Academic, Industry, & Capstone Design-A View

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The interdisciplinary design project I & II courses (IDP) span two sequential semesters offer opportunities for engaging industry partners while addressing academic needs and perhaps serving as a discipline specific capstone design project. The structure of the IDP is presented which encompasses a discussion of the significant elements underlying conduct of actual projects and involving clients. The significant elements of the IDP are presented and discussed from expectation to communications/documentation. The need to identify technical advisors beyond the instructors is noted. Multidisciplinary design team projects influence the learning and application of the process of design in concert with outcomes of design. There are impact to grading, employing the design process, and actual project outcomes. A set of guidelines for project selection is proposed recognizing the necessity of coupling students and industrial concerns for support of the project. Besides the traditional ways of defining resources, students interning at various industry firms secure expertise from those firms in the form of informal consultancy. Clients can come from "industry", "faculty," and "organization/government" sectors with varying capacity to participate in design projects and at different levels.

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Capstone design courses present unique development and growth opportunities for the students. Equally, these courses present the involved faculty non–routine management and learning challenges. These will vary as the mix of students, selected projects, academic requirements, and industry participation. Folded into the considerations are questions (and the list can be expanded considerably) such as:

- Is the IDP to be a discipline specific capstone, fully interdisciplinary, or a combination?
- Who are the industrial partners?
- Do industrial partners' personnel and/or faculty serve as technical advisors to capstone projects?
- What are the outcomes (expectations or results) of the clients versus those of the academics? Who defines the suitable outcomes?
- How are outcomes/expectations melded into the academic environment replete with the timing/scheduling required for academic purposes?

At the University of Tennessee at Chattanooga (UTC), the engineering curricula call for engineering students to participate in the IDP which is the culmination of design throughout the curriculum[1]. For several of the engineering disciplines, this design sequence of courses will also serve as a discipline specific capstone. This is a function on the discipline and specific project. The interdisciplinary design project course sequence (IDP) also serves to lead the students through the engineering design process and address communication skills, professional ethics, environmental and social implications, and teaming.

Typically, the IDP is conducted by organizing the student participants into project teams (nominally 5 to 8 projects with 6-12 students) which will be maintained throughout the IDP. Each team will work on a different capstone project previously selected by instructors from solicited entities. Projects are sought for the IDP from industrial firms, service firms, non-profits, organizations, government, and faculty sponsors. These are all considered industrial partners and will be termed as clients for the purpose of this paper.

With coverage (academically and professionally) for the IDP and an intent to employ realistic projects ("externally generated"), there has evolved a number of instruments for assessing student and team performance. This enables a grade distribution to a team component and individual component. A typical distribution is: Team Component- 50% (Semimonthly Reports- 5%, Team Presentations-10%, Mid-Term Report-15%, Final Report--20%), and Individual Component- 50% (Individual Project Journal-20%, Individual Presentations-10%, Peer Evaluation-10%, Class Participation-10%). The weighing of components may vary between semesters depending on need to increase student emphasis on one aspect and reduce in another aspect, such as project journals increasing and Individual Presentations decreasing.

IDP is structured with five significant themes threaded through the duration of the capstone design. These are: outcome expectations, client and technical

advisor involvement, student involvement, creativity and thinking, and communication/ documentation. These are themes that are sought and elucidated throughout the IDP by team and individual assignments. The "hard" defined project outcomes for each project may be achieved for student competency and engineering program evaluation yet is it important to evoke these other elements as well.

Supporting the IDP and providing a text and reference is a textbook[2] on engineering design with a mechanical engineering orientation. In-class lectures and student assignments integrate, for example, additional topics of decision-making, system engineering, project scheduling, estimating, etc. There are numerous resource texts for these.

Project Outcome Expectations

Each project outcome expectations will vary based on the perspective of the client, instructors, and student team. Outcome expectations must be established which recognizes and accept that the IDP is academic and must meet an academic timeline for evaluation which may or may not equate to a desired project outcomes timeline. Secondly, each project starts at a different beginning point giving a project timeline which may not mesh with executing the design process from start to end within the academic timeline/schedule. These differences must be reconciled, acceptable outcomes established, and put in context for the student teams at the onset of the IDP projects. The established framework to achieve this agreement must adhere to the following tenets.

- The projects are conducted in two semesters.
- There are academic learning objectives/outcomes that need to be accomplished.
- Individual client views/expectations must adjust to the level of student involvement and level of engineering effort needed given other demands on the students.
- The selected projects are not critical, necessary, or time-sensitive to the client.
- The outcomes permit the students to meet the learning sought: engineering design process, professional development, and communication.

Within this framework, the outcome expectations are defined by the client, student team and instructors. This is done through the development of a project/problem statement, project objective, and definition of project scope/statement of work and a work breakdown structure. A key item is establishing the project objective. Normally each project undertaken will be at a different initial state/status of definition and specificity. Thus, the elapsed course time required by the student team to complete the items varies from project to project. The projects do not fit neatly into the structured-course mold for an academic semester or academic year timeline for teaching the engineering design process as is the case of the IDP. For example, well-defined project statement and objective is readily defined by the rules and regulations and competition dates of the Society of Automotive Engineers (SAE) Mini-Baja collegiate competition which has industry linkages inherent. The contracting project undertaken is a loosely defined project to define, site, and design an intermodal transportation center (ITC). This facility should accommodate parking and passenger transfer in a city environment. It must serve multiple transport modes, alternate-fueled urban transport vehicles, automobiles (conventional, hybrid, electric, hydrogen fueled), mass transit (conventional, hybrid, and alternate fueled), bicycles, etc. which has diverse and less direct industry linkages.

The engineering discipline breadth of IDP projects necessitates guiding each team's work on the learning/executing the engineering design process and developing/ encouraging industry linkages for technical inputs. This is key consideration for the IDP since real (industrial) projects do not neatly fit (timing and progress) the structured learning pace in the academic environment. The student teams repeatedly do grapple with non-alignment of design engineering process in the capstone versus the structured-course learning experienced to date. The integration and balance of the discontinuities while maintain the industry involvement is an ever present focus. Faculty with strong industrial interactions (or experience) is a positive factor for the IDP as well as with clients/technical advisors.

Client and Technical Advisor Involvement

With multidisciplinary design capstone and/or client offered projects, the role of a client and/or technical advisor(s) can provide significant impact to the capstone project. The role can assume markedly different involvements and functions. It is through the technical advisor(s) that detailed design elements and considerations can be evoked in IDP projects. Having the availability of a technical advisor to the team can result in marked differences in the project outcomes. The technical advisor may be from the client or faculty.

The designation and offering of a technical advisor from the client or other faculty to a project is the "simple piece of the equation." Securing the access, time and input becomes the "difficult part of the equation." If it is an external client, often business demands and pressures on time inhibit the interaction between the team and technical advisor. This is also manifest by issues with communications and securing data and/or information. When the technical advisors

are from faculty, instructional demands, research, and schedules can significantly hinder interaction with the project team.

From accumulated IDP experience, securing involved and contributing technical advisors require extension beyond offering to host an IDP project. The characteristic sought for client/advisors are: student intern at a client offered project, alumnae at the client with direct interest in the project, a faculty researcher offered project, or faculty offered IDP project and assigned as technical advisor. The efficacy of these guidelines is demonstrated by two projects. Measurement of foam billets and the design of an intermodal transportation center (ITC).

The foam billet measurement project served as an industry/client offered project. It originated from two alumnae who were employed at the particular company and offered the potential to reduce waste and improved product quality. There was a student who was interning at the company. This combination provided close interaction by the project team and company. The team actually provides economic justification to the company's headquarters for the in-plant system.

Second, the ITC project had as client a faculty researcher who also served as advisor. The project team had to make contacts with government and private engineering companies project participants. The project involved all aspects of defining need and siting, sizing, facilities to meet vehicular needs, and designing the facility. The team cultivated clients/external advisors who embraced the project objective recognizing the contribution to the community. Their contributing meeting time and data/information result was a design which led to a national competition award.

The client and technical advisor provide an important link with the specific projects. They assist in framing the specific course requirements to the project and providing a connective link from theory to application. Indeed, the technical advisor is given access to the electronic course system so that the advisor has the capability to keep up-to-date and communicate with the project team.

For faculty serving as technical advisors a mechanism is being put in place to recognize and give accountability to their participation. The mechanism will provide the advisor recognition for time and responsibilities devoted to the respective project. Particularly, principle/common instructor will be maintained for the IDP and all projects. Distinct projects are separated into meeting times (or sections) and faculty assigned to each as a co-faculty. This provides of recognition for faculty as discipline specific technical advisors and accountability of faculty to course requirements.

Overall the level of engagement for clients and technical advisors is an ongoing area of focus to balance expectations and needs. One circuitous route for having industrial involvement although it may not be client-based has been student team members who are interns. These students often access and utilize the technical expertise and know within that company.

Student Involvement

The IDP introduces new components of learning on the student which may not have been encountered to any extent in other academic work. The student is now to be self-directed and contribute to the "Team." The requirement creates dependency on others' work for a significant component of the grade. Equity issues arise and are heightened given the variability of team member participation. Many of the students also work which complicate the matters of engagement and involvement. Peer evaluations are conducted and yet these present the student the dilemma of the evaluation while having to work and interact with the other team members as peers.

The learning experience of functioning, working, and communicating within the environment of a team begins to expose group dynamics which may not have been dealt with before. The student as a team member must learn and handle the interpersonal components that surface including the issues of high performers, low performers, procrastinators, asserters, and in-betweens. This theme is where added industrial involvement would be welcomed.

Creativity and Thinking

The IDP is a vehicle to evince creativity and cogent thinking of the teams through the respective projects. Execution of the projects can surface and expose areas for enhancing and growth of the student's capacity. The design process activities have shown areas where increased emphasis is desirable. Gaps have also been identified in the "design across the curriculum" program used. Several are identifying conceptual alternatives, evaluation criteria and methods, decision making criteria, and designing to an integrated objective (or integrated outcome). Strengthening these areas will enhance translating non-definitive project objectives or statements into definitive project objective and design envelope. From the design envelope requirements, performance envelopes or engineering characteristics leading to enhanced preliminary design, analyses, simulations, etc. The theme embodies integrating and asking questions such as: Why? How?, Alternatives?, System compatibility?, Functioning?, etc.

Redesign of selected course components and enhanced assignments are anticipated to add to strengthening this element. Efforts will encompass

integration of advanced modeling and simulations components and analytic processes.

Communication (Documentation)

Communication is integrated into the IDP and seeks to build-on and enhance the communications skills of the student. There are repeated written and oral requirements. Two such are project status presentations by the team at mid-term and end-of-term and mid-term and end-of-term reports. Clients and advisors are invited to attend the presentations and to assess all team presentation not just theirs. Reports are provided to clients as well. The presentation assessments by the clients are more positive than faculty instructors. Each student is required to give an individual presentation each semester.

A project engineering journal is kept by the student. This assists in the student recording their efforts and activities regarding contributions to the project as well as items dealing with IDP. Semi-monthly status memos are filed by each team as well.

Improvement and Enhancement

IDP is to be divided into sections under a common course heading with each section representing a project. Student project self-selection occurs at registration. A context faculty is assigned to a section providing supporting assistance and receiving credit. IDP grading weights are modified to increase the individual component and reduce the team component with assigned support faculty contributing to grading. Each class will be delivered in one session per week.

Specific clients and projects will be defined and scoped prior to start of IDP with recognition of the engineering student mix in each section. An agreement for client and course faculty is being developed to capture understandings and willingness to participate including technical advisory role. A series of project progress presentation will be delivered to the client at the client's facility (if possible) by the team during each semester of the IDP. Client/technical advisors will be asked for feedback. Technical presenters are planned for specific project or projects during the course of the IDP. Industry presenters are used to all course sections for technical discussion.

Compact and intense delivery of the design process will occur at the start of IDP. Early introduction of the projects to teams will enable the process of design to be practiced while balancing with outcomes. The acceleration of the project start enables integrating great use of simulation and modeling tools, testing and prototyping of components, and feedback and modification to the final design.

Conclusions

Engaging and holding the industrial client interest and involvement over the span of the IDP presents challenges. The issue is significant given normal (and abnormal) business demands, requirements, and pressures placed on personnel tapped as an advisor(s). Capstone design projects that have an active link between the client and a team member in the capstone offer higher potential for industry's continuing involvement throughout IDP.

The use of an electronic course management system can facilitate communication at certain level with faculty and teams. Technical document capture and technical documentation is not easily facilitated. Communication with external clients is an issue and the course management system has not enhanced this with the capstone projects where external clients/advisors have been integrated as participants in the project. The team participants in projects have proven very resourceful in utilizing expertise from their interning organization to support their assigned project. They tap these resources in a consultancy role for a specific issue/element of the project even though the organization may not be in the client/advisor role.

Project Examples of Client Partnering

1. ATV Mini-Baja competition-SAE: Industry client funding, In-house faculty technical advisor,
2. Measurement System for Foam Billets: Industrial client/alumni advisors, student intern at client (1st Place College Research Day),
3. Intermodal Transportation Center: Faculty client, faculty technical advisor also instructor of IDP- 2nd place award in NCEES design competition.
4. Bio-Waste Facility in Haiti: Facility to handle human wastes using indigenous resources and society norms. Organizational client, technical advisors from organization, some student team members with related previous work experience.
5. Dominican Republic Projects: Potable H_2O System for rural/poor community of fishermen and Electric Power Unit for fishermen's freezer-using indigenous resources- Non-technical organization client, no client technical advisor

References

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