Direct, Authentic and Formative Assessment of Cross-College Industry-Sponsored Capstone Project Teams

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Since 1994 Lehigh University's Integrated Product Development (IPD) program has provided a series of capstone courses that has engaged students from our 3 undergraduate colleges in industry-sponsored new product development and process improvement projects. In that time span more than 50 different companies and individuals have sponsored project teams in such diverse areas as biofeedback devices, manufacturing automation, supply chain redesign and commercial products sold in stores and even on shopping channels. Our industry sponsors have had direct impact on both what we teach and how we assess the individual and team performances in these courses. Now in 2011 the IPD courses enrolled 192 students working in 29 teams of 6 or 7 students each. In order to manage these diverse project teams from a wide array of industry sectors, the authors have developed a set of direct, authentic, and formative assessment tools to be used by the team advisers for the multiple gradable moments that occur throughout the two-semester capstone experiential courses. This paper will describe the context of these courses, give specific examples of individual and team performance activities and the assessment rubrics we use to evaluate them, describe how we use our assessment tools to manage the IPD process, and finally, end with the greatest challenge we face in preparing our students for professional careers.

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Introduction

In 1990 based on an industry workshop sponsored by Lehigh University's Department of Mechanical Engineering and Mechanics, the faculty, staff and industry representatives designed, developed and implemented an award-winning capstone program called Integrated Product Development or IPD. Throughout the IPD program's history, industry sponsors have played a key role in influencing the course content, pedagogy and assessment. Based on the success of the 1994-1995 pilot courses with 3 sponsors, Lehigh's IPD program won the ASME award for curriculum innovation. In 1997 with 5 companies and local entrepreneurial start-ups as sponsors, Lehigh University, featuring the IPD program, received the Newcomen Society's award for the promotion of America's free-enterprise system. And in 2006 Professor John B Ochs won NCIIA's Olympus Innovation Award for being the program's founder and only director.

Now in 2011 the IPD program has grown to 15 sponsors enrolling 192 students in 29 cross disciplinary teams of 6 or 7 students in each team. Today our sponsors represent established global firms, local entrepreneurial startups, student startups and local nonprofit organizations working on social entrepreneurial initiatives.

Throughout the past 22 years our industry sponsors have helped design, implement and continuously improve our program including the development of assessment tools and methods.

IPD Capstone Course Description

Lehigh's IPD program is based on a philosophy of experiencing new product or new process development in the broadest context focusing on the form, fit, features, function and finances of a real-world project. The faculty are considered experts in the IPD process that is described on the IPD web site as 3 descending levels each with increased details.[1] Our industry sponsors provide the business and social context for our student teams to apply what they are learning in lectures and 'best practices' workshops. In what we describe as an on-campus co-op, the sponsors also act as industry mentors with the relevant business knowledge and know how.

The IPD program is a required 2-semester 5-credit capstone course for students enrolled in Mechanical Engineering, Materials Science and Engineering, Bio Engineering, Design Arts (our equivalent to industrial design), and Supply Chain Management. We also attract a smattering of students from other majors, such as computer science, theatre, management and marketing, who take IPD as an elective.

For most students the IPD program starts in the second semester of the junior year and concludes at the end of the fall semester of their senior year. In some cases individual students or teams of students continue with a focused research aspect of their IPD project as their senior thesis.

Our industry sponsors provide the projects and their financial and personnel resources to help us get our students to the point that they will be able to hit the ground running when they join the professional workforce (perhaps at the company) upon graduation. Many companies also provide summer internships between the spring and fall semesters to review potential hires. For 22 years industry sponsors' main reason for involvement with the IPD program has remained the same: to hire our best students and to that end are very interested in what we do to prepare them and how we do it. The IPD web site lists our current sponsors and their projects.[2]

In the IPD program, students experience the new product development or process improvement process with the help of faculty and industry sponsors. In both of these instances, students must identify the business opportunity; develop the business case; identify customers, stakeholders and end users; develop customer needs and target specifications as compared to competitive benchmark solutions, the status quo and existing patents; employ brainstorming techniques to generate hundreds of concepts; perform concept selection and concept testing; develop product architecture and apply industry design methods; fabricate build and test mockups and prototypes; complete detail design models, drawings and bill of materials; apply design for manufacturing techniques; plan the marketing and manufacturing launch; identify the first buyer/users and propose the level of resources needed to reach the first customers; while developing economic models of 'what if's'; and creating and managing intellectual property.

Feedback from the first workshop in 1990 to today's sponsors, tells us that IPD mirrors the product/process improvement methods used by most of our industry sponsors. Furthermore, having our students experience this process is important to them. Equally important to our sponsors is the development and assessment of our students' 'higher order' skills, often called 'soft' skills in engineering programs. These skills include working in and leading a cross disciplinary team, communicating through oral, visual and written media, managing information and data, managing a project while behaving in an ethical and professional manner.

Direct, Authentic and Formative Assessment

Direct, authentic, formative assessment tools are designed to evaluate and measure a student's performance, output or artifact in a given area by observing actual work activity, in real time so that the evaluation and feedback may be used by the student to improve what they do and how they do it. In the context of the IPD capstone courses they are applied to both individuals and teams by both industry sponsors and faculty.

Authentic learning requires authentic assessment. As an example, IPD students are graded on their ability to function on and lead a team. Rather than having the team build a pasta tower or complete a ropes course (inauthentic), the IPD assessment tools focus on capturing the actual interactions and work product created by the team as they move through the project itself.

Direct assessment of a student's teaming skills occurs when the team adviser observes the team as a whole as well as each student's performance in the team environment at weekly meetings. It's more common to see teamwork assessment done indirectly by using self or peer evaluation. We use these to supplement the adviser's evaluation but not to give grades directly.

An example of formative assessment, which by definition is done periodically, can again focus on the teamwork example. When observing team interactions at meetings and work sessions, advisors who see team members not contributing will provide feedback in order to help the team improve while still working on the project, rather than at the end. They may redirect the team by suggesting a 'best practice' such as having every team member accountable for one agenda item. The result of the suggested "fix" can then be followed up at subsequent team meetings. The student and team will receive not only periodic grades for the teamwork but know how to do better, while still participating in the project.

The kicker in all of this is that it takes resources, time, training and constant monitoring, managing and regulating the team advisers, especially challenging with 29 teams focused on diverse projects, 15 team advisers and an equal number of industry mentors. We have found that weekly meetings of the team advisers over lunch with a formal agenda are a valuable way to insure the proper use of our assessment tools. At these meetings, to which all other support personnel are invited, we review the past, current and next phases of the IPD process. We review the upcoming deliverables, presentations, report milestones and the associated rubrics, which capture what we call gradable moments.

Examples of Gradable Moments

In addition to weekly lectures on best practices at various phases of the IPD process, student teams are expected to meet twice each week, once with and once without the team adviser. Each week the team is

expected to post a weekly brief report on the collective and individual accomplishments as well as the hours spent. At 1/3, 2/3 and the end of each semester, the team writes a progress report and gives an informal Tackboard or formal final poster and oral presentation to industry, faculty and student reviewers. At the same time the individual student notebooks and confidential peer evaluations are reviewed by the team's adviser.

Assessment rubrics have been developed to provide grading equity and consistency across all teams, all projects and all advisers. A rubric is both a way to provide students with your requirements/expectations and a grading scheme. It uses content specific and generally recognizable language to describe levels of performance from 'Excellent' (93-100), 'Good, but could be better' (83 to 92), 'Limited, but okay' (73 to 82), and 'Deficient and needs work' (50 to 72). If the work or performance being graded doesn't meet even the language in the deficient category, an 'Incomplete' can be given until the advisor and student decide on a remedy. There are a total of 21 rubrics completed each semester for each team and another 9 for each individual student.

Rubrics to assess a student's contribution to the team are used by advisers to inform the grades given for individual performance, which is 20% of their final IPD grade. The rubric captures observable performance, while the weekly briefs and peer evaluations round out the picture. The categories in the 'Individual Contribution' rubric are: 1) Technical/Business Contribution, 2) Workload and Resourcefulness, 3) Teamwork and Leadership, 4) Professionalism and Interaction with the Sponsor. Each of these is then graded based on the 4 levels of performance. As an example of the descriptive language of the rubric, the four levels for #3) Teamwork and Leadership are:

Excellent: Inspired the vision of the team, nurtured a team harmony, and took on a role of leader when appropriate. Always a team player. Guided the progress of the project and delegated responsibilities; was paramount in project's success.

Good: Willingly took on a leadership role as needed and did so efficiently and effectively. A team player. Interaction with team mates was positive and contributed significantly toward the project's success.

Limited: Accepted leadership in minor aspects of the project but was not efficient or effective. Sometimes a team player. Interaction with the team did not contribute significantly toward the team's success.

Deficient: Did not assume a role of leadership in any aspect of the project. Rarely a team player. Contribution to the team was at times counterproductive.[3]

An incomplete might be in order if the adviser finds a combination of issues: time reported on weekly briefs is low, multiple peer reviews show poor performance, and direct observation by the adviser indicates 'free-riding' by the individual. An incomplete is a warning to the student that if the current level of performance continues, they might be 'fired' by the team and will have to drop the course and delay graduation for a year. Because our assessment is formative and continuous with key milestones at 1/3, 2/3 and 3/3, of each semester, incompletes are rare.

Managing IPD Projects through Assessment

The 'Tackboard Oral Presentation' rubric is used to assess the whole team. This unique presentation rubric is used at 1/3, 2/3 and 3/3 of each semester with the evaluation categories dependent on where the team should be in executing the IPD process. Through ongoing discussion of team progress and IPD process at the weekly luncheon meetings, teams can be kept on schedule to meet and be graded on major milestones throughout the project. The rubric for Tackboard 1, semester 1 includes the following major categories: 1) Relative Progress, 2) Project Scope, 3) Value Statement, and 4) Communications. An example of the language used at the two extremes for the 'Value Statement' categories includes:

Excellent: Tackboard reflects that the team has an understanding of both the business & technical challenges of this project and that they are building a foundation which will allow them to move forward in a business context, and

Deficient: There is little or no reference to the technical or business challenges that might occur within this project.[4]

The rubric for Tackboard 2, semester 1 includes the following major categories that reflect where the teams should be at this milestone: 1) Mission, Needs and Target Specifications, 2) Concept Generation and Selection Process, 3) Description of the "Best" Concepts, 4) Rationale for the Definition of 'Best', 5) Plans to Test your Best concept. An example of the language used at the two extremes for the 'Rationale' category includes:

Excellent: Team has clearly articulated why their top concept was chosen & how it is relevant to the market/business context. The team has shown why many of the concepts that were generated & screened were rejected and the team has justified & supported the concept selected as compared to other benchmark solutions.

Deficient: The rationale for the concept selected is unclear and/or is irrelevant to the market/business context. The team has not shown that any other concepts were generated, screened & rejected and they have not justified and/or supported the concept selected as compared to other solutions.[5]

The rubric for Tackboard 3, semester 1 (final) includes the following categories: 1) Overview of the Semester's Work, 2) Proposed Solution and WOW Factor, 3) Technical Content, 4) Business Content, 5) Conclusions, Recommendations, and Next Steps. The description of the 'excellent' level for all five of these categories is shown below.

Overview-excellent level: The team is able to clearly articulate the overall goals of the project with enthusiasm. They are able to answer questions on the topics presented as well as other relevant topics. They have taken full ownership of the project & presented it in such a way that they could have been mistaken for employees of the company.

Proposed Solution-excellent level: The problem & solution & how it will be accomplished is discussed, supported by quantitative information & compared to the competition. The solution is innovative - WOW!

Technical Content-excellent level: The technical requirements, information and specifications presented here indicate that the solution is based on sound engineering/technical principles. Technical content is well developed, explained and presented.

Business Content-excellent level: The business context & financial issues related to project are based on sound business principles & are clearly represented. Business content is relevant, and well presented.

Conclusions-excellent level: Plan for production & future implementation are fully outlined and discussed. A marketing plan & product or process introduction scenario are addressed. The future steps of this product or process is clearly mapped out.[6]

In total for all rubrics for each category and for each of the four levels, we have generated over 300 written descriptions of the performance levels. Each week the advisers meet to review progress of each team as measured by these rubrics. On a regular basis the language of these is reviewed and updated as needed – a continuous improvement process that goes well with ABET reviewers.

Our Biggest Challenge: Written Communications

Throughout our careers teaching engineering design and managing student projects there is one constant with regard to student performance: our students cannot write. This could be due to the fact that they do not read or write throughout the engineering curriculum. Regardless of the cause, the students enrolled in IPD must communicate professionally with their sponsors though email, weekly briefs, progress reports, phone calls and online conferences. In 2005 our sponsors made this point loud and clear when a full 1/3 of team progress reports were returned to us as 'unprofessional' with format, grammar, spelling errors and in several cases, writing that was deemed incomprehensible. This occurred even after faculty had read and graded the reports, in some cases awarding A's. Upon inspection we determined that faculty advisers were not reading the reports with an eye on format, style or professional tone.

Our conclusion: writing is too important to leave to the faculty. For the past 7 years we have been working with a new group on campus called writing fellows, students who've been identified as excellent writers and are trained to work alongside faculty to help fellow students improve their writing in the context of the course in which they are working. With 15 writing fellows working with two teams apiece, writing each of the 5 progress reports became a five week process from outline to final approval with at least 3 revisions to each report. The process includes multiple reviews for style, format, professional tone and comprehension. While the write-review-revise process frustrates many students and some advisers, we have not had a single report rejected by an industry sponsor since the program has been in place and we believe that at last most students are learning to write more effectively.

Conclusions

In this paper we tried to demonstrate the role that direct, authentic, formative assessment tools play in providing a capstone course experience that has been not only recognized for its value to our industry sponsors but in part, developed by them. They have helped us devise methods to both teach and measure them so that we produce students who can hit the ground running when they arrive at their first jobs. Through the use of rubrics at gradable moments throughout the project, we are able to measure student performance that mimics what they will be doing when hired and guide them through the challenges faced by other first-time employees. In particular students who graduate from our IPD courses learn by experiencing the new product development process, to work and in many cases lead teams, and finally, to communicate professionally, both through their writing and oral presentations.

References

1. Lehigh University Integrated Product Development (IPD) web site http://www.lehigh.edu/IPD Follow the 'About IPD' heading.
2. Ibid. Follow the 'Current Projects' headings.
3. Ibid. Follow the 'Assessment Rubrics' headings, 'Individual Contribution' rubric.
4. Ibid. Follow the 'Assessment Rubrics' headings, Spring Semester 'Tack Board #1' rubric.
5. Ibid. Follow the 'Assessment Rubrics' headings, Spring Semester 'Tack Board #2' rubric.
6. Ibid. Follow the 'Assessment Rubrics' headings, Spring Semester 'Final Oral Report' rubric.