COMPARISON OF FIRST-YEAR DESIGN-IMPLEMENT EXPERIENCES, THEIR ASSESSMENT AND RESOURCES

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Abstract

The results from a survey of first-year design-implement experiences are presented. The data was collected from four engineering departments located across Europe and North America, and covered a range of topics broadly categorized under four headings: Project Information; Teaching and Learning; Assessment and Learning Environment.

All the project deal with large student cohorts that are organized into a number of small teams. The projects are all minor components of the students' first-year and are run with relatively modest amounts of money and faculty time commitment. The emphasis is on practical sessions and self-directed learning, with a limited number of lectures. Assessment is all team-based, with some moderation of grades achieved through peer assessment.

Considering all the projects presented here have been developed independently there is a surprising level of consistency across the different institutions. This is probably due to the lessons learned from the development of capstone projects over a larger number of years.

Keywords: design-build, design-implement, project, first-year

Introduction

Hands-on project activity is increasing used in engineering education to enthuse students and to develop learning. Of course, project activity has always been used, but there has been a subtle change in emphasis over recent years, with the project itself becoming less important than the actual project experience. There has been a gradual recognition that project activity is an excellent learning opportunity that needs careful planning and execution if its benefits are to be maximized.

The CDIO initiative is based on '… the principle that product and system lifecycle development and deployment — Conceiving, Designing, Implementing, and Operating — are the context for engineering education' [1]. One of the ways in which CDIO promotes this concept is through the suggestion that engineering programs should have '… two or more design-implement experiences, including one at a basic level and one at an advanced level' [2]. Terminology varies from institution to institution and a design-implement experience may also be known as a design-build experience, design-build-test; project based learning, or a host of other names. Nonetheless, the intention remains the same, and a useful definition is provided by Malmqvist et all [3] who describe a design-build experience as '… a learning event where the learning takes place through the creation of a product or system. The product that is created in the learning event should be developed and implemented to a state where it is operationally testable by students in order to verify that it meets its requirements and to identify possible improvements.' This paper will follow the CDIO convention by using the title design-implement experience (DIE).

Much of the developments in design-implement experiences has focused on the penultimate and final years of the degree programs, often known as capstone projects. However, with the format of the capstone project maturing, attention is beginning to turn to the first-year DIE and how it can developed to accommodate students in the initial stages of tertiary level education.

A useful comparison of capstone projects is presented by Malmqvist et al. [3], although no comparable study exists for first-year design-implement experiences. The objective of this paper is to address that void somewhat by comparing a number of first-year design-implement experiences at CDIO partner institutions, to highlight any common ground and to discuss the differences.

Survey and Data Collection

The data presented in this paper represents the findings from a pilot study at four CDIO partner institutions (Table 1). The data was collected using a spreadsheet survey tool designed and distributed, via email, which enabled the data to be more easily processed on submission.

Table 1 – Projects Surveyed

Institution	County	Course/Project
Chalmers University of Technology	Sweden	Introduction to Mech. Engineering
Hogeschool Gent	Belgium	CDIO
Queen's University Belfast	UK	Model Racing Car
Queen's University, Kingston	Canada	Practical Engineering Modules

The survey comprised 96 questions organized into four sections: Project Information; Teaching and Learning; Assessment and Learning Environment. An example page from the survey is shown in Figure 1.

Questions in the Project Information section gathered fundamental data about the projects, such as name, class size, running costs, etc. The Teaching and Learning section addresses learning objectives, teaching and learning processes and the CDIO syllabus topics. The methods of assessment used, their weighting and timing are compiled in the assessment section. While the learning environment attempts to categorize the physical resources required to run the projects.

The general approach during the development of the survey was to collect quantitative data where possible as this would enable comparisons to be made more easily and would present a better basis for providing definitive guidelines. With this in mind, the survey was designed with question that generally required either numerical or yes/no answers. Where possible, when descriptive answers were required, a drop-down box with a number of options was provided to maintain consistency across respondents.

Project Information

	Basic Information	
1	*Institution*	Queen's University Belfast
2	*Name of course/module*	Introduction to Engineering
3	*Name of project (if different from course/module)*	Model Racing Car
4	*Program year (nominal)*	1
5	*Proportion of (nominal) academic year (%)*	6%
6	*Number of students*	85
7	*Cost per student in year 1 (USD)*	USD 20
8	*Cost per student in year 2 (USD)*	USD 5
9	*Date survey completed (YYYY-MM-DD)*	2007-04-04
	Project Characteristics	
10	*Primary technical discipline*	Mechanical Engineering
11	*state discipline if 'Other' chosen in question 10*	-
12	*Primary non-technical discipline*	None
13	*state discipline if 'Other' chosen in question 12*	-
14	*Project topic*	Selected by staff
15	*Team based (Y/N)*	Y
16	*Competition based (Y/N)*	Y
17	*Links with industry/community (Y/N)*	N
18	*Formal project management system (Y/N)*	N

Figure 1 – Sample page from survey

This initial work was part of a larger undertaking to survey design-implement experiences across all years and from a much larger range of CDIO participants. Therefore, in that respect the objective of this initial work was twofold. Firstly it would assist with the development of the survey tool before a larger roll out and secondly it would provide much needed information on first-year design-implement experiences. It is the second of these objectives which will be the focus of remainder of this paper.

Results of Survey

General Characteristics

Of the four projects surveyed, three cater for mechanical engineering students; while the fourth is across all disciplines in an applied science faculty at Queen's University, Kingston. None of the projects make any attempt to cater for a secondary non-technical discipline, such as business or entrepreneurship. With many of the original CDIO partners coming from a mechanical or associated background the current results should be readily applicable; although they should also provide useful information for those from a different discipline.

Each of the projects cater for the whole cohort and so are dealing with large numbers of students. The single-discipline projects report between 85 and 225 students, while the multi-disciplinary project has 575 students. All of the students were organized into small teams, of between 2 and 6 people, and in all cases the team selection was decided by staff or was random.

Interestingly, two of the projects incorporated a competitive element as part of the standard structure. This is a feature often seen in higher level projects and, if this small sample is representative, is clearly an aspect of first-year DIE's also.

Three of the four projects were worth 5-7% of the academic year, with the fourth reporting a weighting of 13% of the 1st year. Even with one outlying data point at 13%, all of these projects can be said to make a small contribution to the first year of the program. This is in stark contrast to higher level projects, which can often contribute as much as 50% or more of the final year. The costs involved in running 1st year projects is also relatively modest, with respondents reporting expenditure of $5-20 (USD) per student. Although. it is important to note that these are indicative running costs for the projects and do not include set-up costs or overheads (staff costs, room charges, etc).

Teaching and Learning

When asked about the learning objectives, three out of the four respondents cited a knowledge of the design process as their primary learning objective. And in this context, it is probably safe to assume that the design process is equivalent to the underlying theme of CDIO; that engineers conceive, design, implement and operate products and systems.

There was also a surprising amount of consistency among the other learning objectives listed. Team work and interpersonal skills was the next most significant response and it was followed by professional skills, such as written and oral presentation. In many ways the learning objectives reflect the modern work environment and are clearly trying to present a realist view of engineering as a career, rather than engineering as a science.

Considering the learning objectives it is not surprising to note that lecture classes did not feature prominently in the timetable. Of the timetabled hours, an average of 22% was spent in lectures, 50% in practicals and 25% on self-directed learning. The balance was made up of other activities. Therefore, on average, three-quarters of all time was devoted to experiential learning activities

As mentioned previously, the DIE's surveyed did not contribute significantly to the first-year of the program, and this is borne out by the allocation of timetabled hours. The total hours timetabled for the projects ranged from 18 to 40. Interesting, only one project had a recommendation for time required outside the timetable, although others commented that students would often work outside the timetabled slots if they become engaged in the project.

The academic staff generally seemed to contribute a similar amount of time as had been timetabled for the students. This is contrary to the usual perception of design-implement experiences, but is probably possible because of the extensive use of teaching assistants and the recycling of established projects each year. Only one respondent reported the teachers spending additional time outside the timetabled classes and this DIE required the projects to be unique to each team and unique each the year.

To enable a better understanding of the learning objectives, the respondents were asked to rate the importance of each of the CDIO syllabus [4] items at the x.x level. The results, shown in Figure 2, mostly corroborate the stated learning outcomes. The two notable exceptions are syllabus items 2.1 (engineering reasoning and problem solving) and 2.2 (experimentation and knowledge discovery), which rate highly in the results, but are not explicitly stated in the learning outcomes. This may point to the fact that these are seen by teachers as an implicit part of all engineering activity and therefore do not need to be stated. However, it may also be that they are not quite as important in first-year projects as they are perceived to be. Quite often first-year DIE's are will adopt a 'join-the-dots' style approach to the core engineering activity, and will instead concentrate more on the development of personal and professional skills in the students.

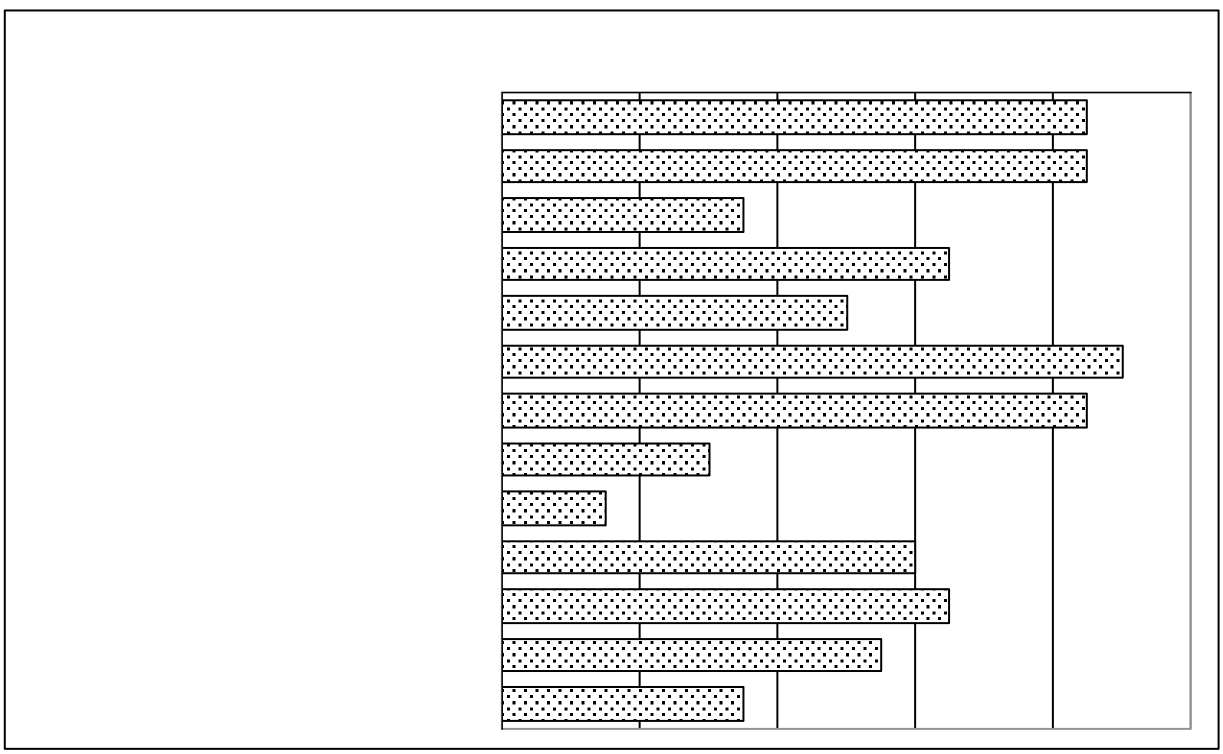

Figure 2 – Relevance of CDIO syllabus elements to first-year projects

If syllabus items 2.1 and 2.2 are discounted from the results, the remaining profile agrees well with the stated learning outcomes. The design process (4.3, 4.4 and 4.5) are rated highly, as are teamwork, which come out as the most important, communications and personal skills. It is noticeable that operating (4.6) does not feature as strongly as conceiving, designing and implementing, although not totally unexpected. Anecdotal evidence would suggest that the operating phase of CDIO is not well addressed by many of the current design-implement experiences in place at universities.

Assessment

The assessment of team projects is often controversial, because of the inability of team projects to accurately reflect individual student contributions. Nonetheless, the results indicate a strong tendency for group assessment, with all projects making use of team reports and half also making use of team oral presentations. A further consistency existed among the projects that utilized competition as part of the project. Both used the results of the competition to formulate a contribution towards the final mark – another team based mark.

Peer assessment is often seen as a method of differentiating individuals and it was used in three of the projects presented here. However, the method in which it was used is different in each case. One project assigned 30% of the overall mark for peer assessment. Another used it to moderate the individuals' marks about the team mark, while the third project used it as evidence in an objective assessment of whether the individual students should pass or fail the project (irrespective of the team mark).

Outside these common threads of assessment already mentioned, there was also a written exam - for the project that did not use peer assessment – and a portfolio assessment.

All the assessment procedures occurred either in the middle or at the end of the project.

Learning Environment

Another common concern surrounding the introduction of design-implement experiences is the provision of adequate learning spaces. In many cases this is a genuine concern, but it is also difficult to get a firm grasp on the detailed requirements. The survey attempted to capture data on space requirements for each project, but the results were inconclusive as dedicated space rarely exists for specific projects and teams tend to utilize space that is both multi-user and multi-use.

There was no real consistency across the projects in terms of the type of space available, although the two most prominent were the studio and storage facilities. Aside form these, there was a general requirement for all type of learning space - computer room, studio, workshop, machine shop and operate area. About the only conclusion that can be made at present is that the projects will inhabit any spaces that are available to them.

Tools are the other main resource necessary for the completion of design-implement experiences. All DIE's surveyed provided access to basic hand tools and most also provided access to non-powered workshop tools. With the large numbers involved, supervision of practical activities can be difficult, therefore tools of this type are ideal as they are relatively low risk in normal usage.

Student in the large multi-disciplinary project at Queen's University Kingston had access to a full range of tools, including machine shop tools, to accommodate the wide range of project activities undertaken by the students. In some ways this provision reflects the multi-disciplinary nature of the students undertaking the work, but it is possibly also indicative of the nature of the projects, which are industry/community focused and therefore perhaps more realistic than an average first-year project.

Discussion

Design-implement experiences have been a common feature of the closing years of engineering programs for some time. While these have generally been research oriented and single or two-person endeavors there has been a gradual movement towards team-based projects with better defined learning objectives. With this change in higher level projects becoming more commonplace, the spotlight is beginning to shift onto the other end of the degree program and the first-year students.

First-year intakes tend to be characterized by large numbers and relative inexperience. And when challenged with the introduction of a first-year design-implement, the natural instinct is to question the available resources – is there enough time/money/space to deal with a class of this size? The initial survey results would suggest that these issues are not as significant as they would appear. Academic staff do not seem to spend any additional time outside the timetabled hours, the direct running costs are low and the evidence is that people use whatever space is available. It seems obvious, but one way to ease the process is to use the same project brief for all students, rather than providing different projects to each team. It is also helpful if the projects can be recycled each year without becoming stale.

The second point to come out of the survey is the emphasis on active experiential learning. The stated learning outcomes indicate a desire to teach team work, communication, interpersonal and professional skills within a product development environment. Engineering science does not feature prominently in any of the projects descriptions and, with the exception of very basic theory, it is probably considered to be unnecessary in this early-stage learning experience.

Assessment of team projects is often another common area of concern. Usually over how to differentiate the individual members in each group. This is often addressed through peer assessment or individual elements of assessment to provide the required spread of marks. The projects surveyed here tend to follow this approach to a greater-or-lesser extent. There is probably always a case for differentiating marks, if only to motivate students. But the process need not be laborious. In the final reckoning any changes (large or small) in an individual's project mark is only going to have a slight effect on their overall degree performance. It is also important to remember that the primary objective of a design-implement experience is to fulfill the learning objectives, not provide a grade for classification purposes.

Conclusions

- The survey has been a useful tool for collecting quantitative data on first-year design-implement experiences. The format has enabled easy comparison across projects and provided scope for future development

- Methods of accommodating large groups of first-year project students has been described. In particular, the implications on time, money and resources have been discussed and found to be within the reach of most average engineering departments.

- First-year design-implement experiences tend to focus on active experiential learning in a practical environment. The work is supported by direct supervision and mentoring in addition to a limited number of lectures.

- Assessment is largely team-based with moderation of the marks mostly achieved by peer assessment.

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Bibliographic Information
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