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Perceptions and Experiences of Industry Co-operators in Project-Based Design Courses*

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Undergraduate engineering programmes often use design projects to facilitate students' experiences in solving authentic engineering problems and these design projects are frequently developed in co-operation with industrial partners. To inform mutually beneficial university–industry relationships, this exploratory study gathered data on the experiences and perceptions of industry co-operators in three undergraduate design courses, in which students completed a major design project provided by industry co-operators. Findings revealed an understanding of industry's motivations to become involved in the curriculum and identified the benefits sought, expectations of graduate engineers and student learning outcomes. Findings also revealed the critical importance of effective administration and communication in university–industry collaboration.

Keywords: design; industry co-operators; qualitative research

INTRODUCTION

LIKE MANY PROFESSIONS, engineering faces the challenge of preparing graduates for professional practice through an undergraduate curriculum framed largely on theory and analysis [1, 2]. In this learning context, engineering design projects are the primary vehicles through which students gain experience in solving authentic engineering problems. Design projects typically involve creative, open-ended, problem-solving experiences. These experiences require skills that employers identify as critical to successful engineering practice, such as the engineering design process, and practical skills including communication, team orientation, cultural awareness and leadership [3–6]. To optimize their authenticity, design projects are frequently developed in co-operation with industrial partners.

LITERATURE REVIEW

In addition to a solid knowledge of engineering science fundamentals, theories and methods, industry is calling for graduate engineers to have a rounded set of professional knowledge that includes: (1) a good understanding of design and manufacturing processes; (2) an understanding of the historical, economic and environmental context of engineering work; (3) good communication skills; (4) the capacity to think critically and creatively; and (5) the ability to work as part of a team [1, 7, 8]. Design projects are often identified as a preferred vehicle by which students can learn this set of professional knowledge [1, 9]. The engineering literature contains numerous descriptions of individual courses and multi-course models in which undergraduate design education is facilitated by some combination of projects, case studies, competitions and design exercises that include reverse engineering, re-designs and new designs [10–17].

Models of design education built around design projects often involve industrial partners in critical roles [18–20]. Industrial roles in design courses include, for example, project provider (becoming the client/customer to the student team), project sponsor (providing the project as well as funding, equipment/materials and/or technical expertise), project liaison (providing the project and dedicated staff time to guide the student team), consultant or technical resource to the student team, jury (providing informal or formal assessment, critique or evaluation of the project and the student team) and/or providing awards to the student team [11, 19].

For industry, involvement in design education provides opportunities to influence the engineering curriculum, to access resources for concept development and to advance workforce development initiatives. For students, the benefits of having industry involved in the curriculum include exposure to professional practice and positive motiva-

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tional effects related to responsibility and accountability to the industrial partner. Industrial involvement supports faculty goals of enhancing connections with industry, developing classroom teaching innovations and obtaining independent feedback on student learning [11, 18, 21].

Despite the learning potential of design education, several authors highlight difficulties inherent in assessing and evaluating its impact on the experiences of students, faculty and industrial partners involved [11, 22–24]. Existing evaluation studies vary widely in the quality of their design, the evidence reported and the communication of the results [11, 25]. In response to the calls for a more systematic approach to using both qualitative and quantitative measures to assess the effectiveness of design education, a study was designed that included an examination of the experiences and perceptions of industrial partners in a design education initiative in a Biosystems Engineering programme.

RESEARCH CONTEXT AND PARTICIPANTS

This paper describes the experiences of industry co-operators (ICs) in a series of three vertically integrated courses called the Biosystems Engineering Design Trilogy (DT). Each three credit-hour course consists of two 80-minute lectures and one 180-minute laboratory session weekly for a 13-week term. The broad conceptual goals of the DT are to expose students to the design process, to present design as both information and experience, to complement design with learning in professional skills and professional practice and to ground learning experiences in team-based work in authentic, small-scale design projects for local ICs.

DT I emphasized a basic understanding of the engineering profession (history, regulation and codes of ethics), oral and written communication skills and the design process. DT II emphasized concepts of safety and human factors engineering, project planning and engineering modelling. DT III addressed running a design business, ethics and professionalism, valuation of engineering services, ISO certification and financial reporting.

In all three courses, student teams of three to five completed a major design project provided by an industrial partner. Projects included designing, enhancing or modifying devices used in agriculture, designing agri-business operations and modifying common household items to take advantage of local conditions or respond to unique user needs. Project expectations ranged from a conceptual design in DT I, a detailed design with engineering drawings in DT II and detailed design, drawings and economic analysis in DT III.

Recruitment of ICs occurred in two stages. First, a centralized unit (IDEA) recruited design project applications from ICs for all engineering disciplines at the university. The IDEA co-ordinator assessed whether the ICs' proposed projects truly represented design tasks and further assessed into which engineering discipline the project best fitted. In the second stage of recruitment, the IDEA co-ordinator and DT instructors selected suitable projects in terms of scope, timelines and deliverables for either DT I, DT II or DT III. Once a design project was accepted, the IC was invoiced US$500 to offset costs of administering the IDEA programme and to supply funds to the student teams in order to procure materials to complete the design project.

Each DT instructor invited the participating ICs to attend the first lab of the term and briefly present their projects to students. Students then submitted their proposals to their instructor, indicating to which project they would like to be assigned. Once the instructors established the design teams and passed the IC's contact information onto each team, formal communication between the instructor and the ICs ended. After this point, students initiated all contact with their IC as required to receive additional information and feedback on the design project. At the end of the term, ICs attended a public presentation of all design projects.

The six ICs participating in this study were involved in seven design projects in the DT. All participants were male and represented local businesses and locally significant industries. Two of the six ICs were professional engineers; four ICs came from varied educational and professional backgrounds, including skilled trades, technical education, business education and a Ph.D. in agriculture. All but one IC were involved in the DT for the first time.

METHODOLOGY

A comprehensive examination of the experiences and perceptions of ICs in the DT required a qualitative research methodology. Qualitative methodologies enable inquiry into understandings of a social or human condition, experience or problem, based on building a complex, holistic picture, formed textually and analyzed inductively [26]. Qualitative research reports detailed views of small numbers of participants, utilizing rich description and interpretation to better understand a phenomenon [27].

In this study, data collection consisted of in-depth one-on-one interviews with each of six ICs in the DT courses. The interviews were designed and carried out following established guidelines for long interviews [27, 28]. Interviews ranged from 60–90 minutes each and were guided by a semi-structured interview protocol (Table 1) to ensure systematic data collection on topics including ICs' reasons for participating, their design needs, their expectations of student performance and their assessments of project outcomes. Each interview was audiotaped and transcribed verbatim. Written

Table 1: Interview protocol—questions and possible probes

- (Icebreaker): Tell me something about yourself.
- What has your professional career path been? What role has design played in your career?
- How do you define design?
- What are key components of [a definition of] design? Who or what has guided or shaped your definition of design?
- How do you understand your involvement in the DT as a client?
- What motivated you to become involved in the DT as a client? What are your most important needs in terms of design? In what ways does the DT support these needs? What do you hope to accomplish by being involved in the DT as a client?
- What are your expectations for the DT courses?
- What design skills do you consider necessary for graduating engineers? What are your expectations of the students in the design course? What are your expectations of the faculty of the DT? How do the courses meet these expectations? How do the courses fall short of these expectations? How do you measure success of a design course? How do you measure success of a design project?
- How do you evaluate the DT courses?
- How did the projects develop design skills? What strengths do you perceive of the courses in their current form? What recommendations do you have for improving design education generally? What recommendations do you have for improving specific courses in the DT?

notes taken during the interview captured non-verbal features such as atmosphere, body language and thematic turning points. Data analysis followed qualitative practices for data coding using the constant comparative method [29], in which evidence was examined for both common themes and differences across data files from different sources and within individual files. In this article, verbatim quotes provide glimpses of the rich data set generated.

FINDINGS: PERCEPTIONS AND EXPERIENCES OF INDUSTRY CO-OPERATORS IN THE DT

Table 2 summarizes the key findings on the perceptions and experiences of ICs relative to their involvement in the DT, accompanied by sample qualitative data. These results demonstrated that ICs appreciated the complex and iterative nature of the design process. Nevertheless, they were motivated to participate in design projects with students to support the educational experiences of future engineers, but also because students' expertises and fresh perspectives bring added value to their businesses. ICs saw the design projects as opportunities for students to learn and demonstrate the complex knowledge and skill set inherent in engineering practice: theoretical knowledge, creativity and technical, interpersonal, business management and communication skills. To support ICs in achieving their educational and business goals through design projects, participants expressed a need for more effective communication about the goals for different levels of design courses and, more generally, with the university, DT professors and students.

IMPLICATIONS

While the primary goals of any undergraduate engineering courses focus on student learning, it is also important to understand and incorporate the experiences and perceptions of ICs into the structure of the curriculum. The recommendations of ICs presented in the findings provide numerous starting points to enhance both their actual experience as well as their perception of their value to the programme. Personal contact, front-end documentation (e.g. a 'participation contract'), ongoing communication throughout the term and year-end follow-up by the DT instructor and/or co-ordinator not only mitigate potential pitfalls in project progress, but validate the critical role that ICs play in the learning experiences in design courses.

Industry co-operators in the DT lacked understanding of the organizational structure of the university and which of their contacts (e.g. the project recruiter, the course instructor or the DT co-ordinator) should be their primary contact. In effect, industry is not interested in the departmental breakdown in a school of engineering, but rather values a business-oriented approach to collaboration. In such an approach, ICs may be drawn into collaboration with the university through the DT, but then may initiate ongoing contact through their DT contact for other purposes such as collaborative research and student co-op/internship programmes. Regardless of interest and initial contact, industry expects co-ordinated and responsive referrals to appropriate personnel. While university thinking relative to student is shifting to a customer-service orientation, the same orientation towards industry is critical to maintain and enhance relationships. A co-ordinated vision and strategy across the faculty or school—and ultimately the institution—for university–industry collaboration, appropriately supported by senior administration, is the umbrella under which local initiatives like the DT could operate. A co-ordinated vision and strategy would not only support an individual faculty in its collaborative efforts with industry, but also advance the recognition of the critical contributions ICs make to a student's education.

Table 2: Key findings

Ic's experiences and perceptions on	Findings	Illustrative quotes
Definitions of design	A process of creating, from a concept to completion, a tangible, functional end product (primary criteria to evaluate success of a student project) Design process characteristics: constraints; iteration and continual improvement; creating; problem-solving; testing	' . . . A process of creating something. Here it is at the end; you can touch it'; 'take a concept or idea and create a workable product out of it, applying real-life constraints . . .' ' . . . That's really the proof in the pudding . . .does it work?' ' . . . It has those elements of problem solving, process or iteration . . .enhancing and optimising, . . .then testing it out and constantly just improving on our design.'
Motivation to become involved in the DT	Opportunity to move forward on projects that organizations did not have enough human resources and/or a specific technical expertise to address Students as a resource and source of talent; additional input into organizational 'repertoire' of ideas and knowledge 'Pre-screen' students as potential future employees Cost-effective source of engineering input (ICs contribute US$500 per project to cover project administrative and material costs) Organizational commitment to the university	'One of the things we don't have in our organization [is] easy access to . . . engineering expertise . . . . We lack the electronics expertise . . . and that's really what I was trying to tap into' 'University students are a great source of talent . . . . You can access them [. . .] relatively cheap . . . . You can get some real innovative ideas from an outside source.' '[Students' work gives] one more piece of information to add to the lexicon' ' . . . We're always keen on supporting the university and the students . . .and grooming them for the future'
Benefits sought via involvement in the DT	Outsider's perspective; innovative perspective Take student work and move it forward within their organizations Organizational experience should be secondary to students' experiences	'I think I'm too close to [the project] now and I just can't see the forest through the trees anymore. I was hoping for a whole new, fresh outlook as to approaching that problem' 'I had a pretty good idea of the general concept . . . and I wanted to get some additional input as to how to actually make this work' 'It's about the students, not about the companies and that's the way it should be positioned.'
Expectations of graduate engineers with respect to design knowledge/skills	Knowledge expectations: good general knowledge of fundamental engineering principles and theory; fluent in project management tasks Skill expectations: competence with new technology; hands-on abilities (e.g. fabrication tools) Attitude expectations: flexibility, problem-solving orientation; fundamental curiosity; self-directedness; overall good people skills	'The hope is they come out of university and they've got that [technical, theory] background' 'My core expectation would be their ability to analyse the project, set timelines and project deliverables in a manner that fits into our goals' 'Technology skills to use, say, AutoCAD to its full extent and fabrication skills to take things to prototyping' ' . . . The imagination to come up with . . . innovative solutions tempered by practicality,' ' . . . a mindset, the way one reacts to a problem'
Positive student learning outcomes	Project scope well-focussed High amount of research carried out Numerous design options evaluated, realistic options developed Design concept derived that was in some cases feasible and could be moved forward Strong communication skills in oral presentations, professionalism and written reports Strong team skills	'Did the projects develop design skills in the students? Absolutely. It gives them a taste of what it's like [in industry] . . . . It teaches them how to learn and how to problem solve'
Involvement in assigning student grades	Not seeking the opportunity to be involved in grading students Did not perceive grading as their role	'I don't see that benefiting the students. I just don't see that as the proper place [of industry]' An assessment role: "what the students could have done better or things to think about for the future. Just give them that feedback . . . versus saying 'you're an A and you're a B' "
Areas of weakness in the Industry Co-operator–Design Trilogy collaboration	Lack of understanding that project results would vary from conceptual design through to detailed design, depending on which DT course the project was assigned to Lack of clarity on IC's role and responsibilities toward the students	'My major disappointment wasn't the performance of the students. It was my lack of understanding of the programme' 'I was surprised that there wasn't more interaction . . . to explain a little more thoroughly what our role is'
Recommendations for an enhanced experience for future ICs	DT instructors to collaborate with the IC to understand the complexity of the project and ensure IC's held reasonable expectations of student teams Provide written document and personal contact by instructors to outline roles and responsibilities of ICs relative to students University-facilitated contact with students early in the term ('team building' between students and ICs) University to build in follow-up mechanism to facilitate ongoing student work on the project (paid basis) with the ICs after the DT ended	' . . . What we want out of it: a working product or just a concept?' ' . . . I [recommend] a little more introduction up front and maybe just a more practical realization of what our expectations should be' 'After the initial acceptance of the project to have a wine and cheese meet-and-greet, so [the students] could feel more comfortable approaching us' ' . . . There's nothing in place in the programme to allow us to contract with the students to take the project to completion'

FUTURE WORK

As an exploratory investigation of the experiences and perceptions of ICs in the DT courses, this study took a cross-sectional approach, gathering data from one cohort of ICs over one academic year. While the small number of participants (six) is appropriate for a qualitative approach and allows for deep understanding, a longitudinal study exploring the changes in ICs' experiences and perceptions over multiple years of participation in the DT would illuminate an aspect of the design education experience about which little is known. Second, the research with this group of ICs was part of a larger exploratory study that also examined the experiences of students and instructors in the DT courses. A stand-alone study to gather data from a larger group of ICs (with an eye to multiple types of industrial members) would generate knowledge needed to inform relationships between industry and universities and to enhance the learning experiences of students engaged in design projects.

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