Lessons Learned in Integrated Product and Process Design Education

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Abstract

Through six years of experience the faculty and administrators in charge of teaching the Integrated Product and Process Design (IPPD) course sequence at the University of Florida have accumulated a wealth of knowledge regarding the effective delivery of a multidisciplinary course that involves nine engineering fields. Each year the IPPD program hosts approximately 26 industrially-sponsored projects carried out by a group of over 150 students who are supervised by 23 faculty from different engineering disciplines. This paper presents a succinct description of the organization of the course from an administrative and academic point of view, followed by a summary of selected lessons that serve as useful guides to ensure the successful completion of challenging projects, including issues such as techniques for effective project management, interacting with industry, and just-in-time course-content delivery. Experience in managing a variety of projects led us to propose a slightly different structured design procedure for projects that involve significant levels of integration of software and hardware components so that common pitfalls and impediments to progress are effectively eradicated. Industry praises the IPPD effort as an outstanding experiential education program, with benefits for students, faculty, and industry. Five years of student self-assessment results clearly demonstrate the program’s educational objectives are being met.

Introduction

The Integrated Product and Process Design (IPPD) program is an innovative undergraduate engineering education initiative first developed at the University of Florida in the academic year 1994 under the auspices of the Southeastern University and College Coalition for Engineering Education (SUCCEED) initiative that in turn is sponsored by the National Science Foundation. The pilot testing was done in the 1995 academic year, and since then the program has been offered as a two-semester course available to senior engineering and business students. The students work in five to seven member interdisciplinary teams, under the direction of one faculty member who acts as a technical coach. Each team also includes the participation of a liaison engineer representing an industrial sponsor, namely a private company, or a government institution or laboratory, who charters the design team with the task of designing and building authentic products and processes of financial or strategic value to the sponsor.

IPPD is fully institutionalized at the University of Florida, and the two-semester course serves as an optional substitute for a capstone design course and for a technical-elective course. Students gain practical

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experience in teamwork and communication, problem solving and engineering design, and develop leadership, management, and people skills. Teams and individuals are evaluated based on clearly defined project deliverables and on their performance in lectures and workshops.

This paper provides an overview of the IPPD Program at the University of Florida and reflects on the results of five years of self-assessment activities. More specifically, the document presents relevant lessons learned in the areas of effective project management, industry interaction, just-in-time course content delivery, and hardware-software integration.

**Overview of the IPPD program**

**Course structure**

The IPPD course is supported by four key principles: (1) multidisciplinary teams of five to seven students working on industry-sponsored design projects, mentored by a faculty coach and supported by an industry liaison engineer, (2) a structured development process based upon recognized industry best-practices and tailored to fit an 8-month development cycle, (3) use of industry-standard design tools (such as Pro/ENGINEER and Mentor Graphics), and (4) adherence to well-defined project management methods. The structured development process for hardware projects is illustrated in Figure 1. The design process is initiated with the formation of project teams. This step begins with team recruitment and project staffing. Once the multidisciplinary teams are formed, an overall project management structure is established and a leader, financial officer, recorder, and weekly meeting schedules are determined. The first deliverable is the generation of a name and logo for the team; thus formally establishing team identity.

The remainder of the structured development process encompasses two consecutive semesters of extensive work commitment by each team of students. The product and process design activities involving hardware deliverables are organized into five consecutive phases that follow the paradigm discussed by Ulrich and Eppinger [2000]: conceptual design, system level design, detailed product/process design, verification, and production. The product and process design for software deliverables has similar phase divisions and is examined later in this paper. Figure 1 shows a schematic representation of the development sequence followed for hardware projects. The end of each phase shown in the figure is given by the successful completion of a clearly defined deliverable or by meeting a major milestone. The structured development process culminates with the delivery of a working prototype to the industry sponsor.

The embodiment of the design process into the curriculum takes on the multi-faceted format of lectures, workshops, and team-teaching activities. The lectures, given twice a week by engineering faculty and by guest lecturers from industry and from the business school, are used to formally introduce each aspect of the design process via theory, examples, case studies, and in-class activities. The lectures are presented in a just-in-time fashion, such that upcoming deliverables are explained one or two weeks in advance. Each team holds weekly design workshops where they focus on the project details and the coach-assisted adaptation of the lecture topics to the specific project requirements. These workshops typically involve the participation of industry liaison engineers via teleconferencing. Additional support is provided to train students in the use of specific development tools and techniques. The IPPD program meets ABET requirements and feedback from project reviews provides a conduit for departmental curriculum improvements.

**Student and faculty participation**

The program currently involves faculty and students from nine engineering disciplines, as well as students majoring in business. At this time the undergraduate rolls include over 150 students who are coached by a group of 23 faculty. An annual fluctuation in the number of students involved from each discipline occurs depending on the expertise base required to execute the available projects, and on the level of interest that
can be generated among the pool of available students. A typical team composition involves 5 to 7 students from appropriate disciplines, a faculty coach, and an industrial liaison engineer and his/her technical support staff. As is done in industry, the team composition is driven by the technical requirements of the project. Successful student recruiting culminates with enough students of each discipline to staff all the projects. There is some flexibility in the specification of the needed disciplines. For example, in selected projects aerospace engineering students are often considered as interchangeable with mechanical engineering students, and business students may be recruited in place of industrial engineering students.

Figure 1. Integrated Product and Process Design Program structure for hardware-oriented process deliverables

**Number of sponsors and projects**

Since its inception in 1995, a total of 51 companies have sponsored 159 projects in the University of Florida IPPD program. The program has reached a nominal annual operating level of approximately 26 projects and 23 sponsors. Approximately 2/3 of the sponsors are repeat participants from a previous year.

**Lessons learned**

Some of the key lessons learned from the past six years of the IPPD program are examined in this section. In some instances the experiences are shared from the point of view of the IPPD Director (the administrator’s perspective) and the point of view of the faculty (the coach’s perspective). The administrator’s point of view addresses issues pertinent to running the entire IPPD program, whereas the coach’s point of view addresses issues relevant to the successful execution of multidisciplinary projects. These dual viewpoints are shared in the context of project management and industry interactions; experiences in hardware-software integration and just-in-time course delivery are explored from a unified viewpoint.

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Project management—the administrator’s point of view

The project management within the IPPD program involves three layers; namely, administrative, academic, and technical. Administratively, the IPPD Director is responsible for the academic and financial success of the program. The academic responsibilities are shared among the faculty coaches where a smaller group of the faculty prepare and deliver the course material and the individual coaches reinforce their students’ learning of the material through weekly team workshops. Industry speakers also deliver supporting lectures. Among the key financial responsibilities, a major activity is securing and stewarding the centralized program funds, and obtaining industry commitments and payment for sponsored projects. The technical and individual project management is shared among the students with technical support provided by the team’s faculty coach and industrial liaison.

The students are given a *New Engineer’s Training Manual* that describes in great detail the Integrated Product and Process Design program. More specifically, it discusses the structure of the course, identifies the deliverables that must be produced and the expectations that must be met by each team and individual, explains the performance evaluation policy, and documents the rules and regulations associated with the use of the resources available, such as engineering design stations, and shop facilities.

In addition, the *New Engineer’s Training Manual* includes attachments with detailed specifications for the required engineering documentation, ordering materials, travel, and other pertinent details relevant for the effective execution of the project. Through the lectures, workshops, and support material, the students are taught how to effectively manage their project. The course syllabus and the list of dated deliverables provide a road map. The students begin by first becoming acquainted with the customer (industry sponsor), soliciting a prioritized set of project requirements, and formally establishing the product specifications. After selecting a final concept, the formulation of the product architecture suggests a division of labor among the students and suggests the points at which all contributions must converge to produce an effective final product and manufacturing process. This results in the ‘living’ project plan. The team leader is responsible for ensuring that each team member is given sufficient tasks, thus fully engaging each participant as a team player.

Weekly faculty meetings provide a forum to communicate upcoming deliverable expectations, discuss biweekly course management survey results and proposed corrective actions, share project status and get technical and team management advice from a diverse group of faculty coaches. During each faculty meeting, three groups are identified to give a five-minute presentation on their deliverables at the beginning of the next lecture. By discussing each project in a round-table fashion the faculty can identify which projects are at risk and then collectively propose action items that can help to resolve the problem. Given the diversity of faculty disciplines, in most instances one of our faculty members has the right technical background to suggest a path to resolve technical issues. When required, the director may have to go back to the project’s executive sponsor to request additional resources to support the team.

To help identify projects that are at risk of failure, the program holds several peer-review sessions scheduled prior to all the major industry reviews. During the peer reviews each team presents a rehearsal of their upcoming industry-review presentation before a group of five other teams and a panel of coaches. The coaches and the student audience ask questions and make suggestions to the teams on all aspects of the presentation, focusing on the features that require improvement. The coaches then report back to the director to identify at-risk projects. During the second semester of activities, two internal project reviews are held with the objective to expose all project risks and provide corrective actions. The format is a private 20-minute presentation by each team in front of a panel of coaches with expertise in the particular project’s domain (e.g., digital design, or chemical engineering). To maximize their value, these reviews occur early in the detail design phase and after the initial prototype testing.

In response to industry feedback we have increased the emphasis on project risk identification and mitigation. Such feedback was also used to decide on new additions to the *New Engineer’s Training Manual*,
such as new material on project management, and to include new industry lecturers to reinforce the practical aspects of the students' education. One complaint from our students has been that we do not expose them early enough in the lecture series to project management techniques. Due to the heavy emphasis on learning the structured development process up front and the furious pace of the deliverables in the first eight weeks of the project, we have not been able to schedule project management lectures any earlier than the fifth week of the program.

The handling of proprietary material is a sensitive topic within academe in that education is expected to include mostly materials that are open for external evaluation. Yet, interesting and challenging engineering projects often exhibit a need for protecting the company’s investment into the program. One of the lessons learned is that catastrophic project failures can be best avoided if before the initiation of the project the IPPD director and the industrial partner define a clear proprietary-protection agreement regarding all activities that involve the access to or use of proprietary materials. Midstream proprietary agreements tend to add anxiety and confusion as to how the student should handle the exchange of information within the classroom as part of their deliverables. The situation is especially delicate if such information has already been part of an earlier deliverable produced before the agreement was made. The University of Florida program was faced with a serious dilemma regarding proprietary issues when one of the engineering departments involved decided that none of their students could participate in IPPD projects with proprietary clauses. The argument furthered was that the students need to successfully satisfy learning requirements in the area of report writing, and that the practice of not disclosing proprietary reports prevented a reasonable assessment of the extent of learning. The faculty of the objecting department resolved the issue by agreeing to allow the students to participate in proprietary projects provided that the students publicly demonstrate mastery of the material during design reviews and in the major project reports. The policy developed recommends that the proprietary report content be summarized in one section and this section be removed from the archive copy that is available for public viewing.

**Project management—the coach's point of view**

A key project management issue for the IPPD team coach is addressing the intellectual aspects of the project and the associated risk management. At the beginning of the program, a typical student team member will have completed a junior-level education in his/her engineering discipline and should be well prepared to excel in traditional aspects of course work. However, any reasonable industry-sponsored project will require that the students reach beyond their undergraduate training and experience. Hence, the key questions for the coach to answer are “How will the IPPD students develop intellectual property for the project?” and “How should the project be managed to provide training in the new engineering disciplines where the team is lacking knowledge?”

Our experience is that undergraduate students can perform complex engineering design tasks through association by examples. It is therefore critical to the success of the project that the coach identifies for the team examples of related design and design theory, software simulations, hardware emulators, and CAD training activities. The industry liaison engineers can provide block diagrams, schematics and physical examples of previous designs. Sometimes graduate students with unique design expertise are hired to assist the team. Engineering faculty not affiliated with the project can provide good design references, too. Moreover, industry can provide application notes, manuals and training courses for using complicated equipment and their CAD software. Training seminars offered by equipment manufacturers are often made available free to students and university faculty.

The coach should have a clear idea of what the students will need to learn to complete the project and the resources that will be needed to accomplish this learning. In addition, the project should not step beyond the bounds of what motivated undergraduates can do in nine months. For instance, we find that electrical engineering students can design and test analog and digital boards, electronic systems, and embedded
controllers. In contrast, undergraduate students cannot be expected to do original mathematical theory, integrated circuit designs, and RF/microwave designs.

The coaches’ experience shows that projects can fail due to unforeseen intellectual and practical issues. For example, the required CAD software can be too expensive, too hard to use, or incompatible with available computer platforms. Some features of CAD software will simply not work as advertised, or there may not be sufficient design libraries to do the project. Library management for complex CAD packages is very important—proprietary issues and limited company CAD personnel can impede borrowing from or adding new parts to a company design library. Third-party software, such as proprietary Windows drivers, could require special licensing agreements that may take too long to negotiate during the course of a project. The challenges imposed by the project may lead the team to work with newly emerging interfaces and standards that often are poorly supported, that have proprietary content, and as a consequence, the coach finds the team cornered in a situation where it is impossible to successfully continue on a productive design path.

The coach has to recognize quickly when an issue has potential to become a significant impediment. So, every project with risky intellectual developments needs to have a relatively safe design strategy as a fallback position. If a team cannot design one aspect of the project, then can the project be re-scoped to accomplish something useful for the company? Can a piece of equipment or circuit board be purchased to perform a useful substitute function for the project? It is critical for the coach to watch the team morale when the project gets difficult and when proposed solutions are not working. The coach needs to teach the students to work around problems, consider alternatives, and propose acceptable project changes to the company. A badly managed team adopts a “give-up and complain” mentality when it encounters a major obstacle.

Another lesson learned is that a project must be re-scoped when it is clear that the initial design objectives are not going to be met. Since it is impossible to extend the design timeline, the project goals must be reduced. The student team and the faculty coach must make a realistic case for project modification and present it to the liaison engineer, and must also provide revised project goals. The liaison engineer wants to see that a serious attempt was made to follow the original project definition, and wants to be given a clear explanation of the circumstances that preclude the original project definition from being executed in a timely fashion. A negotiation proceeds in which a new and realistic timeline, a re-allocation of resources, and a revised project deliverables list are agreed upon. Experience has shown that the re-scoping process can be successful and regarded as acceptable by the industrial sponsor whenever it is clear that the faculty and the student team have pursued the original plan with determination, hard work, and intelligence.

**Industry interaction—the administrator’s point of view**

The industry interaction begins when the director contacts executive directors of different companies to solicit design projects with the goal of eventually securing participation through a letter of agreement. The letter of agreement specifies the level of funding, intellectual ownership, liability, industry-liaison support, and the project scope. The Dean of Engineering, the Director of Sponsored Research, and the industrial sponsor’s executive champion jointly sign the letter of agreement. In about 80% of the cases, the letter of agreement stands as the sole contract for the project execution. The remainder of cases are handled through more formalized contracts. The letter is sent to the industrial sponsor along with an invoice once a project summary has been agreed upon. It usually requires several iterations of a project summary to develop an appropriate, achievable project scope. Subsequent iterations are often made after a faculty coach has been assigned to the team and a detailed dialog is established with the liaison engineer.

We have learned that the most difficult and most time-consuming activity in the management of the IPPD program is the recruitment and scoping of 25 to 30 projects before the start of the fall semester. Beginning in the month of January, all current, past, and potential sponsors are mailed project sponsorship request
letters and IPPD program brochures. The brochures include a program overview, the history of the 159 projects undertaken to date, an up-to-date faculty listing and project selection criteria. Over the next seven months, the director works with the industry contacts to obtain approval at the executive level to support the program with a project, and then works with managers and engineers to define appropriate projects. The faculty coaches are heavily involved in the project selection and scope definition. Faculty develop a rapport with their current sponsor and typically stay with that company for future projects. For new sponsors, a team comprised of the director and selected faculty coaches from a variety of disciplines visits the sponsor site with the goals of persuading a sponsor to join and to sort through potential project ideas.

Once the project commences in the fall, the faculty coach and the project team handle the majority of the industry interactions. This interaction between the team, coach and liaison is critical to the project outcome. Each team and coach typically meet on a weekly basis to address the current and future deliverables, quantify the progress of the project, discuss issues that have arisen, and to make modifications to the task assignments. Depending on the liaison’s schedule and the project status, weekly, biweekly or monthly teleconferences with liaison engineer are held. Frequently the liaison engineer participates in the teleconferences accompanied by other company experts on a particular issue at hand. Some projects require frequent visits to the industrial sponsor’s site for gathering data, finalizing design details, as well as for visual inspection of existing equipment, fabrication of prototype, and testing. The projects that seem to reach higher levels of success are those that have a liaison who is readily accessible, involved, with high interest level. The liaison serves as an extended team member and a role model for the students. A significant part of the students’ learning comes from interactions with the liaison engineers. The role of the Program Director is to make sure that there are no administrative bottlenecks that preclude the team from maintaining timely communications and making travel arrangements to interact with the sponsor.

Industry interaction—the coach’s point of view

A coach’s industry interaction starts at the project definition phase. Typically, the coach and the potential liaison engineer meet at the company site to discuss project ideas. Often, the liaison engineer has a design idea or two that can be considered as the basis for a project. The coach knows the student capabilities, the in-house technical resources and the project schedule. Together they can define a general project idea, or perhaps a list of several ideas to select from. Then, the liaison engineer can add detail and formalize a project by writing a brief project summary in an official form provided by the IPPD program. The coach works to make sure the project is important to the company, but not critically important (otherwise the company should do the project themselves on an accelerated schedule). In addition, the project must be within the capabilities of the students and should not require unbudgeted technical resources.

The project summary provided by the liaison engineer is a great teaching document for the student team. It contains concepts and jargon the students very likely do not understand, and presents a problem that is very new to them. Working through these concepts and jargon is done through background presented by the coach, a site visit to the sponsor, and through question sessions often held via telephone with the company liaison engineer. This mode of operation represents a new style of learning for the student team. The team evolves a project concept from the summary form and these interactions—all customer specifications and needs are typically identified within the first 4 weeks of the program. At this point, the team is in a position to identify areas where technical training and CAD tool needs are apparent. Manuals and references are acquired for understanding technical issues.

A weekly teleconference with the liaison engineer is essential to discuss issues and gather customer information. Written minutes must be kept for each team meeting so that specific student responsibilities are easily identified, allowing also for measuring individual students’ performance in the future. Many sponsoring companies require that the team publish agendas and minutes as part of their ISO 9000 compliance. One lesson learned is that an Internet web site is a very valuable tool for supporting all

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communications between the liaison engineer and the student team. Electronic copies of all designs, meeting minutes, reports, in-class deliverables, and technical manuals can be made available on the web site. When anyone in the sponsoring company needs to know what the student team is doing they can simply refer to the web site.

Two weeks after the team is established they visit the company and meet the liaison engineer. For many of the students, this is their first company visit. Besides learning the etiquette of being a good guest, they are required to ask questions about the project so they can proceed with their designs. The liaison engineer introduces the team to the relevant equipment and processes associated with the project. This visit shows the students how the design project will interface with the company's equipment and establishes a personal relationship with the liaison engineer.

Eight weeks into the project, the team presents its Preliminary-Design Report to the liaison engineer and any other interested members of the company. This is a critical review from the project management perspective because, typically, the company signs-off on the team-generated project proposal. For the students, it is the first critical design review they have ever experienced. Professional engineers often find problems with their proposed work and the students have to learn how to respond to the criticism and how to modify and fortify their proposed design.

An additional System Level Design Report and Final Design Report are extremely important for the development of the project and for the training of the student team. Since these major project reports are followed by reviews in a public forum, the students are motivated to deliver a high-quality professional presentation in response to the peer pressure generated for the event and the coach's expectation of valued deliverables. To prepare for a project review, the students must collect all the different aspects of their work and assemble them into one cohesive story. They must prepare professional-quality slides and a professional-quality report. They must work as a team, edit each other's work, and then undergo a peer and faculty review of their proposed oral presentations. After all this preparation the teams are finally ready for the presentation of their project to an audience composed of industry engineers including their company liaison and other company representatives. Each student team member must demonstrate effective growth in communication, presentation, writing, organization, and marketing skills.

**JIT course delivery**

Throughout the two semesters of activity, a fifty-minute lecture is generally held twice a week. The lectures provide just-in-time (JIT) presentation of materials required to meet the deliverables schedule imposed by the structured development process. The IPPD faculty team-teach the course, and industry speakers provide supporting lectures. A constant struggle is to deliver lecture content that is relevant and appealing to a large number of the students from different disciplines. Since the program may involve as many as ten different academic disciplines, it is rare for the speaker to succeed in engaging the entire class during a lecture. It is evident that many of the mechanically-oriented students pay less attention during electronics or software-oriented lectures, while the same holds true of the electrical and computer engineering-oriented students during machine-systems oriented lectures. Since the course attempts to teach all the students a process they can use throughout their careers to develop any kind of product or process, we have found that it is impractical to break up the course into discipline-specific lectures (say, for example, requiring that only electrical engineering majors need attend a specific lecture). Furthermore, once these engineers transition to industry, they may spend significant time working on problems that lie outside their academic disciplines. This fact is frequently reinforced by comparing the educational background with the responsibilities of the liaison engineers, since it is not uncommon to find a significant disparity there. For example, we have worked with liaison engineers who were trained as mechanical engineers but whose primary responsibility is to develop object-oriented software, and with electrical engineers who are charged with manufacturing and assembly responsibilities.
Each team holds weekly workshops to adapt the lecture topics to specific project needs. The coach acts as a facilitator for the workshops; therefore the coach must understand how to tune the generic deliverable content to a meaningful project activity. The attendance of the coach to the faculty meetings is key to keeping a consistent level of content across all the project teams. It is critical that the Program Director and other experienced coaches spend time training coaches who are new to the IPPD program regarding the deliverable content.

**Hardware-software integration**

Since the inception of the IPPD program, software engineering has played an increasingly important role in the project success. Our experience indicates that software is rarely ready for integration when the hardware prototypes are ready to begin testing. Major contributors to delays in software development include a lack of attention to development issues early in the project, beginning coding before the requirements are understood and documented, and the inability of inexperienced students to foresee features needed for the effective integration of their code with existing systems.

A software engineering process tailored to integrate seamlessly with the overall IPPD methodology was developed and documented in the *New Engineer's Training Manual* to address key hardware/software integration issues. This process provides a structured approach and defines a series of software deliverables targeted at increasing the chances of timely, successful hardware-software integration. The software development process features the following five major phases (see Figure 2): (1) System requirements and product design, (2) Detailed design and test planning, (3) Code/unit test/build and integration, (4) Product verification, and (5) Product release.

These phases mirror the hardware development process timeline. The specific phases and deliverables are illustrated in Figure 1 as if they are standalone and sequential; however, in practice the deliverables overlap and often parts of the software product functionality may move to the next phase, ahead of others. In this way, critical modules can be prototyped rapidly and tested to reduce project risk. The goal of the first phase is a complete and testable set of software specifications. These specifications provide the key technical content for the Preliminary Design Report and review. It is expected that the end of phase two be completed a few weeks ahead of the hardware system level design phase. This early finish permits the software engineers to begin their coding activities prior to the end of the first semester, hence ensuring that integration testing can start as soon as possible. The key activities in phase four—product verification—are testing to ensure that all the software functionality has been established, and testing to guarantee that the final product (i.e., the integrated hardware and software suite) meets the required performance specifications.

Projects involving software and hardware solutions must deal with a number of significant challenges that must be overcome through the intervention of the team coach if the project is to be successful. For example, our experience shows that many computer-engineering students participate in IPPD prior to completing courses in software engineering, where they learn how to design and develop software. It is also not uncommon for them to be missing a course in operating systems, where they learn to write code that must coexist with large systems. Due to these shortcomings, the students are likely to become frustrated with the enormous amount of planning and specification work required prior to writing the first line of code. The requirement to reuse existing code—a good target is 80% reuse—conflicts with their experiences of writing short, standalone code. Another challenge that we have to respond to is that in our university the students are trained to develop embedded code on the Motorola HC11 series of microprocessors. While this processor provides a flexible platform for teaching embedded systems programming in semester-long courses, it is not appropriate for industrial applications, and the students find that they are expected to learn very quickly to master the intricacies of developing code for an unfamiliar microprocessor architecture. Another problem is
that after the initial learning curve has been completed and new embedded code has been generated, the team may find that the code must be tested before the required hardware is actually available.

Figure 2. Integrated Product and Process Design Program structure for software-oriented process deliverables

Given the nature of these challenges, a major lesson learned is that in software-related problems the company liaison engineer and the faculty coach must recognize early the criticality of timely software development. The liaison and coach need to agree on and implement the following strategic activities to ensure the successful integration of the hardware and software components of the project: (1) agree upon software deliverable milestones and aggressively abide by the development schedule, (2) provide access to software libraries available to the sponsor company, and regularly review progress on targets for code reuse, (3) do not begin coding until the requirements, specifications, and design constraints are agreed upon, (4) identify a microprocessor expert—either an in-house engineer or graduate student—and make this individual available to the team for embedded systems training on the target chip, and (5) when possible, purchase hardware emulation software so that the team can test the embedded code and drivers prior to the availability of the hardware.
Assessment results

The students complete self-assessments of educational objectives at the beginning and at the end of the course. The educational objectives include the following: (1) applying engineering knowledge in design, (2) understanding how to integrate product and process design, (3) understanding structured design methodology, (4) understanding principles of teamwork, (5) understanding principles of effective oral communication, (6) communicating effectively orally, (8) understanding principles of effective written presentations, and (9) communicating effectively in writing. Figure 3 shows the composite results compiled since the 1996-1997 academic year. Analysis of this data shows that in most of the nine categories, significantly more students report in the “very-good to excellent” rating categories (a rating of 4 to a rating of 5 on a 5-point Lichert scale) when comparing the pre-IPPD to the post-IPPD self-assessment results. More quantitatively, in seven categories the data reveals double-digit percentage increases from pre self-assessment to post self-assessment ratings of very good to excellent. In addition, over the same data-collection period, 92% of the post-assessment respondents agree or strongly agree they are confident to practice design in industry, and 90% of the respondents agree or strongly agree that the course improved their ability to conduct independent research.

Comparison of Pre and Post Self-Assessments of Educational Objectives
IPPD Program 1996 to 2001
592 Pre Assessment Respondents
428 Post Assessment Respondents

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Figure 3. Integrated Product and Process Design Program Educational Objectives from 1996 to 2001.
Conclusions

This paper describes some of the lessons learned during six years of continuously improving the Integrated Product and Process Design courses at the University of Florida. The program has provided an enriching experience for both the students and the faculty participants, and the participating industry sponsors have benefitted from early access to potential new hires, an opportunity to participate actively in the transition of students to professionals, and interaction with a talented and diverse faculty body.

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