Texas A&M University (TAMU) started the Product Innovation and Development (PID) Initiative in 2012. The main objective of the initiative is to provide engineering students at all levels with opportunities in learning product development in the real-world setting.

This article discusses the details of the activities organized by PID Initiative and how they impact the student learning. The focus of PID Initiative activities is innovative product development. Undergraduate students from ETID department are recruited to form teams that develop new products. The student teams, with the help of faculty members, generate ideas for new products, conduct market analysis, design and manufacture the product, sell the products, and provide technical support to the customers. The PID Initiative projects generate revenue to support student learning. The objective is to become self-sustainable in the long run. Some of the project materials are used in several courses to enhance the current curriculum. Through the product development process, PID Initiative provides the students with entrepreneurial experiences. Examples are provided to illustrate the PID Initiative process. To further increase the impact, future plans include organizing student seminars and offering a certificate in new product development.

1. Introduction

Engineering students in different majors spend most of their time taking courses within their own program/department in addition to common body of knowledge (CBK) courses such as Math, Physics, and Chemistry. They have a chance to work on some real-world projects during their senior year in capstone/senior design courses. Before students get a chance to work on their real-world projects, which typically happen in capstone/senior projects, some of the students would have made the decision to transfer out of engineering school. Based on the feedback from industry, even students who finished their engineering degree need more experience with real-world product development experience.

To enhance the educational experience for students, TAMU made significant amount of investment in seven activities. The majority of the investment went to Activity 1 with a goal of enhancing the students' preparation for the workplace and society through high impact learning, and the advising for progress toward degrees²⁰. Through a competitive proposal, ETID Department received an initial funding, with the possibility of renewing the funding for two additional years, from the university to create a high impact learning environment for students.

Many researchers have studied the limitations of traditional pedagogical approaches¹⁹. Classroom approaches often fail to facilitate the highest level of thinking; they are theoretical, and fall short of bringing real-world perspectives. Classroom discussions are often confined to the topics and discussions as determined by the instructor. The instructor takes an active role and the students work within the well-defined boundaries established by the instructor. These pedagogical approaches are essential to an extent as designed in the curriculum. However, the instructors can make the students more involved in their learning process if they can bring real-world problems into the classrooms. This could be achieved by assigning projects that require hands-on experience and interaction with the industry. Student learning does not have to be limited by taking courses.

High impact educational practices were first introduced by Koh⁹. The subject has since been discussed by many researchers^{3,8,13}. High-impact learning practices can take many forms including first-year seminars, learning communities, common intellectual experience, service-learning, undergraduate research, internships, projects, study abroad, capstone experiences and many other activities. The main theme is experiential learning: "What I hear, I forget; what I see, I remember; what I do, I understand."⁹ High-impact learning practices can provide intensive learning for students, improve learning motivation, retention, postgraduate attainment, and help students reap economic, civic, and personal benefits from their educational experience. Many high impact learning activities involve hands-on experience¹⁶. In addition to the learning, high impact educational practices can help students build substantive relationships with teammates and sponsors and provide opportunities for students to reflect on the person they are becoming. Students can also get rich feedback from various sources.

While high impact educational practices have been proven to be beneficial in many aspects, there are challenges to implement the practices that work best for a specific student body. Finding the resource to support the implementation of high impact educational practices is one of such challenges. The support ETID received from the university provided the seed fund that is needed to start the implementation effort. However, long term support is the main challenge to be tackled.

2. The PID Initiative

With a goal to provide high impact learning opportunities to students, a team of three faculty members was formed to find the best way for deployment. As discussed in the previous section, there are many activities of high impact learning that can be implemented. Given the limitation in resource, the team decided to select a focus area. To this end, it is important to review the structure, faculty and student bodies of ETID first.

Background in ETID

ETID is a unique department within the College of Engineering at TAMU. There are three programs within ETID: Manufacturing & Mechanical Engineering Technology (MMET), Electronics System Engineering Technology (ESET), and Industrial Distribution (ID). The department offers courses in electrical, mechanical, manufacturing, and management subjects. These course are similar to courses offered by Mechanical Engineering, Electrical Engineering, and Industrial Engineering, some even use the exact same text books. Compared to the courses offered by the traditional engineering departments, the courses offered in ETID have more laboratory components and focus more the hands-on experience gained by students. With the exception of the ID program, ETID programs focus on undergraduate education. ID courses focus more on the application side of management science and adopt a case and project based pedagogical method. Other than a few courses offered by MMET and ESET that are taken by ID students, there is not much interaction among the three programs.

Most faculty members have Ph.D. degrees in engineering and Management Science, and have industrial experience. While some faculty members have interests in fundamental research, more are interested in conducting applied research and working with industrial partner on practical projects.

There are about 800 undergraduate students within ETID. Most of them have more interests in hands-on experience than in theory. Vast majority of students find jobs in industry after graduation, while a very small percentage moves on to pursue graduate studies. ETID graduates typically work as test engineers, field engineers, application engineers, product engineers, operations, and technical sales.

Selection of focus on product development

A few years ago, feedback from all program's industrial advisory boards indicated that the students' knowledge and skill in product development can be strengthened. In order for companies to increase productivity, reduce development cycle time, and stay competitive, it is necessary that a good process for product development is in place and employees know how to follow the process^{11,12,17,21}. Faculty members in ESET program realized that there was a gap between what engineering technology students learn in college and what they would face in industry. To reduce this gap, ESET program started a major curriculum revamping effort to shift the focus of the original Electronics Engineering Technology (EET) program to system and product development¹⁴. Several new courses in product development were created and the program name was changed from EET to ESET.

A quick review of literature reveals that there are many efforts made in introducing the product development process to students^{5,6,7,18,22}. Early exposure to innovative product development process and tools is shown to be effective in getting used to the product development process^{1,23}. Knowledge in product development is also essential for entrepreneurship, which is a major interest area for engineering technology students^{1,4,15,24}. Due to the multi-disciplinary nature of ETID and encouraged by the successful implementation by Birmingham *et al*², a particular interest in multi-disciplinary product development is identified.

With the unique position of ETID and the review of literature, the team quickly selected product innovation and development as the focus of the high impact learning for students. The learning activities are determined to have the following important characteristics: student-centered, high impact as measured in depth and breadth, multi-disciplinary, real-world product development, and long term self-sustainability. The name of Product Innovation and Development (PID) Initiative was selected.

Mission and organization of PID Initiative

Mission Statement: 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 market needs. The goal is to educate TAMU students capable of leading successful product and service innovations.

The organization of the PID Initiative is as follows:

Steering Committee: consisting of the three ETID program directors.

Working committee: consisting of three ETID faculty members, one from each ETID program.

Faculty advisors: consisting of faculty members with expertise and interests that match particular projects.

Student assistant: consisting of students from College of Engineering who are paid to work on PID Initiative projects.

Instructors and students: consisting of instructors and students in relevant ETID courses. Parts of PID Initiative projects that are appropriate for certain ETID courses will be developed into laboratory materials, case studies, course projects, and capstone projects.

The organizational structure may be enhanced in the future as needed. For example, the Steering Committee may include external members from industry.

It is worth noting that PID Initiative projects will be carried out by undergraduate student assistants who are paid by hours. It is expected that the PID Initiative projects will generate enough revenue to cover the cost for product development and student assistants. An effort will be made to use the PID Initiative projects components in as many courses as possible to maximize the impact on students. As discussed in the literature, resource for high impact educational practices is one of the main challenges. In order to be self-sustainable, student workers must run PID Initiative projects as a typical business. This will bring the business and technical design together with multi-disciplinary efforts by students.

The PID Initiative Process

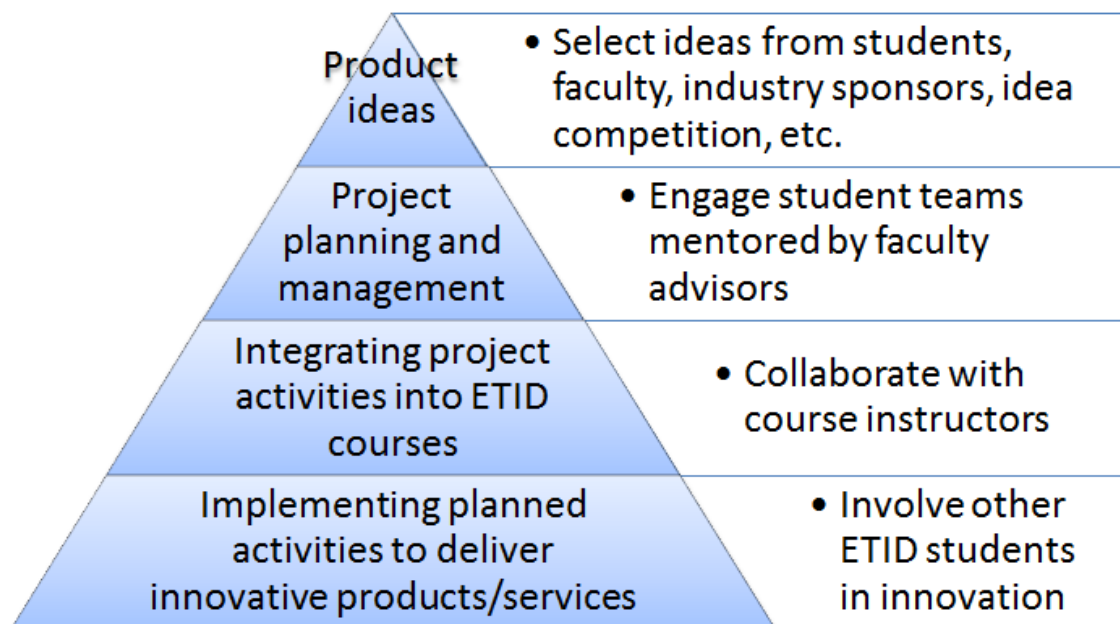


Figure 1. The PID Initiative Process

The PID Initiative process is illustrated in Fig. 1. The first step is to come up with product ideas. These can be from student assistants, faculty members, industry sponsors, and idea competition ran by PID Initiative. After the product idea is selected, student teams will be formed and faculty advisors will be identified. Once a PID Initiative project is started, student assistants will conduct business analysis including market analysis, sales estimation, cost analysis, profit prediction, breakeven point analysis, and initial investment estimation. If the product is determined to be appropriate for PID Initiative, the students must design and make the product. Meanwhile, they must try to integrate the product development effort into the ETID curriculum. A PID Initiative project may be supported by faculty members, industry partners, and other profitable PID Initiative projects. It may also be a part of a major external research project with involvement of faculty members and graduate students.

Although the PID Initiative is not-for-profit, students working on any particular project need to focus on both the bottom line and the educational benefit since PID Initiative needs the income to fund more students and product development efforts. In this sense, students working on PID Initiative projects get the full benefit of understanding how a business works.

Unique Features of PID Initiative

Compared to high impact educational practices implemented on many other campuses, the PID Initiative has the following unique features:

- The learning is centered on the students. Faculty members only serve as advisors.
- The learning happens inside and outside of the normal curriculum.
- Student assistant do not receive course credits; instead, they benefit from project-based learning and receive student worker pay.
- The PID Initiative projects are managed in a way similar to that in a business. For each PID Initiative project there are two distinct objectives: generating profit (or breaking even) and making a positive impact on the curriculum.
- Students learn every aspect of the entire product development process instead of just the technical aspect of an engineering design.
- The PID Initiative must be self-sustainable. If a project is not profitable in the long run, it exits the project portfolio of the PID Initiative.
- Most of the projects will be multi-disciplinary. Initially, students from the three ETID programs will be recruited. In the future, students from other departments could also participate.

Metrics for evaluation

Since the main objective of PID Initiative is to improve students' educational experience, the evaluation of PID Initiative will focus on the educational aspect of the projects. Specifically, the following metrics will be used:

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

3. Example PID Initiative Projects

Since the establishment of the PID Initiative, two products have been under development. The first one is an educational kit intended for high school students interested in robotics. The second product is a coaster set for former students. Another project is in the brainstorming stage.

Krisys Robot Kit

Krisys is a programmable autonomous vehicle currently used for a course project and outreach by ETID (Fig. 2). It was based on a platform that was used in an ETID course. A part kit is usually provided to the user. The user then follows instructions to populate the PCB board, assemble the autonomous vehicle, and program the micro-controller. In this process, the user can learn electronics, hardware, and software development. In the past few years, Krisys has been used as a training tool in summer camps for high school students, high school science and engineering teachers, other camps recruiting women and minority students to engineering. Three student assistants were hired to develop a product out of the Krisys platform. The intended customers include high school students, community colleges students, and hobbyists.

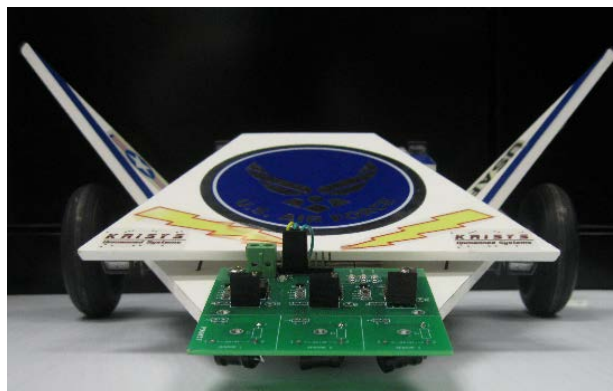


Fig. 2 Krisys robot

Three undergraduate students from MMET, ESET, and ID were hired to commercialize the Krisys robot kit. This project is slightly different from a typical PID Initiative project in that the main technical design was completed before the start of the project. The focus for the student team was marketing and reducing cost of parts and labor. Surveys were conducted to the high school students and teachers during the outreach activities in the summer where Krisys robot was used as a training tool. A price was determined based on the survey results and online search for similar products. After email contacts and visits to several high schools, the student team was able to generate more than twenty five sales of the Krisys robot kits. To reduce the cost, the team worked in three areas: cost of parts, cost of labor, and cost of technical support. The electronic circuit design was optimized. Three YouTube videos were made to reduce the needs for in person support to the customers. A website was created with many supporting documents and links to the YouTube videos. These include the step-by-step instructions for populating the PCB and programming the micro-controller.

Three ENTC courses used Krisys as a case study or course project. A House of Quality was created in one course (ENTC 333) to gather the Voice of Customer and derive the product requirements. A Six Sigma project was carried out by two student teams to improve the process of selling the Krisys robot kits. Krisys was also used in an ID course as a case study for market analysis. The results from these three courses were fed back to the PID Initiative team. Through this process, more than seventy students received educational benefit from this project as they were given the background of the Krisys project and PID Initiative. The students develop appreciation of the practical aspects of their learning. The cost of parts was reduced by 25%. The three student assistants gained valuable experience running a small business while getting paid.

Within four months, the Krisys robot project reached a breakeven point. A small profit is predicted for the next a few months. It is expected that the income from the Krisys project will be used to support other PID Initiative projects. This is the first success story for PID Initiative.

ETID coaster

In an MMET course, students use machine tools such as a lathe or a milling machine to make small parts in laboratories. In another course, students work on compression molding as a part of polymer processing laboratory exercise. Usually these parts will be disposed after the laboratories are completed. Under the PID Initiative, a project is established to manufacture customized drink coasters in these labs. The coasters are to be given to the donors of the ETID Department. Student assistants are developing procedures to produce molds and coasters for machining and polymer processing labs. Efforts are being made to develop marketing strategies to encourage donations from former students to support this experiential learning exercise.

Invisible stick for vision-impaired

The blind and visually impaired commonly face great challenges in their mobility. A walking stick has an unattractive stigma and can be inconvenient to carry around. To improve the daily life of the disabled, a project is proposed for students to develop a low cost walking aid, an invisible stick, for the blind and the visually impaired. The proposed product can operate like an automotive parking sensor and can be in the form of a laser pointer. The invisible stick can be used to scan and probe the surrounding and can inform the user potential hazards in the path. The stick will consist of a range sensor to detect obstacles when pointing to different directions. The sensor output (the distance from the stick to the detected object) can be transmitted via wireless technologies from the stick to a receiver worn by the user. The information can be in the form of audible signals received by the user from an earphone. The product should be small and lightweight, and can be offered at a low cost. The project is going through brainstorming stage and students from all programs in the ETID Department can contribute to the development of the product.

In addition to these three projects, PID Initiative is also in negotiation with an industrial partner for an external research project which may be divided into several smaller projects including some PID Initiative projects. Student teams will be building a prototype and get paid for their efforts. This is a one-time R&D effort. The PID Initiative teams will function as the R&D arm of the company. As long as there is an opportunity for students to learn product development, PID Initiative will be flexible in terms of the type of products or services, scope, and duration. As more experiences are accumulated, more models of operations will be developed and enhanced.

Through the PID Initiative projects, students realized that nowadays products in the market are getting more complex and high-tech and life cycle of a product is getting shorter and that they need to work together with engineers from other disciplines in order to develop marketable products. Engineering students also realize that the success of a product relies largely on marketing, sales, and other business aspects. The students recruited from EET, MMET, and ID programs work as a cohort for a new product development process. The cohort of students from inter disciplinary backgrounds working on a common goal learn systems thinking and methodologies. They develop a holistic way of thinking that is required to find solutions to their problem. The students have a task at hand, which is to produce, and commercialize a new product. The students face various hurdles and struggle to manufacture and sell their products. Every time the students overcome a hurdle, they acquire a new knowledge that will last a life time. This is unlike a traditional classroom where the knowledge acquired is most likely to be used for a test and assignment and rarely beyond the end of the semester. Students who are not allowed to wrestle with issues will likely not achieve the level of accomplishment and retention as those who are allowed to do so¹⁰. The projects thus help to create students who are competent enough to face real world challenges which are essential for being the entrepreneurs and managers of tomorrow. The PID Initiative projects created many opportunities for curriculum enhancement. Examples, lab exercises, and cases studies were created in several courses.

4. Impact on curriculum

One of the basic requirements of PID Initiative projects is that it must have an impact on curriculum. This requirement is to ensure that the impact of PID Initiative project has breadth in addition to depth, which is experienced by the limited number of student workers. With this requirement in mind, the student workers working on a particular project will look into all opportunities to make a connection between their project and ETID courses. Typically these are the courses they have taken or taking currently. The faculty advisors will also provide suggestions on which course to look at. Depending on the scope of the projects, related courses can use parts of the project as an example, a case study, or a course project. Students in these courses will have an opportunity to work on a real-world problem instead of problems from a text book. Some PID Initiative projects are a part of external research projects. They can be capstone projects or research projects involving student workers.

For the Krisys Robot Kit Project discussed earlier, the evaluation of the impact can be summarized as follows:

- Three student workers were hired to work on this project. They did the market analysis, survey for customer needs, cost analysis, optimized the circuit board design, and designed curriculum modules for three courses.
- In IDIS 330 students conducted research on the sales management process for Krisys Robot. The group of students who were assigned the Krisys project conducted an in depth analysis of the unique selling points of the robot and presented to the entire class of 112 students the sales and marketing strategies for the product. The student learning experience was unique because of the product's (i) targeted market (the real market was educational institutions), (ii) classification (not a commercial product), and (iii) history (made in the department by the students).
- In ENTC 329 (Six Sigma and Applied Statistics), two students teams worked on Six Sigma projects that aimed to improve the process of Krisys Robot Kit. Many useful analysis and suggestions were made as a result of the course projects to the student worker team for further improvement of the service and bottom line. Ten students were impacted by the PID Initiative project.
- In ENTC 333 (Product Development Process), Krisys Robot Kit was studied as a part of House of Quality laboratory to understand the importance of the Voice of Customer and the derivation of requirements. Twenty-three students were impacted by the PID Initiative project.

5. Conclusions and Future Work

The PID Initiative was started to create a high impact learning environment for students at TAMU. The main theme is the innovation and product development. Though the PID Initiative sponsored high impact learning activities, students will have more opportunities to work on real-world problem. The short term priority of PID Initiative will focus on students in ETID. After successful implantation of several PID Initiative projects, the target will be expanded to students in the college of engineering. In the long term, students from other colleges and business such as business school will be included. It is envisioned that an innovative entrepreneurial culture will be created at TAMU. As the PID Initiative continues to expand, feedback from students will be collected for further improvement.

There are several unique features of the PID Initiative projects: the participants do not receive course credit, instead they get paid; the PID Initiative must be self-sustainable; the PID Initiative projects must have an impact on the ETID curriculum. Not having to take an extra course and getting paid for their time and effort while learning innovative product development can be attractive to many students, in particular the ones with high financial needs. This provides a solution to some of the challenges discussed in the literature¹³. The self-sustainability is certainly a pleasant feature to have during the tough economic times of today when budget cut is the norm of virtually every higher education institution. The output from PID Initiative projects is not limited to a group of students and the product they create. The broad impact is achieved by taking components of the new product development process to classrooms.

For the PID Initiative student assistants, the learning experience is tremendous. For example, for an ID student, learning to build a robot, developing a business plan, and establishing prospective customer contacts is not what the student learns in his/her regular curriculum. The business side of the projects provides a side of the world an engineering technology student does not see in the regular curriculum.

While the main objective of the PID Initiative is to create a high impact learning environment for students, an unexpected benefit is that through this effort there is an increased collaboration among faculty members from all three programs within ETID.

The PID Initiative had a good start and more activities are being planned. An idea competition will be organized to create more product ideas. The results from PID Initiative projects will be presented by the students in ETID seminars. More curriculum enhancement using the PID Initiative project components will be explored. The feasibility of a certificate in New Product Development offered by ETID will be studied. External funding will be aggressively sought to support the expansion of the initial effort.

The first team of the PID Initiative project consists of a sophomore from ESET, and two seniors from MEET and ID. Based on the conclusions of the one the Six Sigma teams, team members

from freshman class, including outside of ETID will be sought. According to the Six Sigma team, freshmen may not be able to make much contribution to the technical design, but will be motivated to learn in the technical courses they take later. Since the student teams are multidisciplinary and can be from freshmen to seniors, there are rich interactions among students with different technical skills and different education experience levels. This kind of team composition is expected to increase the interests of freshmen engineering students and improve the retention rate.

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