FROM GROUP TO INDEPENDENT PROJECT WORK: DOES CDIO PREPARE LEARNERS?

Laura J Leslie[1], Paul C Gorman[2], Sarah Junaid[1]

1 Mechanical Engineering and Design, Aston University. 2 Department of Market Research, Aston University, Birmingham, UK

ABSTRACT

The aim of this research was to investigate the effectiveness of group project-based-learning (PBL) CDIO based modules, in years 1 and 2 of study, on student's skills and competence levels in their individual Final Year Projects (Projects). The question is whether students are able to transfer skills from the group based environments to individual Projects. Two questionnaires (QNRs) were given to Project students; a pre-project questionnaire (QNR1) and a post-project questionnaire (QNR2), to gauge self-awareness of project planning, skills confidence, independence, and the importance of their Project advisor. Following completion of their Projects, students were also invited to participate in focus groups. QNR1 and QNR2 were completed by 37 (45% of cohort) and 36 students (43%) respectively, 13 of which were paired responses between the QNRs. Seven students attended focus groups for further discussion. Results from QNR1 suggested students felt a high level of responsibility for all phases of their Projects, however, they also indicated a reliance on their advisors (QNR2), which suggests they are not always confident with individual work. Focus groups also suggested that some students found the transition from group work to an individual project challenging. QNR1 students perceived themselves as good planners, though by QNR2 that perception had decreased, with 14% of students indicating that they always 'ran behind'. Our results suggest that our CDIO programmes do equip students with confidence in a variety of key skills, including independence and ownership of project work. The results also suggest that there is a need to further develop these skills, including time management, and to ensure students' confidence is a true reflection of competence. It has also indicated that programmes should be designed to more effectively aid students in the transition from group to individual project work.

KEYWORDS

Independence, Project-based-learning, Problem-based-learning, Mechanical Engineering, Standards: 1, 2, 3, 5, 7, 8, 10, 12

INTRODUCTION

CDIO (Conceive, Design, Implement, Operate) was developed in order to provide a framework for engineering educators to enable students to have the correct knowledge and skills to become successful engineers (CDIO, 2018; Crawley, Malmqvist, Lucas, & Brodeur, 2011). In the department of Mechanical Engineering and Design at Aston University, programmes are designed around the principles of CDIO, underpinning four major project-based-learning (PBL) modules delivered in the first two years of study. In these modules, students work in groups on various projects such as the design-build of an electric race car, a functioning wind turbine, an electronic healthcare device, and a 3D printed pneumatic actuator and valve. The aim of these programmes is to equip students with a range of technical and professional skills to help make them industry-ready. Indeed, active learning in Undergraduate STEM programmes has been shown to increase students concept knowledge (Freeman et al., 2014), something which our programmes aim to do.

Measuring student's skills and their perception of their skills is an important tool in understanding how they learn and whether delivery of material is suitable. Previous studies have shown this to be used to aid in student retention (Besterfield-Sacre, Atman, & Shuman, 1998), course delivery (Grant, Malloy, & Murphy, 2009) and staff-student interaction (Bjorklund, Parente, & Sathianathan, 2004).

However, as educators, it can be difficult to measure how successful programmes are in equipping students in certain skills, particularly once students leave the education system and we are no longer assessing them. In the Final Year of study on our programmes, students undertake an individual Project with support from an academic 'advisor'. The Project can be of the students own design, or chosen from a list of varied Projects linked to the academic's research groups and interests. The transition from tutor lead group PBL modules to individual Projects was seen to be a suitable juncture at which to attempt to measure students skills and perceptions.

The aim of this study was to ascertain the effectiveness of the four group PBL modules in the preparation of students taking on their individual Projects. In doing so, we wished to explore the following:

- Independent working: students' perceptions of working independently and of the role of their academic project advisor
- Skills: students' confidence in a range of technical and professional skills such as time management.

MATERIALS AND METHODS

Questionnaires

Two questionnaires (QNRs) were developed with the intention of obtaining both qualitative and quantitative data. The first QNR was delivered to students in week 3 of Teaching Period 1 (TP1) when students were just beginning their Projects (QNR1), and the second in week 24 of TP2 when students had completed their Projects (QNR2). Each contained questions on a variety of topics, only some of which are explored in this study. The question topics investigated in this study and the theme that each addressed are shown in Table 1**.**

Table 1. The question themes in QNR1 and QNR2 alongside the associated areas of interest.

	QNR1 – Pre-Project	QNR2 – Post-Project
Independence	Anticipated responsibility between student and advisor on stages of the Project	Importance of advisor on stages of the Project
Independence & Skill: Time Management	Planned frequency of meetings with the Project advisor	Actual frequency of meetings with the Project advisor
Skill: Planning	The ability to plan	Retrospective look at planning
Skill: Time Management	Anticipated time spent on the Project across the two teaching periods (TP1 and TP2)	Actual time spent on the Project across the two teaching periods (TP1 and TP2)
Skill: Various	Confidence in a variety of skills and abilities (technical and professional)	Confidence in a variety of skills and abilities (technical and professional)
Role of CDIO		Use of CDIO phases in delivery of Project

Focus Groups

Focus groups were made available to all Project students via email invitations. Three groups were run by a researcher unconnected to the course, meaning that the students could feel more comfortable to discuss issues regarding their experiences. Confidentiality was assured, and a total of seven students attended. As an incentive to attend, respondents were given a voucher after participating in a focus group.

RESULTS

Independence – Working with a 'Project Advisor'

Students were asked in QNR1 who they felt would be primarily responsible for the different phases of their Project. The results from this question are shown in Figure 1 and reveal that for all phases of the Project past the Definition phase, the majority of students felt that it was they themselves who held responsibility. In particular, project planning and report writing scored highest with 95 % and 97 % of students respectively identifying these phases as primarily their responsibility. In QNR2, students were asked how important they found their project advisor in the same phases of the Project. The results from this question, shown in Figure 2, suggest that many students found their advisor important in all aspects of the project. 78 % of students felt the advisor was important for defining the project and 69 % for implementing the project. The only phase in which there was a divided answer was in the writing phase, with 42% of students not finding the advisor important and 47% finding them important. To assess changes in individual responses, the paired data was analysed (n = 13). To check for bias, the paired data was compared to this overall data and the distribution of responses was found to be representative. In terms of time spent meeting the advisor, there

was a mixed change in the response when comparing the frequency the students *planned* to see their advisor compared to the frequency they *actually* met their advisor (Figure 3).

In the focus groups conducted, students discussed that the experience a student had with an advisor depended very much on both the type of Project undertaken, and on the personality and availability of the academic.

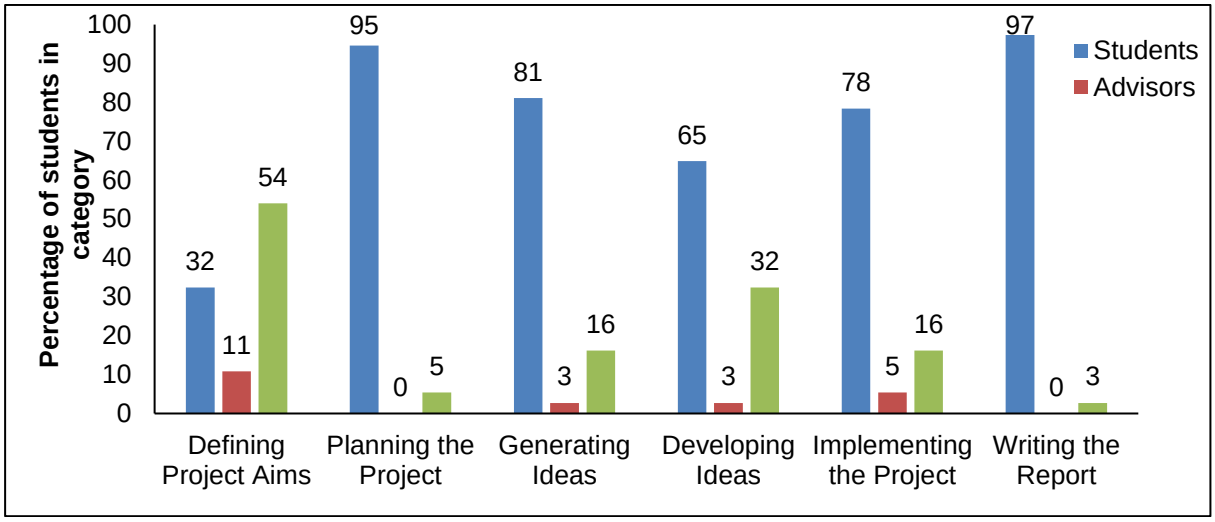

Figure 1. QNR1 data (n=37) asking students who they felt would be responsible for the different aspects of the Project stages

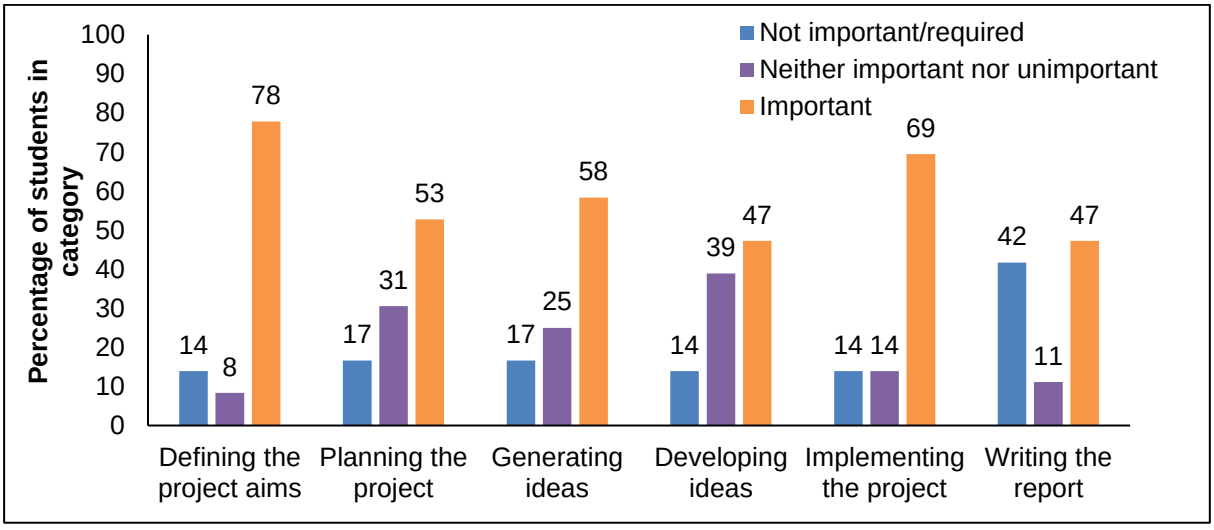

Figure 2. QNR2 data (n=36) asking students how important they found their Project advisors to be in the different Project stages

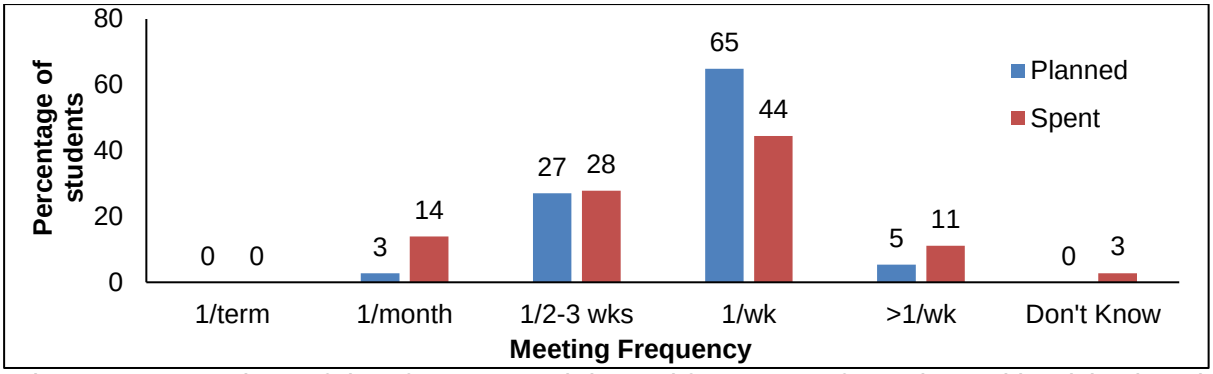

Figure 3. Comparison of data from QNR1 (Planned frequency of meetings with advisor) and QNR2 (Actual frequency of meetings with advisor)

Skills Confidence – Time Management & Planning

Student's confidence in a variety of skills was assessed in QNR1 and QNR2. One of the key skills of interest was time management. Students were asked to identify with one of three descriptions:

- Always plan ahead
- Try to plan ahead
- Always running behind

In QNR1, 64.9% of students identified themselves in the top category (Planners), with none identifying with the bottom category of "running behind". In QNR2 the "Planners" category had dropped to 58.3% and 13.9% now identified with the "running behind" category. This suggests that some students overestimated their ability to plan, or that they experienced unexpected issues that delayed their progress.

Students were also asked to predict the time they would spend in each Teaching Period (TP) on their Projects per week (QNR1) and then to retrospectively look back on the actual time spent (QNR2). The results, shown in Figure 4, display a change in trend between the time planned and the actual time spent, with a shift towards less time spent in TP1 than planned and greater time spent in TP2 than was planned. This could possibly link to the results that showed some students actually started to run behind, based on the fact that TP2 saw a higher workload in terms of hours.

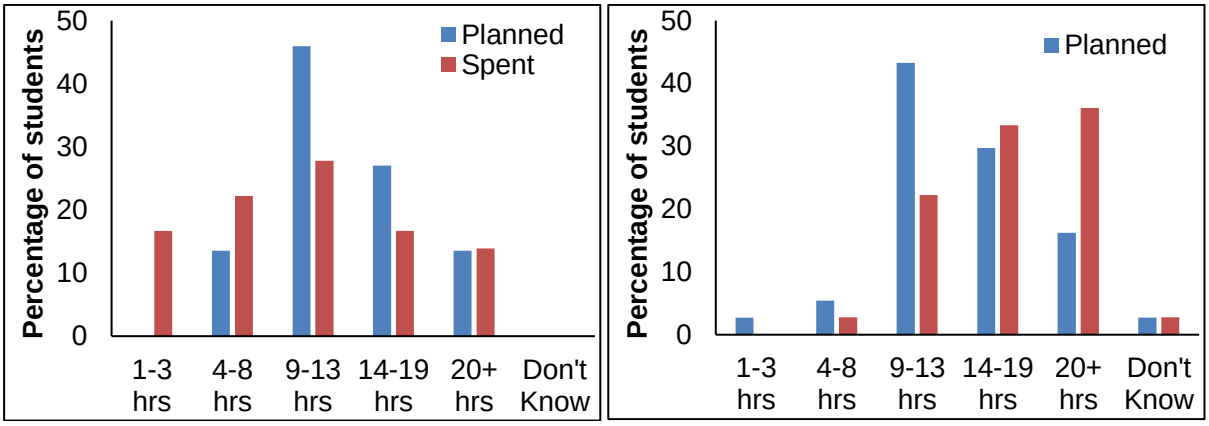

Figure 4. Time planned and spent on Projects per week in TP1 (left) and TP2 (right).

Skills Confidence – Various Skills

In QNR1 and QNR2 students were asked to rate their confidence in a variety of skill using a 5-point Likert scale ranging from 'Not Very Confident' to 'Very Confident'. The list of skills on the questionnaires was selected based on the wording of the CDIO standards, and aimed to reflect the types of skills that should be embedded throughout teaching programmes aligned to the CDIO philosophy. The students who responded with 'Confident' or 'Very Confident' were classed as confident in that skill. Between QNR1 and QNR2, there was a percentage change in confidence in some skills. Most of these were small changes, however, some did show larger changes of 9% or more, and these are highlighted in the results as shown in Table 2.

Table 2. Percentage of students identifying themselves as 'confident' or 'very confident' within list of skills provided. Any skills which showed a change of 9% or more are highlighted green (positive) and amber (negative).

SKILLS LIST	QNR1	QNR2	Difference
Problem solving	91.9	94.4	+2.6
Communication	78.4	77.8	-0.6
Apply engineering science in design-implement projects	83.8	77.8	-6.0
Teamwork	78.4	75.0	-3.4
Work to professional standards in an organisation	75.7	75.0	-0.7
Leadership	75.7	72.2	-3.5
Engineering reasoning	83.8	86.1	+2.3
Professional ethics	73.0	58.3	-14.6
Knowledge discovery	83.8	88.9	+5.1
Consider technology during product development	75.7	77.8	+2.1
Project Management	75.7	61.1	-14.6
Define customer needs	73.0	63.9	-9.1
Transform a design into a product, process, or system	73.0	77.8	+4.8
Create designs, i.e. plans, drawings, and algorithms	73.0	75.0	+2.0
Develop conceptual plans	67.6	72.2	+4.7
Critical thinking	73.0	72.2	-0.8
Self-awareness of knowledge and skills	67.6	63.9	-3.7
Consider regulations during product development	62.2	80.6	+18.4
System thinking	73.0	61.1	-11.9
Scientific thinking	70.3	83.3	+13.1
Develop technical plans	70.3	61.1	-9.2
Creative thinking	56.8	63.9	+7.1
Consider wider concepts during a project (e.g. enterprise, business and society)	32.4	50.0	+17.6
Develop business plans	27.0	36.1	+9.1
Communication in foreign languages	21.6	30.6	+8.9

Role of CDIO

Students were asked in QNR2 if they had used the CDIO process in conducting their Projects. 85.7% of students said they employed CDIO often, very often or sometimes, whilst 14.3% said they used CDIO not at all or not very often when asked the same question. In a following question that allowed open comments, students who had not used CDIO cited a number of reasons, including a purely theoretical project and not having reached the 'Implement' phase yet, due to the timing of their Project. In the focus groups, a consistent theme that occurred in discussions with students was that they felt the CDIO process was not applicable to Projects, and some felt that they would like to have learnt other processes for running projects and experiments.

DISCUSSION

This study was designed to allow an analysis of whether our CDIO aligned project modules in the first two years of study were equipping students with the correct skills for independent project management and delivery, through assessing their perceptions of their skills and independence during their Final Year Projects and how students transition from the group PBL modules into individual Project work.

From the results, it appears that students began their projects with high confidence levels and the feeling of independent responsibility for their work. The majority of students considered themselves good planners and had an expected level of engagement hours with the Project, which was relatively evenly split across the two TPs. Following the Project, students cited a high importance of the project advisor, which was somewhat at odds with their earlier projection of independence. This may indicate a reliance on a team of people with which to discuss ideas, designs, results and plans etc. The earlier modules may give students confidence in their abilities to manage and deliver a project, but that confidence could be partially due to the safety of a team environment. Focus groups did discuss the step from group to individual projects as being difficult. Another explanation is that the Project is a major assessment point of work, which is worth a large percentage of a student's FY, and, therefore, overall degree classification. It could be argued that the importance of the advisor is in providing feedback and validation to the student throughout the Project, particularly in terms of the quality of their work and the likely outcome of the Project. This does fit with anecdotal evidence from project advisors whose students often ask them what grade they think they are heading for at various times throughout the Project.

The majority of students considered themselves as good planners prior to the Project. However, the data showing the change in both the identification with the type of planner they were and the shift in time planned vs. time spent on their projects, would suggest that time management was an issue. In the earlier PBL modules groups are given interim deadlines, or gateways, in which they must show evidence of appropriate progress in the given module prior to the end assessment date. In the Final year Project, there is a short planning viva in week 6, but then no further assessment until the end of TP2 in around week 24. The ability to self-impose deadlines could be lacking and therefore be a reason why students were not able to do achieve an even split of workload in their Projects.

The skills that students most readily identified themselves as confident in were skills that module tutors stress the importance of to students in the earlier project modules i.e. knowledge

discovery, problem solving and team work. The skills which were taught in the modules, but were not necessarily highlighted or discussed, but more embedded in the module were those that students did not identify confidence in, such as creative thinking and considering the wider concepts of a project such as business and society. Students in the focus groups discussed the CDIO process as not always being applicable, though when questioned on this, they could only relate it to group based design projects, and did not believe that it could be used in more scientific based projects. The step up between team projects and individual projects and the associated changes should not be overlooked. This was particularly highlighted by the higher dependence of advisors in the QNR2 outcomes.

CONCLUSIONS & FURTHER WORK

The aim of this work was to ascertain the effectiveness of our PBL modules in preparing students for independent work. The results show that students are confident in a range of skills, that they perceive themselves as responsible for their work, but that they place high importance on the input and guidance of an advisor. Though they did not plan as well as they expected to, and workload was not as evenly distributed across the project as they had planned, they did remain generally confident in their ability as 'good planners'. Their skills confidence increased and decreased across the range of skills, perhaps showing the importance of the individual Project in exposing students to a different type of project and learning experience.

Overall, we believe that our PBL modules do provide a high level of skills and attitudes suitable for independent project work. However, these could be improved to further develop the skills of independent learning and time management, particularly with planning and executing projects without the support of a team, and those that may seem different to projects previously tackled i.e. the ability to transfer skills across to different settings.

The limitations of this study include the non-paired nature of the data (i.e. only 13 of the 36 students completed both questionnaires), and the small size of the focus groups (7 students), which limits the ability to draw conclusive outcomes that are representative. Also, this study looks at only one cohort of students. In addition, students' perception of their skills and their competence in those skills may not be accurate, and are subjective.

Further work will involve comparing students predicted grades and skills confidence with both the grade achieved and the competence that the project advisor suggests for that individual student. Data will be gathered for the next three years in order to capture a larger cohort size and to identify any cohort-specific results. We also wish to expand the data into our Design department, to analyse the difference between students on different programmes.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the financial support received from the Aston Stem Education Centre which allowed the running of focus groups for this project. We also acknowledge the Final Year Project module tutor Dr Upton for access to the students, and the Project advisors for their assistance. And the students themselves for taking the time to fill out the questionnaires and attend the focus groups.

REFERENCES

Besterfield-Sacre, M., Atman, C. J., & Shuman, L. J. (1998). Engineering Student Attitudes Assessment. *Journal of Engineering Education, 87*(2), 133-141. doi:doi:10.1002/j.2168-9830.1998.tb00333.x

Bjorklund, S. A., Parente, J. M., & Sathianathan, D. (2004). Effects of Faculty Interaction and Feedback on Gains in Student Skills*. *Journal of Engineering Education, 93*(2), 153-160. doi:doi:10.1002/j.2168-9830.2004.tb00799.x

CDIO. (2018). CDIO.org. Retrieved from http://www.cdio.org/

Crawley, E. F., Malmqvist, J., Lucas, W. A., & Brodeur, D. R. (2011). *The CDIO syllabus v2. 0. An updated statement of goals for engineering education.* Paper presented at the Proceedings of 7th International CDIO Conference, Copenhagen, Denmark.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, 111*(23), 8410-8415. doi:10.1073/pnas.1319030111

Grant, D. M., Malloy, A. D., & Murphy, M. C. (2009). A Comparison of Student Perceptions of their Computer Skills to their Actual Abilities. *Journal of Information Technology Education: Research, 8*, 141-160.

BIOGRAPHICAL INFORMATION

Laura J Leslie, Ph. D. is a Senior Lecturer and Deputy Head of Mechanical Engineering and Design at Aston University. Her research fields are in learning and teaching, as well as Biomedical Engineering and Materials. She has a particular interest in CDIO, active learning, teaching large cohorts and student centred learning.

Paul C Gorman is a Student Experience Manager at Aston University and oversees the evaluation of learning and teaching modules, as well as student satisfaction, across all Schools of study. His current PhD research project is centred around the marketisation of Higher Education in England. He has presented at numerous international Higher Education conferences over the last ten years.

Sarah Junaid Ph. D. is a lecturer in Mechanical Engineering and Design at Aston University, UK. Her pedagogical research interests include student learning, engineering ethics and professional skills development. She is a member of the Biomedical Engineering research group with an interest in biomechanical testing and computational modelling within orthopaedics.

Corresponding author

Dr. Laura J Leslie
Mechanical Engineering and Design
Aston University
Birmingham. B4 7ET.
+0044 121 204 3747
l.j.leslie@Aston.ac.uk