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PROJECT AND TEAM BASED LEARNING – AN INTEGRATED APPROACH

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ABSTRACT

One of the most important requirements of modern graduate engineers is their ability to manage and/or collaborate in complex, open-ended projects. This requires effective communication skills, both within the engineering profession as well as with non-engineering professionals. It also requires the experience and ability to work independently as well as in a team environment, with the ability to think both critically and creatively. It is widely recognised that project and team based learning, in particular within the framework of larger open-ended design and industry-based projects, provides undergraduate engineering students with the best opportunities to understand the complex multidisciplinary contexts that are typical for many professional tasks. The approach also helps students to develop the skills and gain the experience necessary to carry out projects successfully in the real world.

In this paper, the experiences gained from project based learning within design courses in the Department of Mechanical Engineering at the University of Auckland are discussed. Issues covered include the identification of knowledge gained through project based design courses, the formulation of project objectives in connection with learning outcomes and assessment procedures, and the opportunities and challenges associated with project management and teamwork. Examples are drawn from the students' initial exposure to project based learning in the first year design course, through to the final year open-ended project base course. A critical analysis has been performed to verify actual outcomes against intended outcomes from these courses in the context of the developed methodologies. The effectiveness of our project based learning approach has been monitored for a number of years through an elaborate student feedback process. The main outcomes and conclusions resulting from this feedback are discussed in detail.

INTRODUCTION

The paper presents an evaluation of outcomes from three design courses that are based on project and team based learning taught to engineering students at different levels of a four year degree program in the Mechanical Engineering Department at the University of Auckland. In terms of study years, the freshmen design course (first year) focuses primarily on a structured design experience, whereas courses for third and fourth year students focus more on less structured open-ended design experiences. The main objective of the freshmen design course is to bring students' attention to the concepts and practice of engineering design with some limited hands-on experiments and projects. On the other hand, the main objective of the senior year design courses is to focus students' interest in the design of real life products based on either guided or open ended design experience using, where possible, industry-based projects. The ultimate objective of these courses is to provide students with the

opportunity to work in realistic cooperative design environments in which they; employ critical thinking, apply learned theoretical knowledge and gain skills for self-motivation and lifelong learning through teamwork [1]. Although the teaching approach for these courses varies according to set requirements for the different levels of students, there is a common approach in all courses with respect to the project based learning component. The underlying objective of this research study was to investigate, from different perspectives, the issues surrounding the expectations and learning outcomes from a project and team based approach.

Traditionally, engineering design courses commonly combine lecture delivery with team project assignments, where small collaborative groups of students work on a specific problem. The benefits expected from the addition of project and team based learning include; greater interpersonal communication skills, knowledge sharing and information dissemination, along with a degree of self-learning of new material. The design courses studied here, recognise the necessity for modern engineering graduate to possess strong technical knowledge along with a wide array of personal, interpersonal and system building skills that will allow them to function effectively in real engineering teams producing real products and systems [2]. The idea behind this research was to examine the effectiveness of the project and team based learning approach and the assessment criteria used, for the range of design courses which had the following learning objectives:

i) Develop innovative design concepts which would enhance the competitive advantage of a particular product, using a systematic approach.
ii) Develop a good understanding of real life consumer product design processes and the environment within they need to operate.
iii) Become familiar with some modern design tools and techniques.
iv) Understand customer perceptions regarding designed products.
v) Develop creativity skills.
vi) Learn the importance of sharing responsibility through teamwork with members having different norms, backgrounds and value systems.
vii) Develop good professional dissemination skills in terms of communicating ideas and concepts through presentations (e.g. reports, workbooks, posters, oral presentation and interviews).

According to cognitive science research regarding the nature of learning [3], students construct knowledge; they do not take it in as it is disseminated, but rather they build on knowledge they have gained previously. They benefit from working together, and may learn best from teaching each other. As a whole students learn through making cognitive, social and experimental connections. In this context, project and team based learning plays an important role. In project-based learning, students work in teams to achieve optimal solutions for particular design problems that represent “real world” situations. They develop skills in collecting, evaluating, and synthesizing information and resources in a professional manner and then propose an optimal solution showing alternative approaches. As current employers have frequently expressed a desire to have graduate engineers (students) who can think critically, solve problems, and work in teams, project and team based learning is recognized as a better platform for engineering design courses. Project-based learning is a well-known method for imparting thinking competencies and creating flexible learning environments as well as directing students to foster learning and develop thinking skills [4, 5]. Project and team based learning methodologies place students in an active learning environment that puts them at the centre of the learning process. The knowledge gained through active learning is constructive knowledge achieved through active thinking and problem solving, both of which are important for modern graduate engineers. Project-based courses usually provide students an opportunity to improve multidisciplinary teamwork, communication skills, project management, and problem solving abilities, as well as to immerse them in an environment that will enhance life-long learning [6]. A related pedagogical approach of project based learning, is problem based learning, which is well recognised within higher education. Although this approach is similar to project based learning, it constrains students' activities more, by asking them to solve specific problems rather than relying on the students to come

up with their own problems in the course of completing a project. The acquisition and structuring of knowledge in problem based learning is thought to work through the following cognitive effects [7]:

i) initial analysis of the problem and activation of prior knowledge through small-group discussion,
ii) elaboration on prior knowledge and active processing of new information,
iii) restructuring of the knowledge with the construction of a semantic network,
iv) learning in context and,
v) stimulation of curiosity related to the presentation of a relevant problem.

The project and team based engineering design courses studied in this research utilise problem based learning, where open-ended mini projects are assigned to small groups of students. The students are provided with some specific objectives along with a typical design problem (real world product design and/or industry based design problem). Individual teams, made up of 3/4 members, are formed by the students themselves from their respective class colleagues and are required to achieve a competitive and an optimal design solution within the project schedule (for example, within 40 hours). The project schedule is provided by the lecturer along with comprehensive guidelines. To ensure that each team member contributes fairly to the team effort, CDIO-based team contract guidelines are provided to the students. To avoid conflict among team members, each member must sign the agreed team contract, developed during their initial team meeting, and submit this to their assigned tutor before commencing work on the actual project itself. In addition, at the end of the project, students must submit a completed peer assessment form. The primary aim of the 'Peer Assessment' is to review how the members of the team evaluate their own and the other team members' contributions and performance throughout the project. The peer assessment is taken into consideration when evaluating students' final grades. The secondary aim of the peer assessment is to examine the distribution of workload among team members and assess their ability to share responsibilities while achieving the project goals.

In our research we study students' performance in teamwork while they explore real-world problems assigned in the project. In addition, we examine students perceptions of project-based learning in achieving the expected outcomes which include a deeper knowledge of subject matter, increased motivation and improved problem-solving skills. Finally, we verify the applicability of the developed project based design courses with respect to their effect on developing in-depth understanding of the knowledge acquired, performance-based assessment procedures and student ownership of their own learning. Accordingly, this paper focuses on the project and team based experiences gained by the students in three design courses in terms of learning objectives, implementation procedures, assessment criteria and expected outcomes. In the next sections, we describe our research design, then present and discuss the major findings along with some statistical analyses. Finally, we present our conclusions.

RESEARCH DESIGN

This study is based on data from a large research study involving different classes in the Mechanical Engineering Department at the University of Auckland. The data was collected from three designed based engineering courses, one from 4th year, another from 3rd year and the third from 1st year of a four-year undergraduate engineering degree programme. During 2005, the responses from 50 students from the 4th year course, 30 students from the 3rd year course and around 500 students from the 1st year course were collected. From the total responses obtained from students, 48 4th year, 15 3rd year and a random sample of 30 1st year were used in the analysis. The engineering design courses studied in each year, were all developed around a set of standards for lesson plan and assessment criteria. The standards, specified learning objectives along with guidelines to achieve these. For the assessment criteria, quality indicators were clearly stated and scoring criteria made available to students

with regard to what was being judged and the standards expected for acceptable performance.

Objectives of the research

The research was designed with a specific set of objectives, which are:

i) to assess the achievement of the learning objectives through the use of project based courses
ii) to identify patterns of individual student's knowledge gained through teamwork
iii) to assess the usefulness of team contracts in the learning process
iv) to assess the applicability of the developed tools and methods used
v) to identify shortcomings in our approach to team based learning, if any, in our project based engineering design courses.

Method of data collection

Data was collected by a well-formatted questionnaire. Respondents (students) were asked to submit the completed questionnaire immediately after the submission of their final reports in the respective design courses. Key question areas included in the questionnaire are highlighted here.

The first part of the questionnaire contains questions regarding peer assessment which emphasises the distribution of workload among team members (relative contribution) and the nature of the contributions with respect to teamwork along with individual and team (performance) ratings. The second part of the questionnaire is related to teamwork itself. This part comprises the questions on student perceptions of

- the achievement of learning outcomes related to the specified learning objectives,
- responsibility taken by team members,
- expression of opinions in team discussions,
- ways of resolving disagreement in the team,
- application of teamwork,
- additional support required,
- individual contributions made towards achieving the project goals and, most importantly,
- the knowledge gained through working in a team.

Open ended comment sections on project and teamwork were also incorporated in the questionnaire. Comparative analysis between the expected performance suggested by the students and the performance assessed by the assigned authority was also carried out.

PROJECT SETUP

Guidelines and tools provided to the students

To enhance the "real life" experience of the students, a scenario was developed in which they were presented with well formulated "client" letters explaining the design brief and the business requirements expected from the ensuing product design. In the final year design project, the project was formulated and presented to the class by the Manufacturing Manager of the client company. CDIO-based guidelines for teamwork contracts, project scheduling, guidelines regarding presentation material and modes of presentation (structure of the submission and suggested format of design portfolio), and peer assessment forms were also provided to the students at the outset.

Assessment processes

As each particular project based learning instructional environment is unique, individual assessment strategies were developed for each course. Among the several alternative assessment techniques used, evaluation by external experts and peer evaluations was applied. Since project based learning usually involves a culminating experience such as a formal presentation, a written report, or a portfolio submission, the evaluation of these

capstone projects by outside experts seemed appropriate. Thus, in the performance evaluation processes used, course instructors, tutors and external company experts and design professionals were usually involved.

For a better understanding of the evaluation process by the team and its individual members, pre-prepared assessment criteria were delivered to students at the beginning of the project so that they can understand the assessment procedure. These assessment criteria are based on the *quality of the solution, design proposal, quality of artefact, design process, group management and evidence of work effort (e.g. workbook)*. The quality of the solution represents the innovative nature and commercial relevance of the proposal including its feasibility and practicality. The design proposal represents the clarity and effectiveness of drawings, quality of text and explanation presented in a professional manner. The quality of the designed product or artefact should clearly demonstrate its conformance to stated parameters. The design process used by the students should reflect a structured approach to achieving the design specification and parameters through an appropriate methodology of concept exploration, development and selection using appropriate decision making tools. Group management is evaluated in terms of the quality of team structure and evidence of the team working effectively. The evaluation of the workbook is to ensure the regular, thorough and methodical documentation of design work and project organisation.

In addition to written submissions such as a design proposal, interviews with student teams are carried out in the 3rd and 4th year courses. The evaluation of performance in the interview is based on professionalism and attitude, presentation quality and the ability to respond coherently to "client" questions. As an integral part of the assessment process for individual students, peer assessment is applied as a means of moderating individual student behaviour within the team setting, as evidence of contribution towards teamwork, and as an indication of skill level development across individuals within the team.

MAJOR FINDINGS AND DISCUSSION

Method of analysis

Qualitative as well as quantitative analyses have been performed for this study. Semi-structured interviews with students during the project, relative performance testing and assessment of presented material have also been considered for the analysis. In addition, the data collected by the questionnaire survey has been utilised for both statistical and qualitative analysis purposes. From this we compared self-assessed ratings of a student's performance with their team members' ratings of them. To test the acceptability of an individual student's self-assessed score, we calculated the average rating for a particular individual provided by the team members against his/her expected rating and conduct a correlation study. We have also performed a comparative analysis (ANOVA) between the data from different courses with respect to the contribution to teamwork, and individual and team performance. Further ANOVA studies tested the nature of the distributions concerning the individual contribution to teamwork and suggested performance by the students for different courses. Students' perceptions of project based learning, teamwork and the assessment by a panel of course evaluators (composed of lecturer, tutors and company experts) has also been performed for a particular course (4th year) to identify variations.

Analysis of the raw data collected from the questionnaire survey, observations, and students presentations (e.g. technical reports) revealed some issues that repeatedly appeared. The first issue concerned the achievement of the learning objectives from the courses, which had been defined at the beginning of the project or course. The responses shed light on students' views on their achievement of the learning objectives expected from the course, and it was interesting to compare their perceptions with the course organisers' intentions. The second issue that emerged from the study was the applicability of teamwork within project based design courses. The third issue referred to the additional knowledge (apart from the specific design tasks), gained through the use of teamwork. The fourth issue related to the setting of project based learning tasks within the context of realistic industrial environments.

Students' perceptions of the achievement of learning objectives

The key question regarding learning objectives was "Did the learning outcomes you achieved from working in a team in this project/course match the learning objectives specified in the project handout"? To respond, students were given five options such as; yes to all objectives, yes to most of them, yes to some objectives, yes to a few objectives and no. The responses are very positively in favour of the achievement of learning objectives as shown in Figure 1.

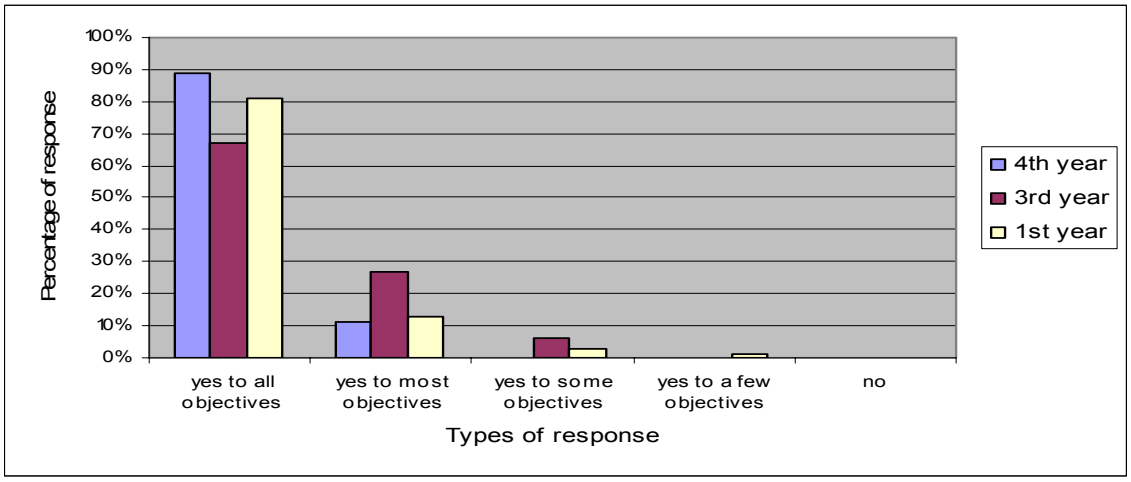

Figure 1: Response to the achievement of learning objectives from the project through teamwork

The figure shows that 89% of fourth year students, 67% of third year students and 81% of first year students stated that all of their learning objectives had been achieved through the project and team based design courses. If we consider the average responses from three different courses we find that, on average, 79% of students said that all of the learning objectives had been achieved, whereas 17% of the students believed that most of the learning objectives had been achieved. 3% said that some of the objectives had been achieved, while only 0.33% of the students said that a few objectives had been achieved. From this response, we can substantially conclude that the project and team based learning is very effective in achieving both the technical and the pedagogical learning objectives in these design courses.

Teamwork and project based learning

As expected from project based design courses, students are supposed to achieve the learning outcomes through teamwork. Teamwork involves tasks being shared amongst team members to complete a project successfully. It is expected that responsibilities are fairly equally shared by each team member. During the distribution of the workload, special knowledge possessed by individual team members should be taken into consideration. The study finds that different teams identify the components of project slightly differently, although the main components are almost the same since their ultimate goal is to complete the respective project on time with significant outcomes (e.g. artefact, design portfolio, workbook etc.). To analyse the nature of the contributions to teamwork, we categorise the components under five headings as follows:

i) Needs assessment and initial research,
ii) development of alternative concepts and final selection (product design specifications and alternative concepts),
iii) drawings, sketches and other related activities (calculations, measurements etc.),

iv) product creation or poster creation (that includes material collection, assembly, testing, finalising), and
v) design portfolio (report writing).

We present here comparative charts (see Figure 2 to Figure 10) to show how the team members contribute to teamwork. The X-axis of each figure represents the range of contribution where the numbers 4, 3, 2, 1 and 0 represent major contribution, significant contribution, moderate contribution, minimal contribution and no contribution, respectively, for different tasks.

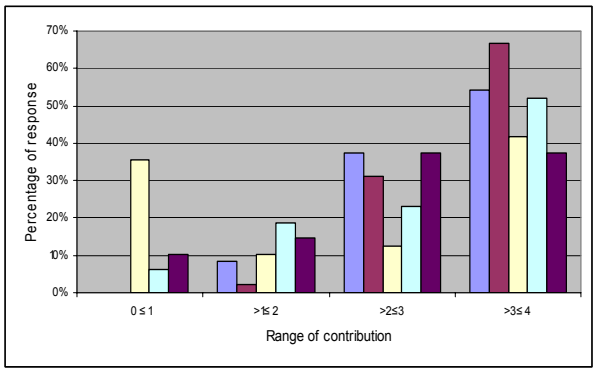

Figure 2: Contribution to different tasks in a team (4th year)

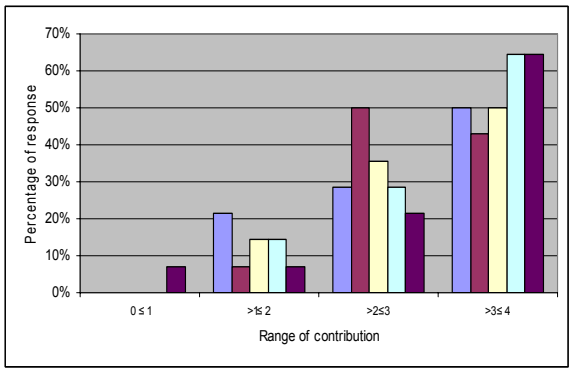

Figure 3: Contribution to different tasks in a team (3rd year)

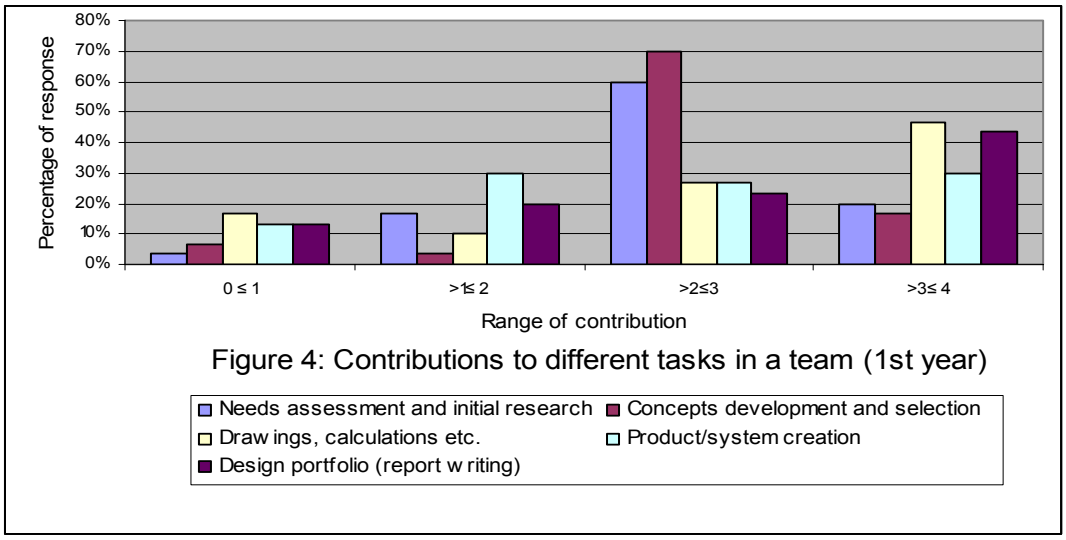

Figure 4: Contributions to different tasks in a team (1st year)

From Figure 2, we see that on average, 50% of the fourth year students contribute within the significant to major range to all components of the project in teamwork. 28% of them contribute moderately to significantly to all tasks while about 11% contribute from minimal to the moderate range. Only about 10% of students contribute within the zero to moderate range to some specific tasks, especially to drawing and concept development. From the data we can say that almost 90% of students contribute to some extent to all tasks within the project. According to Figure 3, we see that about 54% of the third year students contribute to all tasks at a significant to moderate level. About 33% contribute at the range of moderate to significant level, followed by 16% contribution at minimal to moderate range. Only 1% of the students fell into the zero to moderate levels, with contributions to only a specific task, in particular the design portfolio. That means that almost all students have contributed to all tasks to some degree or other. However, a different picture emerges for first year design course students (see Figure 4). About 31% of first year students contribute within the significant to major range for all components of the project. On the other hand, 41% contribute to all tasks in the range from moderate to significant. 16% of students contribute within the range from minimal to

moderate. Another important finding here is that about 10% of students contribute in the range from zero to minimal level for all task. This figure gives us an indication that first year students stick to their assigned tasks within the project and appear reluctant to contribute to other tasks which they have not been assigned to. The result is reasonably expectable considering the first year students' lack of design experience of working on projects and within teams.

Using teamwork in a project based course, we cannot expect that everyone will contribute the same amount to all tasks. Rather, we can expect that students will divide their workload as per their expertise and share their knowledge and skills within the team to help achieve the specific goals of the project. The results obtained from the students' contribution in different tasks, strongly support this expectation by the educators and employers of graduate engineer in this modern society [1, 8 & 9].

From Figure 2 through to Figure 4, we can see that the majority of fourth year students emphasise concept development and selection of optimal design, while third year students emphasise product fabrication and the production of the design portfolio. First year students, on the other hand, emphasise concept development and optimal design selection. For further analysis, we compared the relative positions of different years on specific components of a project and these are presented in Figures 5 to 10.

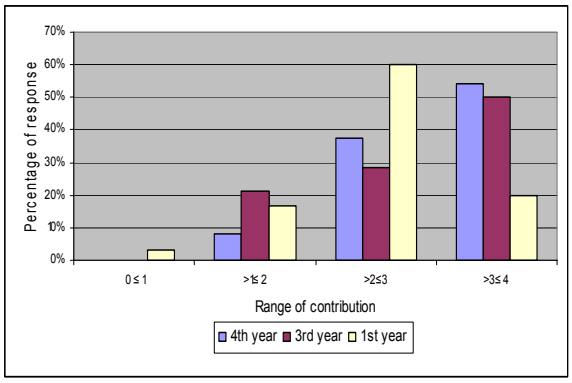

Figure 5: Comparative picture on "Needs assessment and initial research"

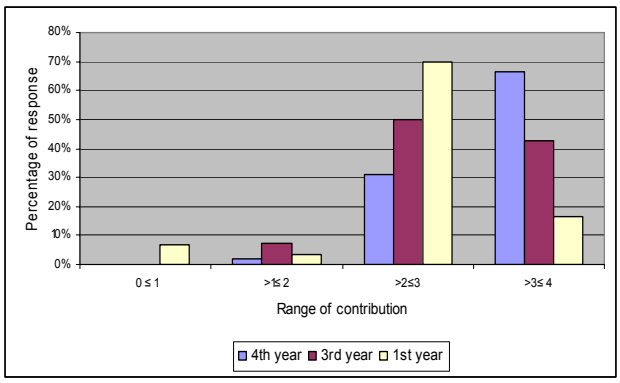

Figure 6: Comparative picture on "Concept development and design selection"

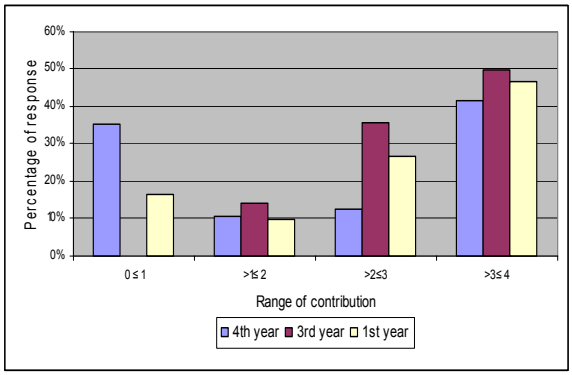

Figure 7: Comparative picture on "Drawings/ calculations etc."

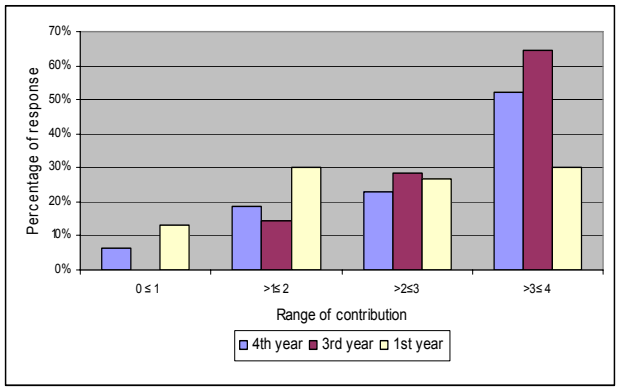

Figure 8: Comparative picture on "Product/ system creation"

Figure10 shows the comparative picture on overall contribution to teamwork by the students of different years. 71% of third year students contribute from a significant to moderate level compared to 54% and 33% of the fourth year and the first year counterparts respectively. On the other hand, 60% of first year students contribute from a moderate to a significant level compared to 46% and 29% of fourth and third year students respectively. We can infer from these findings, that first year students are fairly conservative with respect to their overall contribution to teamwork based on assigned responsibilities. On the other hand

3rd and 4th year students are more inclined to contribute to every task conducted by the team. This may come from the increasing level of maturity and understanding about teamwork and project based work from these students. Obviously, first year students have had very little exposure, if any, to project and team based learning. However, we have conducted ANOVA studies to examine whether there is a significant effect from maturity and experience on individual performance in project and teamwork.

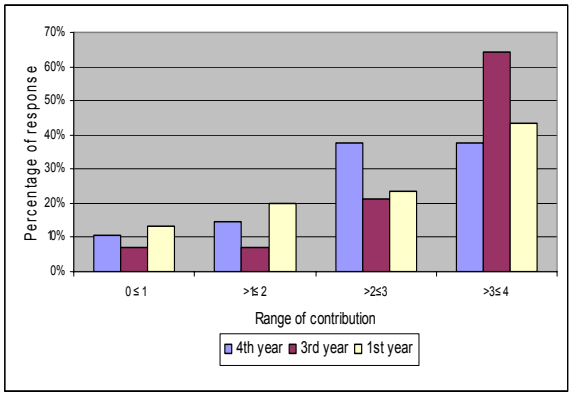

Figure 9: Comparative picture on "Design portfolio (report writing)"

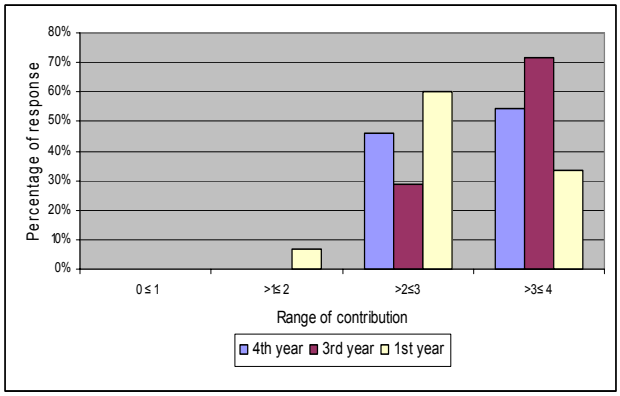

Figure 10: Comparative picture on " Overall contribution to teamwork"

Our research hypothesis, therefore, is: *there is an effect from maturity on performance in project and team based learning*. The related null hypothesis is: *there is no effect from maturity on performance in project and team based learning*. With these hypotheses, we conducted a one factor independent measure ANOVA study. The result of this is presented in Table1.

Table 1: The ANOVA Summary on Performance comparison.

Source of variation	Degrees of freedom	Sums of squares	Mean square	Variance ratio (F)	Probability
Between conditions	2	8.69	4.34	5.72	$p < 0.01$
Within conditions	81	61.55	0.76		
Total	83	70.24			

From the analysis we find that there is a significant effect from the maturity of students on their performance. To be more specific, we conducted a post hoc test (the Tukey Test) [10]. From this we found that the difference between first year and fourth year students is highly significant according to the Tukey HSD (Honestly Significant Difference) test. Although there is a considerable difference between third year and first year performance, we cannot conclude that there is a statistically significant variation. From the study we found that there was a small, but not significant, difference between fourth year and third year students' performance. The study also shows that there is a significant effect of maturity and experience on performance when using teamwork within project based learning. This finding supports the concept that senior year students have had more exposure than junior year students to teamwork and project based learning, as they progress from structured design experience to open-ended design experience.

A further ANOVA study was performed regarding the trend of contribution to teamwork in the context of developing maturity. In this case, our research hypothesis was that *there is an effect from a student's maturity on their overall contribution to teamwork*. The alternative hypothesis was that: *there is no effect*. The summary of the study is presented in Table2. From the analysis we find that there is no significant difference between senior year students

and their junior year counterparts. From this result we conclude that, irrespective of seniority, students will tend to contribute to teamwork to the same extent.

Table 2: The Summary of ANOVA study on contribution comparison.

Source of variation	Degrees of freedom	Sums of squares	Mean square	Variance ratio (F)	Probability
Between conditions	2	266	133.21	0.16	$p > 0.05$
Within conditions	81	66858.06	825.41		
Total	83	67124.48			

Further analysis has been performed with fourth year students to see whether there is any correlation between individual contribution to teamwork (as claimed by individual team members) and individual's average performance in teamwork (as suggested by the other team members). We find a positive correlation such that, as an individual's assessment of their performance increases, so too does their colleagues overall assessment increase. Using a scatter plot, we can show this relationship (see Figure11). However, to find the significance level, we compare the calculated value of "r" with the value found for "r" in standard statistical tables. The calculated value of Pearson Correlation Coefficient r = 0.27 while the value found from tables for "r" with 46 degrees of freedom is 0.24. at p =0.05. From this, we can claim that there is a significant correlation between the contribution to teamwork and an individual's performance while learning from a project based design course.

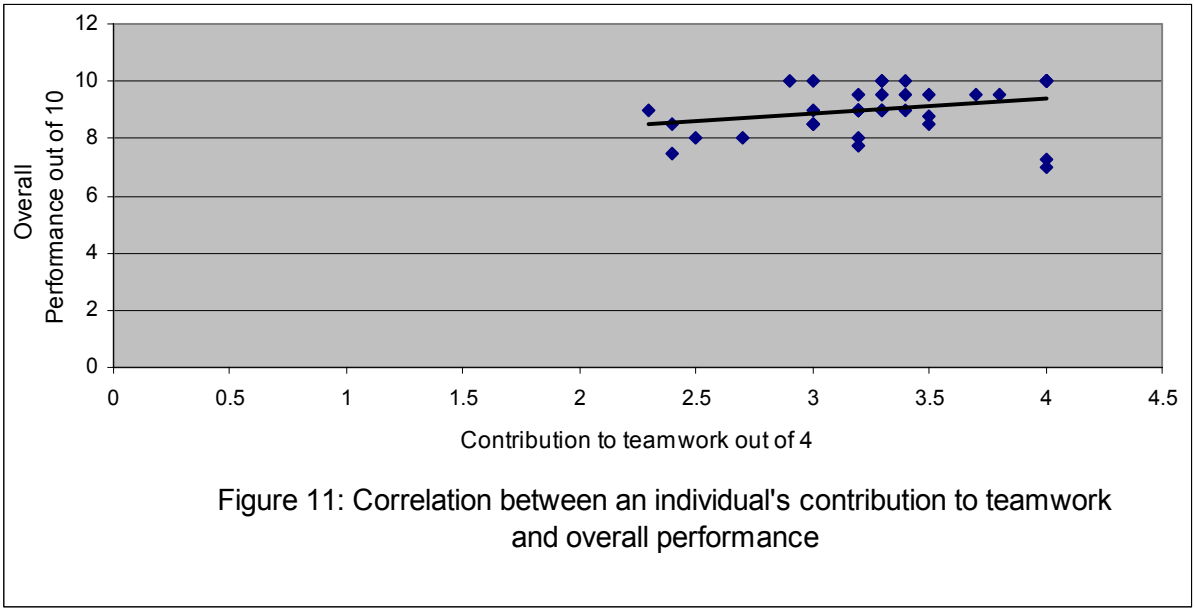

Figure 11: Correlation between an individual's contribution to teamwork and overall performance

Before the study was conducted we had expectations that the 'Team contract' might play an important role in indirectly enhancing the individual's contribution to teamwork. The main objective, however, of the CDIO based team contract is to ensure fair working policies for all members in a team. We examined this issue by collecting the data relating to the usefulness of the team contract as perceived by the students. We analysed this with respect to five usefulness categories as shown in Figure 12.

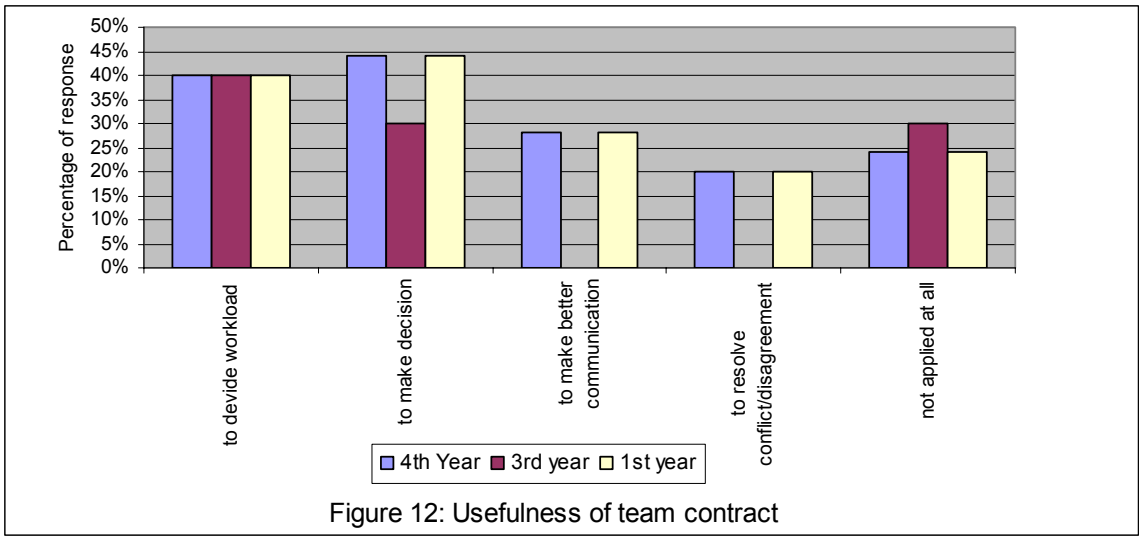

Figure 12: Usefulness of team contract

The figure shows that on average 40% of students from each study year used the team contract to divide workload, while on average 39%, of students used it to make decisions. A significant finding was that around 26% of students did not use the team contract at all. With respect to the methods used by students to resolve conflict/disagreement, the results are shown in Figure 13.

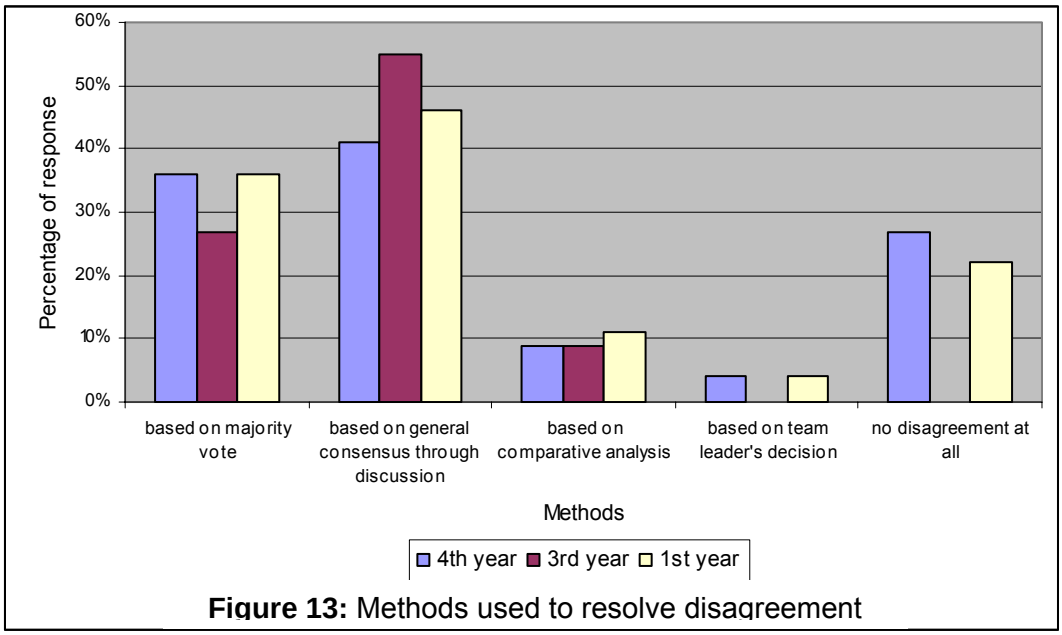

Figure 13: Methods used to resolve disagreement

Additional knowledge gained apart from the specific design tasks

As stated earlier, the project and team based design courses were developed with some new pedagogical learning objectives, in addition to the purely technical objectives, in particular that students learn in a "real" industrial working scenario. We investigated the students' perceptions about the most important learning outcomes from the courses apart from the technical objectives. The findings are presented in Figure 14. From this we see that on average, 64% of students from all years say that they have learned the importance of sharing responsibilities through teamwork. 34% of the students from all years mention that they have gained important knowledge regarding the generation of ideas and selecting an optimal solution by working in a team. Around 21% of all students emphasise that they have recognised that interpersonal communication skills are important in developing teamwork.

16% of the fourth year students say that they have gained professional presentation and other related skills.

All these findings indicate that students, through project and team based learning, gain some important knowledge and skills that are demanded in real design environments [8, 9].

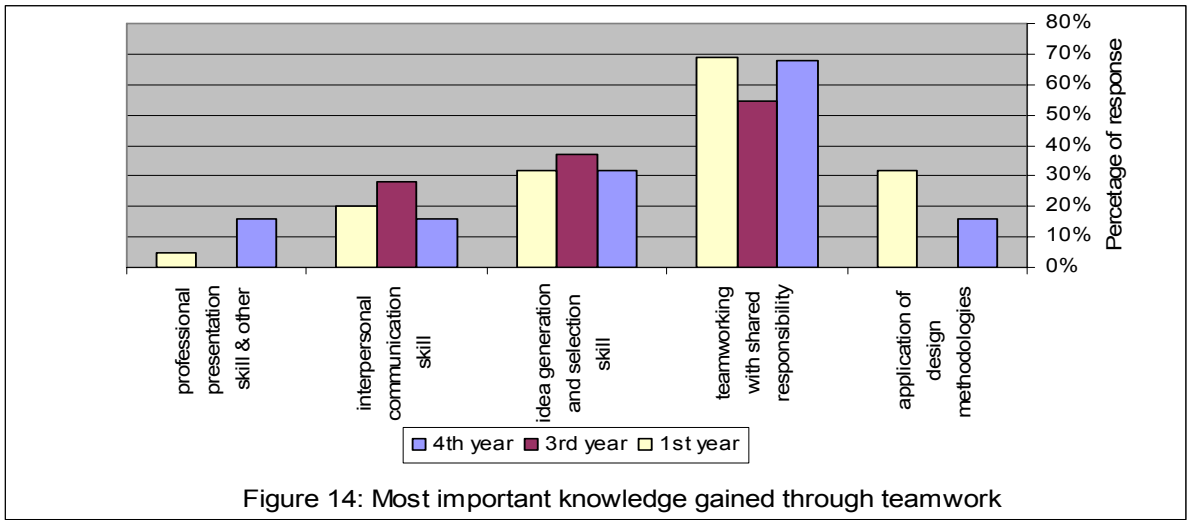

Figure 14: Most important knowledge gained through teamwork

Project and team based learning outcomes in the context of industrial environment

Table 3 indicates that students found the learning experience useful for developing the multi-skills expected in design based activities carried out in typical industrial environments. The students learn how a design project can be completed within a specific timeframe while working in a team composed of different people with a range of skills and expertise.

Table 3 : Typical statements provided by students relating to lifelong learning.

- This project based learning is immensely helpful for my future as it improves my confidence level in working in a team environment with multi talented people.
- My experience from working with project based learning is that no one person has all the knowledge needed to complete a design task, this requires multi skills.
- The generation of a "Professional Proposal" is very worthwhile. Creating something real through the project is the most beneficial achievement. I think it will provide an insight as to how to go about creating real life products.
- My observation during the project based course was to see how individuals can offer many different skills and use them together for a successful project.
- I learnt that just one person is unable to cover all of the good and bad points of a concept or design. Working as part of this group strongly clarified this for me.
- Writing a report with inputs from different people is quite challenging as putting all the information together and expressing it properly requires practise, I have learned this well through this project based course.
- Whilst working in a team, it is much easier to come up with an effective solution, rather than trying to figure everything out on your own.
- I have learned that if the work can be split up into different components and the people are expertise on their relevant tasks, then the work can get done faster.
- I've learned a lot about designing a product and have gained a lot of knowledge about design construction.

Table 4 presents some potential challenges regarding teamwork for instructors from students. Most statements are related with the selection of team members and their responsibilities. Although the percentage of responses is relatively low, these still indicate that the methodology used for team building needs to be improved.

Table 4: Some challenges associated with teamwork

- My experience of teamwork during this project is that a lot of people prefer to just pass than do an adequate job, and prefer to leave it up to others rather than work as a team.
- I found teamwork to be a problem because I had some incompetent team members who don't have any expertise and depend on my work.
- I find teamwork is problem when people get sick. Our team performance was degraded because of one team member who was sick most of the time.
- I find that coping with different opinions and personalities was a real challenge.
- If someone is not going to carry out their team responsibilities (and everyone knows what they need to) then a document like a team contract can't influence them.
- In my opinion, team co-operation and collaboration is the key to any group project. Unfortunately, I didn't have enough cooperation from my team members as they were pretty reluctant to work on the project as they presume a pass mark for this course will be enough and it will be achieved by passing responsibilities on to someone else.
- Teamwork could have been much better, if I had been in a team with people of similar mentality to myself.

Finally, we performed an analysis to verify the applicability of the use of peer assessment and the overall assessment criteria developed for these project based courses. The data from the fourth year students only were used for this purpose. Regarding peer assessment, we conducted a t-test with the scores provided by individual students and the score provided by team members. We found that the distributions of the contribution to teamwork, team performance and individual performance for both cases were significantly the same. This indicates that, on average, individual students are not claiming a greater contribution to teamwork and performance than that assessed by their respective team members. This would suggest that the current "Peer Assessment" is working well in terms of evaluating teamwork and individual performance. However, we performed another t-test comparing the individual performance according to peer assessment and that evaluated by the instructor. We found that there was a significant variation between the two distributions. It confirmed that the performance evaluated by the instructor was significantly lower than that suggested by the students. This means that either, students have over rated their relative contribution or, they have misunderstood the assessment criteria being used by the instructor. Although a lower grade given to a student does necessarily indicate a lower learning outcome, the assessment criteria itself or clarification of the criteria may need to be reworked for the future.

CONCLUSIONS

This is based on student feedback obtained from project and team based learning in three different design courses from different years at the Mechanical Engineering Department in the University of Auckland. It has been found that in project based learning, students perceived that they developed stronger thinking and problem-solving skills, effective communication skills, and a greater sense of personal responsibility. Students reported a high level of satisfaction from their experiences in project based learning. They appeared to have a substantially more positive attitude toward the instructional environment as was indicated in their responses to particular questions regarding the usefulness of peer assessment and their use of team contracts. With only a few exceptions, the majority of students agreed that they had achieved most of the learning objectives outlined for the courses. This resulted in students being able to set their strategies, within the team, to achieve their objectives, divide the workload between team members to utilise potential expertise and skills from individuals, and accumulate the necessary knowledge and skills through teamwork, which was reflected in their final presentations. It was found that the collaborative groups fostered a students' sense of collective ownership of the knowledge that was created throughout the project. The sharing of responsibility and contributions to specific tasks highlighted this issue.

The integration of project work within a structured design course curriculum, for freshman level (first year) students, enhanced their understanding and knowledge about real life design activities, which should enrich their current and future learning experiences. It has also been found that the assessment criteria used in such courses needs to be either demonstrated and communicated well, with some practical examples shown to the students beforehand, or be modified to ensure that they match students expectations. Overall, the project and team based courses offered in the Mechanical Engineering Department, seem to be running well and produce worthy engineering graduates capable of fulfilling the demands and meeting the challenges of modern professional engineering practice.

References

1. D.J. Moore and D.R. Voltmer, "Curriculum for an engineering renaissance", *IEEE Trans. Educ.* Vol. 46, no.4, pp. 452-455, Nov. 2003
2. Petter Mansson and Daniel Nyberg, Implementing Product Data Management in Product Development Projects, *Master of Science thesis*, School of Mechanical Engineering, Department of Product and Production Development, Chalmers University of Technology, Sweden, 2002.
3. Claire H. Major and Besty Palmer, 43/99 PBLE: Project based learning in Engineering, Seminar paper, Hosted by the University of Nottingham, 1999.
4. Yaron Doppelt, Implementation and Assessment of Project-based learning in a Flexible Environment, *International Journal of Technology and Design Education*, vol. 13, pp 255-272, 2003.
5. Doppelt, Y. & Barak, M., Pupils Identify Key Aspects and Outcomes of a Technological Learning Environment, *Journal of Technology Studies* , vol. 28 (1), pp 12-18, 2002.
6. Aragaki, Koren K; Huyck, Margaret H; Ferguson, Daniel M, Effectiveness of Assessment Tools on Project Based Inter-professional Education, *2005 ASEE Annual Conference & Exposition*: The Changing Landscape of Engineering and Technology Education in a Global World; Portland, OR; USA; 12-15 June 2005. 8 pp. 2005.
7. Schmidt HG: Foundations of problem-based learning: some explanatory notes. *Medical Education*, vol. 27 pp. 422-432, 1993
8. National Academy of Engineering. (1006 April) Vision for change, A summary report of the 1995 ABET/NSF/Industry Workshop. [online]. Available: http://www.nae.edu/nae/caseecomnew.nsf/weblinks/NFOY-5YGP85
9. National Academy of Engineering. (1006 April) Sustaining the change, A follow-up report to vision for change: A summary report of the 2004 ABET/NSF/Industry Workshop. [online]. Available: http://www.nae.edu/nae/caseecomnew.nsf/weblinks/NFOY-5YGP85
10. Perry R.Hinton, *Statistics Explained*, 2nd Edition, Published by Routledge, Taylor and Francis Group, London and New York, 2004.