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Implementing CDIO principles in an undergraduate teacher education program

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ABSTRACT

At present the University of Limerick has the sole responsibility for educating engineering and technology teachers for the Irish second level system. The course takes the form of a four-year concurrent model degree program that integrates educational theory and engineering. The program underwent a comprehensive review in 2005, providing the opportunity to build elements of the CDIO philosophy into it.

The CDIO framework holds many standards and values that are not only applicable to engineering education but also to an initial teacher education course of study. The key aspects of CDIO such as concrete learning experiences, motivation, collaborative learning and active learning are all attributes that are seen as essential to effective education.

Engaging potential teachers in a constructivist education approach has the capacity to reform engineering pedagogy and support more applicable learning activities. This paper discusses the effects of a project-based approach on the cognitive and psychomotor development of a cohort of 136 first-year students on the revised program. The research also included a qualitative analysis of affective learning and examined intrinsic motivation to engage in ‘learning for learning’s sake’.

Both empirical evidence and statistical analysis were employed in analysing the results. Qualitative as well as quantitative analyses were carried out on the attitudes and learning of the students.

It was noted that some students experienced difficulties associated with the unfamiliar demands of performing in a dynamic, co-operative, higher cognitive learning environment. Student attitude and preferred learning style were identified as important factors relating to the effectiveness of their learning

On the whole, it was found that the CDIO philosophy is generally suited for the education of engineering and technology teachers.

Key Words: Engineering Education, CDIO.

Introduction

At present the University of Limerick has the sole responsibility for educating engineering and technology teachers for the Irish second level system. The course takes the form of a four-year degree program where educational theory and engineering principles are integrated. The students comprise a mixture of mature students, and students who come directly from a secondary education. The teacher education program underwent a comprehensive review in 2005, providing the opportunity to build elements of the CDIO philosophy into it.

Armstrong et al [1] discuss the methodology that deals with transforming the CDIO syllabus into specific learning outcomes of a degree program. Reference is made to how, previous to defining outcomes, 'market analysis' is required. The market that the teacher education program is aiming at is very specific. The required outcome for this program is to graduate teachers who can effectively deliver the syllabus, and who are aware of the fundamentals of educational philosophy applicable to the engineering subject area. Principles of the CDIO approach that stand out as being directly applicable to teacher education are prominent throughout the standards. The development of personal and interpersonal skills is at the forefront of teacher education. The profession places emphasis on working as part of a team, acting as a leader and communicating effectively with people. Active learning and problem solving based activities are based on sound educational philosophies that teacher education programs aim to adhere to. The Piagetian theory suggests that the instructor is not the main contributor to learning. It is however the students' engagement in active learning activities that produces high levels of knowledge acquisition and 'deep learning'. Motivation and its effect on depth of learning are also main concerns of CDIO that apply not only to teacher education programs but to the whole teaching profession.

At present, the CDIO approach is generally found in Universities and students get their first exposure to it there. Often it is in marked contrast to the experiences they may have had at school. It seems logical that if students were to enter third level already grounded in CDIO skills it would be an advantage. This would require a cohort of Technology / Engineering teachers at second level who were familiar with, and able to implement elements of CDIO in the schools. This has obvious implications for teacher education.

As Figure 1 shows, teacher education is subjected to a cyclical process. This shows how teacher education programs have the responsibility of influencing the teaching process at second level. The adoption of CDIO at the initial teacher education stage directly affects second level engineering education, as graduating teachers communicate the principles of CDIO during their teaching career. This knock on effect has implications for future second level students who continue studying engineering at third level. These students will now be more familiar with the CDIO approach to engineering education, where aspects such as motivation, collaboration and active learning are seen as being equally important as the end result.

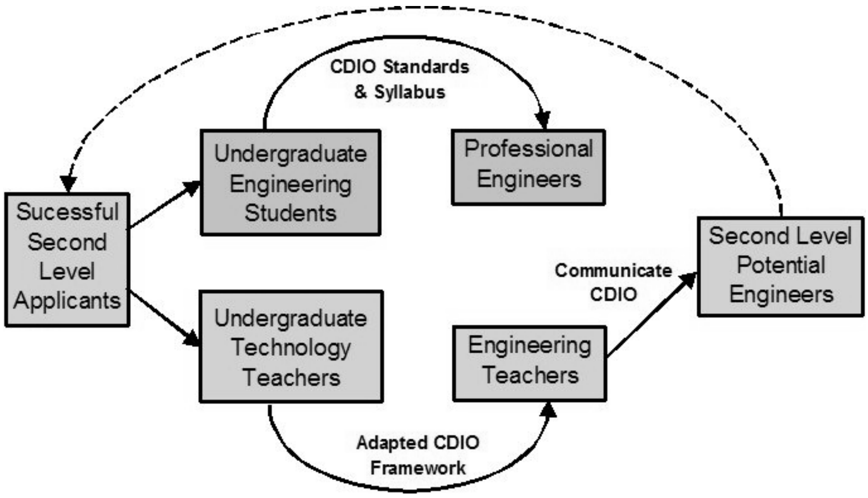

Figure 1 - Adapting CDIO for Teacher Training

Context of the work

Undergraduate programs in the University of Limerick consist of six modules per semester making a total of twelve modules per academic year. Assessment takes place at the end of each semester. A module would typically involve a combination of lectures and practical sessions amounting to 60 contact hours over the course of a semester.

The module that was the subject of this work was taken by first-year students and titled: *Introduction to Materials Processing.* This module addressed a core subject area for the students and dealt with fundamental concepts, principles, procedures and skills associated with process technology. The module consists of twelve lectures and 48 hours of laboratory work over a twelve-week term. Delivery of the module is the responsibility of the lecturer who is supported by a Teaching Assistant who takes care of the laboratory sessions. Two technicians also contribute to the module by meeting the technical needs of the students.

Subsequent to the review of the degree program in 2005 an opportunity arose to integrate CDIO philosophy into new and revised modules. As the entire content of the program was being reviewed, it was possible to design modules in related areas to allow continuity of approach and philosophy. For example the core module of Technical Graphics provided reciprocal applied elements to both modules, thus facilitating relevant knowledge transferability. The focus of the new modules differed significantly from their predecessors in relation to the responsibility and onus to learn. The possible unconscious fostering of the 'developed dependency paradigm' by inappropriate pedagogy was replaced with an emphasis on the intrinsic value of learning and a blueprint for success as an autonomous learner. Although the dynamics and continuity between modules is important, the focus of this paper is the core-engineering module. The module comprised practical exercises, an introductory design problem, and an introduction to theoretical engineering concepts and principles. Four key practical exercises were designed to address specific psychomotor skill development, while at the same time focusing on key educational issues for example:

- Rationale for best practice and Health and Safety procedures
- Development of design principles
- Value of motivation, role of self-esteem and student ownership
- Mixed ability and pedagogical strategy and sequence
- The role of evaluation and assessment

Students were also set a design problem that focused on an application of elements of the product life cycle in the context of second level education. The design process and solutions were subject to peer review and the students were encouraged to participate in a collaborative learning environment. A design report also accompanied the final design prototypes. The focus of the theoretical element of the module was centred on communicating comprehension. Students were encouraged to present information either graphically or written. The focus was not on the mode of representation but comprehension, a distinct shift from the regurgitation of information.

Eighty-three students participated in all elements of the module, with the student body being made up of twelve mature and seventy-one undergraduate students. Although the mature students are traditionally highly motivated, it was assumed that engagement with the learning activity would cause some anxiety by comparison with the undergraduates. It was expected that student attitude and commitment to education would vary between the groups, with their practical knowledge and life experience benefiting the mature students. It was also expected that students would have a range of preferred learning styles similar to trends found internationally among Engineering students. It is well documented [2] that Engineering students prefer to learn in the Active, Sensing, Visual, and Sequential style modes. The expectations were therefore that having altered the content, philosophy and approach to the module and by taking into account the attributes and experiences of the learner it was expected to achieve a more effective learning experience.

Areas to be investigated

Determination of the learning styles of the students

Sadler-Smith [3] defines learning preference as an individual's propensity to choose or express a liking for a particular teaching or learning technique or combination of techniques. Individuals have a tendency to favour one particular style and adopt it throughout their life. Riding and Rayner [4] claim that the awareness of style has the greatest implications for effective learning. If the learning style of the student and the instructional style of faculty are mismatched, the quality of the learning activity is proportionally affected. The implications that this theory holds for faculty is to ensure their pedagogical approach facilitates the preferential learning styles of their student cohorts but also encourage development of less preferential styles. In this research, the learning styles of individual students were compared to their performance in the practical and theoretical elements of the module.

Analysis and quantification of the students learning experiences when faced with an alternative educational paradigm.

Difficulties can be expected when undergraduate students transfer from a product model of education, such as the Irish Leaving Certificate Program. They are confronted with an educational paradigm where expectations are founded on a constructivist educational theory. It is difficult to measure their feelings towards learning in a quantifiable manner.

Therefore qualitative research methods must be used to augment the analysis of the students' motivation, attitudes, self-esteem, and ability to comprehend information. To observe how students act and the attitude they take towards completing predefined tasks can inform this process.

Examination of inter-group variations of student attitude and preferences.
Gender, age, learning styles and educational background are all understood to have considerable effects on how students react to teaching methodologies. The correlation between the differing groups and the result from the assessment mechanism can be used to check for significant implications.

Methodology

Participants

One hundred and thirty six first year undergraduate students participated in the study. Due to the nature of a longitudinal cohort analysis study an expected attrition rate of 38% was recorded. It should be noted that none of these students left the course. The remaining cohort consisted of 83 students. The demographics of this remaining group are discussed in this section.

Table 1 illustrates the breakdown of the cohort with regards to gender and age group. The mature student group represented 12% of the cohort. Ages ranged from 17-34, with a mean age of 19.1 and a standard deviation of 2.9. The cohort was male biased with only 4% of the group being female.

Table 1 - Cohort Composition

Student Type			Gender		
	Number	**Percentage**		**Number**	**Percentage**
Mature	10	12	**Male**	80	96
Undergrad.	73	88	**Female**	3	4

The students came from varying second level educational backgrounds. The division of school types represented in the cohort is illustrated in Figure 2 below.

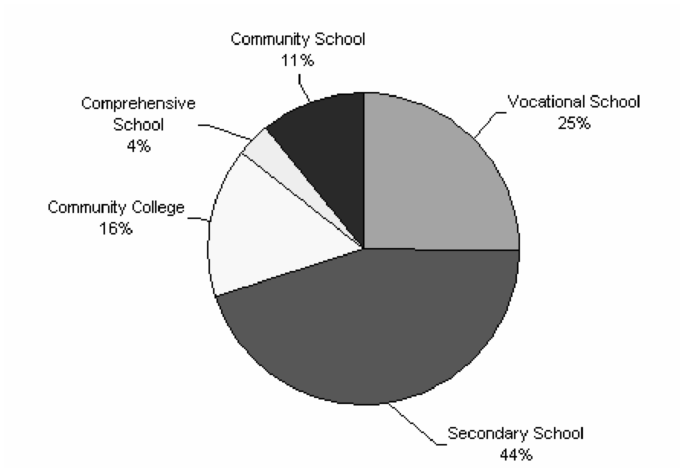

Figure 2 - Educational Background of Student Cohort Design

Design

Questionnaire
Participants preferred learning styles were measured using the 'Index of Learning Styles. The Index of Learning Styles (ILS) is a forty-four item forced-choice instrument developed in 1991 by Felder and Solomon to assess preferences on the four scales of the Felder-Silverman model. Eleven questions are designed to evaluate each of the learning preferences. A specific sequence within the questionnaire surveys the dichotomous learning styles. Seery [5] prescribed some terminology changes to this questionnaire to eliminate ambiguity arising from the questionnaire being originally designed for use in an American context. This modified version was used to conduct this study.

Qualitative Research
Observation techniques were used to analyse attitudes, motivation, and self-esteem of the students within the workshop setting [5]. This method was used as the nature of human attitude and motivations are too complex to analyse quantitatively. As Figure 3 illustrates, three observers were used to record observations of the student progress. This triangulation research method was used to ensure that the validity of the observations was increased.

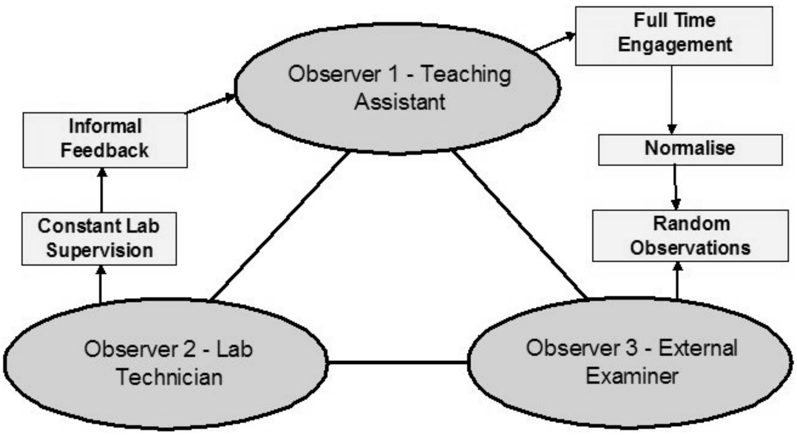

Figure 3 - Triangulation of Observational Research Method

Focus group interviews
The use of interviews enables participants to express how they regard situations from their point of view. Direct feedback between the interviewer and interviewee can result in information being gathered that would not be possible through any other medium but conversational interview. The ease at which the interviewer can look for extra elaboration with regard to a relevant topic during an interview makes this research technique useful. It also enables the researcher to selectively aim questions at different groups to find out their opinions on directly relevant issues.

Design of Evaluation Mechanism:
The module incorporated four assessment procedures. The procedures were aimed at assessing the specific learning outcomes that the module was concerned with, as highlighted below.

1. The end of term exam was orientated towards the **knowledge and**

comprehension of the subject matter and not regurgitation of facts.

2. The in term lab assessment was concerned with assessing the **level of skills and content knowledge** acquired.
3. A project design task was incorporated into the module to assess the students' **awareness of design**.
4. Practical project work that ran through the 12-week span of the module was concerned with providing a **collaborative learning** environment in which the students needed to have engaged with high levels of **motivation and efficiency** in order to complete the tasks.

Implementation

Index of Learning Styles
This was done using a web-based questionnaire.
In order for the students to complete the online questionnaire they had to register their student I.D. number. They were then sent a randomly created numeric access password. This ensured that only the student in question could access their information. When students initially accessed the online questionnaire they were asked to complete a questionnaire surveying their demographics. The students then completed the Index of Learning Styles. The results from these questionnaires were retrieved and analysed.

Workshop Observations
Qualitative aspects such as student motivation, attitude and self-esteem were recorded through workshop observations on an ongoing basis. Student comments that seemed applicable to this study were recorded. Also different cohorts (i.e. mature/undergraduate students) were observed and their attitudes, motivation etc. were compared. Situations observed by the teaching assistant, lab technician and module lecturer helped to triangulate any relevant aspects of the lab sessions thus increasing its validity. Each observer had a role to play in the process. The teaching assistant was in full time contact with the students' during the lab time engaging with them in a facilitative role. The technician's observations were from a practical viewpoint, and their observations of how students were progressing were reported to the teaching assistant on an informal level. The external examiner, who was the module lecturer, acted as a random observer of the lab sessions. The observations here were from an academic perspective. Occasionally, due to these observations being of a small percentage of the lab time, normalisation from the full time observer was necessary.

Focus Group Interviews
Informal group interaction with the students in the workshop setting helped to form an overall perception of the students' attitudes and level of motivation towards the module. The opportunity to randomly select groups from the workshop made this research technique very accessible. Focusing on interviewing all the mature students offered information from a valuable viewpoint. These students were very reflective in their responses and tended to have more accurate observations of what was trying to be achieved. Mixed groups of mature and undergraduate students often formed interesting discussions, where attitudes between the cohorts distinctly differed. Focus groups consisting of only undergraduate students were also interviewed and the significant differences in attitude and perceptions of the module from that of the mature groups were evident.

Project/Course Work

The designing of practical tasks to be completed in the workshop was carried out with special emphasis on the comprehension of key principles and processes rather than the acquisition of skills. Practical project work will naturally enhance the development of psychomotor skills, so therefore one aim of this course work was to ensure students developed deep understanding of the principles of what they were doing as well. The approach that was taken to this design was compliant to the stages of Bloom's taxonomy of cognitive development. The useful structure of levels of development that Bloom's taxonomy is concerned with helped to ensure that the practical project work was sequenced in a fashion to maximise student learning. This hierarchy of taxonomies has a similar approach to learning as the CDIO philosophy.

Evaluation Mechanism

The assessment mechanism used to assess the students learning in the module was implemented through four different procedures. The students were encouraged to research extra information in their own time in order to develop a comprehension of the subject matter. This level of comprehension was examined in the theory paper at the end of the term, through higher cognitive questions and problem solving activities. The assessment of lab based project work not only examined the students' psychomotor skills but also considered aspects such as presentation of work and the pride taken in completing, indicating the students' attitude towards the tasks. The processes that students were left to interpret from peer to peer learning were also observed. Emphasis was put on the implementation of effective design from the beginning of the module. During the semester the students were asked to demonstrate their design skills by generating a suitable design and prototype of a project suitable to teach second level students at a certain age level. The lab assessment was carried out at random during the time students spent in the workshop. Students were asked to demonstrate skills and were quizzed on practical content knowledge.

Results/Findings

The raw data collected from the online *Index of Learning Styles* questionnaire was tabulated (Table 2) and expected trends began to emerge. The results were recorded against a five point scale where 1 represents a very mild preference while point five of the scale represents a high preference for each particular style mode.

Table 2 - Learning Style Scores

Scale	Active/Reflective		Sensing/Intuitive		Visual/Verbal		Sequential/Global	
1	23	12	20	10	5	6	16	16
2	24	3	27	5	19	1	22	4
3	15	1	14	1	28	0	16	2
4	5	0	5	0	17	0	7	0
5	0	0	1	0	7	0	0	0

When grouped into specifics styles, figure 4 illustrates the overall preferential styles of the cohort. This shows a clear preference for the Active, Sensing, Visual and Sequential learning styles.

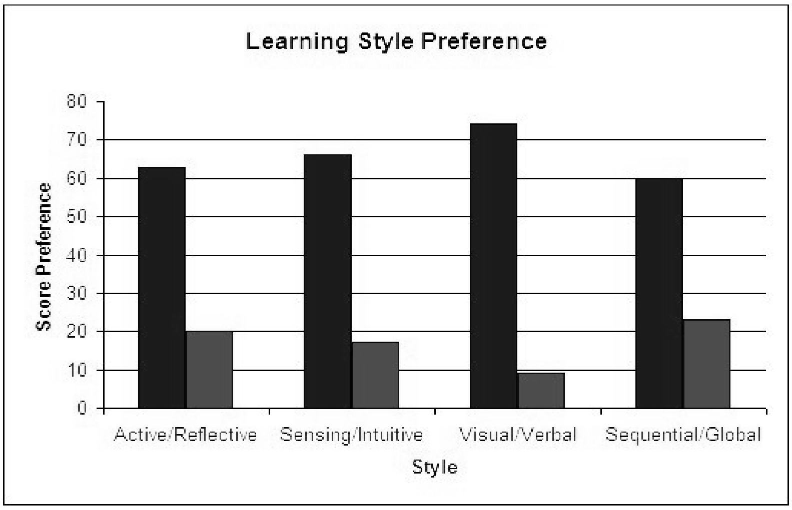

Figure 4 - Learning style preference

Table 3 below, shows the average scores obtained by the relevant cohort groups. It can be seen how the mature student group outscored the undergraduate group considerably on all aspects of the assessment.

Table 3 - Average Percentage Performance of Cohort Groups

Group	Total	Project	Exam	Lab	Design Task
Overall	55	51	57	66	55
Undergrads	53	50	55	65	54
Mature	70	60	80	81	62
Male	55	51	57	67	55
Female	54	49	58	56	58

Figure 5 clearly illustrates the higher average performance of the mature student cohort when compared to undergraduate performance.

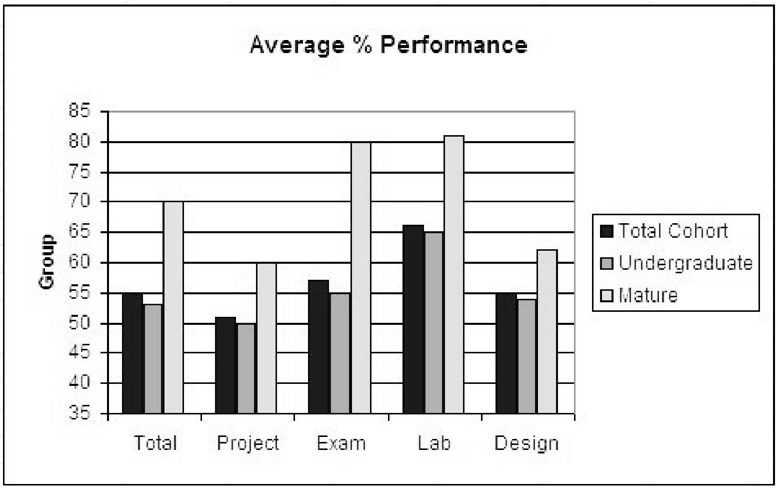

Figure 5 – Average percentage scores for Undergraduate and Mature Student

When comparing the performance of the female group to that of the male group it can be seen (figure 6) that the male group slightly outscored the female group on the practical based assessments (i.e. Project and Lab) and the female cohort slightly outscored the male group on the theoretical based assessments (i.e. Exam and Design Task). However the gender differences cannot be validated due to the percentage of female participants being less than 4% of the total cohort.

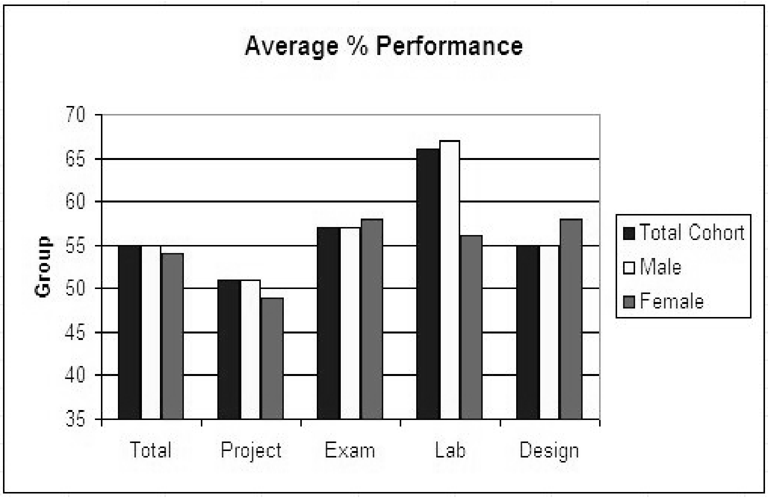

Figure 6 – Average percentage scores for male and Female Students

With so many variables within the student cohort it was important to analyse the significance of these variables against the results of the assessment procedures. The main variables of the study were student type (Mature/Undergraduate), school type (Secondary Schools, Vocational Schools, Community Schools, Comprehensive Schools and Community Colleges) and the dichotomous learning styles. One-way ANOVAs were conducted to test for significance. The results are presented in Table 4 below.

Table 4 - Influence of Student Type, School Type and Learning Style on Module Results

	Total	Exam	Project	Design Task	Lab
Student Type	0.495	**0.000**	0.126	0.107	0.711
School Type	0.429	0.234	0.613	0.449	0.336
Active/Reflective	0.482	0.234	0.133	0.67	0.613
Sensing/Intuitive	0.969	0.083	0.649	**0.007**	**0.005**
Visual/Verbal	0.709	0.729	0.877	0.081	0.295
Sequential/Global	0.101	0.389	0.504	0.239	0.515

Table 4 shows how a highly significant value was recorded for student type in the end of semester examination. On further analysis of this p-value a mean score of 78.21 was recorded for the mature students, while the undergraduate students achieved a mean score of 61.34

The significant values are highlighted in the table above. These imply a high level of significance between being a sensing learner and achieving at the design task and lab assessment. After recording these high significances, compare means tests were

conducted.
The sensing/intuitive style also recorded significant p-values for the design task and lab assessment (p=0.007 and p=0.005 respectively). Examination of the mean scores illustrated that the sensors achieved a higher mean (Sensing, 74.62 in comparison to intuitive, 58.53). A higher mean score was also recorded for the sensing learners in relation to the lab assessment with a mean score of 61.62 in comparison to 47.06. It was also noted that even though the analysis returned an insignificant relationship between the sensing/intuitive learning style and the exam, that the sensing learners also outscored the intuitive learners with a mean score of 64.62 against 58.53.

Discussion

The difficulty with evaluating any learning experiences is how and what to value. Does one measure successful learning in terms of academic or vocational attainment, social or professional conscience or the elevated self-esteem and satisfaction levels of the student? Due to the complex dynamics of the learning activity it is difficult to Conceive, Design, Implement and Operate a generic evaluation paradigm. However, care must be taken to ensure that the evaluation mechanism correlates with the anticipated learning outcomes. This paper examined key facets of the learning experiences for the initial stage of engineering teacher education. The evaluation focused on knowledge acquisition, comprehension, psychomotor skill development and the affective domain.

Resulting from analysis of the module assessment the key differences between the mature and undergraduate groups were apparent. From the results it can be seen that the mature group outscored the younger group in the end of term exam. The significance here is that the undergraduate students were recent graduates of the Leaving Certificate system where they had numerous exams to prepare for. The mature students however, have had little formal academic/exam experience and would be expected to be at a disadvantage. The rote learning approach that undergraduate students would appear to have inherited during their second level education proved to be of no advantage over the non-formulated approach of the mature group. The emphasis on comprehension throughout the module was more beneficial to the mature group.

The significance of how sensing learners outscored intuitive learners in three of the four assessment procedures was an important conclusion in this study. The sensors, who prefer concrete information and are strongly orientated towards facts and procedures found this approach more beneficial. This is in line with the CDIO framework that was implemented over the course of the module, as the emphasis was put on students to concentrate on the facts and procedures and to comprehend the key principles and standards that they encountered through an active learning environment.

Qualitative findings that resulted from this study show that students were highly motivated throughout the course of the module and that the attitude taken towards course work was very positive. The results and motivations of the students who make up the 37% that did not choose the course as their first choice of study was also interesting. The fact that they did not underachieve in comparison to students who did choose the course as their preference shows how they became motivated to achieve in the course work as much as the rest of the cohort.

Although the gender imbalance recorded in this cohort is somewhat representative of females in engineering in the Republic of Ireland, the small percentage of female students significantly limited the capacity to draw valid comparisons.

Conclusion

The study that this paper is concerned with was carried out over a thirteen-week introductory module to engineering. The findings from the study suggest that the CDIO framework can be applied to engineering teacher education. Both statistical and anecdotal results were obtained to emphasise this.

The participating cohort demonstrated a preference for a specific category of learning styles i.e. Active, Sensing, Visual and Sequential. These preferences correlated with internationally perceived learning preferences of engineering students. These learning styles were catered for in the module and certain students benefited more from the active, problem solving based approach.

In general the cohort expressed frustration with the shift to student focused learning. The move from a paradigm of 'developed dependency' to that of an autonomous learner caused some anxiety, especially with the younger students.

The positive attitudes and high levels of motivation recorded in the practical workshop setting and through focus group interviews highlight how the approach to this initial teacher education program instilled a sense of pride and satisfaction into the students. The positive collaborative learning environment that was present throughout the semester also emphasises the benefits of the approach.

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