AC 2010-1079: FIRST-YEAR ENGINEERING FROM THE PERSPECTIVE OF A HIGH-SCHOOL TEACHER.

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Rod Paton holds BSc and MSc degrees in physics from the University of Auckland, New Zealand. He has been teaching high-school science and physics since the start of 1994. For the past 12 years he has been Head of Physics at Westlake Boys' High School, Auckland, New Zealand. Rod has integrated ICT into the school's physics programs and developed problem-solving books and practical manuals to enhance the skills and abilities of all students. His main research interests are centred on implementing steps to improve the problem-solving and academic-writing abilities of high-school senior-physics students and confirming the improvements by measuring the effects of teaching interventions and strategies. Over the years he has successfully developed teaching and learning frameworks in physics that have led to significant improvements for students at Westlake Boys' High School.

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A High-school Teacher's Perspective of First-year Engineering

Abstract

This paper reports the observations of a high-school teacher who spent a full academic year immersed in the University of Auckland's first-year engineering programme. Few formal requirements were imposed on the teacher; by choice he attended the lectures, tutorials and laboratory sessions of several engineering courses. He also enrolled in two university courses in order to learn social-sciences research methods. The teacher's focus was on the peer assessment, problem-solving and feedback used in lectures and tutorials to promote effective learning and encourage students to take responsibility for their own learning. Models (conceptual frameworks) were then constructed to reflect the actions of students and the interactions students have with their lecturers and tutors. The result was a comprehensive view of what is expected of first-year engineering students from a high school teacher's perspective. This view, together with the data on which it was founded, is outlined in the paper.

Background

All first-year engineering courses face multiple challenges: to showcase engineering attractively so that students wish to continue in the discipline, to prepare students adequately for higher-level courses, and to bridge the gap between high school and university successfully. This last is a particularly difficult challenge because it involves both academic and pastoral issues and, further, the university lecturers may have only limited knowledge of the type of education currently provided by their contributory high schools. To properly appreciate the difficulties students face in bridging the gap between high school and university, a university lecturer would need to spend time immersed in a high school, or a high-school teacher would need to spend time immersed in a university. Such immersion, while most valuable, is rarely possible.

The Royal Society of New Zealand (RSNZ) manages an Awarded Teacher Fellowship Scheme which enables experienced school teachers to take a break of up to one year from their teaching duties and instead pursue some other approved activity. The first author of this paper was such an experienced teacher, a Head of Physics Department at a large and well-regarded high school. The RSNZ provided funds that allowed his school to employ a replacement teacher while he continued to receive his teacher's salary. In his year as Teacher Fellow he was mentored by the second author of this paper, an academic at the University of Auckland, who himself had also previously been a Head of Physics Department at another large and well-regarded high school. This academic, perhaps unsurprisingly, has a special research interest in the transition from high school to first-year engineering.

This paper reports on the observations of and the conclusions reached by the first author as he spent a full academic year immersed in the University of Auckland's first-year engineering programme. Few formal requirements were imposed; by choice the teacher sat in on the lectures, tutorials and laboratory sessions of several engineering courses. He also chose to enrol in two university courses in order to learn social-sciences research methods that he applied during his year at the university. While the teacher did involve himself in several courses, there was a particular involvement in the first-year engineering course, Electrical and Digital Systems, coordinated by his mentor. Consequently this paper focuses on that course.

Since this paper aims to present a high-school teacher's view of first-year engineering, what follows is as faithful as possible to the voice of that teacher.

Context

There are some differences between the education systems of different countries: this section provides a brief outline of the educational setting in which the present research took place. In New Zealand, high schools are open for 40 weeks per year and offer five years of education. The last three years are assessed by a national assessment system. In physics, this assessment system is almost entirely based on national external examinations. Consequently, what students study in any physics classroom in the country is, to a large extent, prescribed. Classroom activities are largely structured and teacher-centred. Teachers teach theory, conduct demonstrations, perhaps lead short discussions, and set the students problems to do. Most of these are done in class at school, some at home. Practical work ideally takes place on a regular basis, but this tends to be rather "cook-book" in nature, with students being provided with just the equipment needed and a set of instructions to follow. Class sizes of 25-30 students facilitate good relationships between teachers and students, even though a teacher might have five or six classes to teach each day, five days a week. The national external examinations at the end of high school are particularly important, since students must achieve a certain grade in them to qualify for entry into a range of university degree programs, such as Bachelor of Engineering. Teachers are under pressure from a variety of sources to ensure that their students perform well in these examinations. This pressure, together with the fact that high-school students are younger and less mature than university students, tends to make most teachers adopt a largely teacher-centred learning environment. Some student comments to this effect are presented later in this paper.

The first year of the four-year Bachelor of Engineering (Honors) program at the University of Auckland is taught entirely in-house by the Faculty of Engineering. This in-house program, which moves students straight from high school directly into the engineering way of thinking, is very rare internationally: most first-year engineering courses are taught as service courses by academics from mathematics and science departments, with one or two design or hands-on introduction-to-engineering courses providing a taste of "real" engineering[1].

In the first-year engineering course, Electrical and Digital Systems, somewhat more than 600 students attend three lectures and one tutorial each week of the twelve-week semester. There are two lecture streams: a typical lecture is given to about 300 students. Two lecturers give the lectures, with each of them lecturing both streams for about half the semester. Tutorials are smaller, typically of size 40, and involve several academics. Each tutorial is managed by one academic and one teaching assistant, normally a postgraduate student. While it is difficult to promote active learning in large lectures, this is in fact attempted, and details are given later in this paper. Tutorials are more amenable to active learning and the students also take part in peer-marking exercises in tutorials every second week. These exercises are also described later. In addition to tutorials, informal drop-in clinics are also provided for students. These take place in a large, open workspace and are staffed by senior students who assist students who need help with mastering the course. Laboratory exercises also provide further learning experiences, as do various online resources. While completion of all laboratory exercises is required, there is no attendance requirement for lectures or tutorials. This is very unlike high school, where attendance and punctuality (and clothing) are constantly monitored. In the high-school situation, teachers are able to monitor closely the work students do, since much of this is actually done in class time. Homework assignments also provide a way of monitoring student homework. While student work can also be monitored in a university setting, by online software packages such as OASIS[2], for example, it is not normally done to the same extent. Regrettably, there are many university courses in which students receive no instructor feedback, formal or informal, until more than half the course has passed. Such a lack of timely feedback would be unheard of in a high-school context.

Modes of student learning

It may be argued that the first year of engineering is the most critical for students, for this is when they must make the transition, if they have not already done so, from being dependent learners to being involved and self-directed learners. They must learn to be able to meet their own learning needs, to plug gaps in their knowledge, and to teach both themselves and their peers. These skills are essential if students are to be successful in making the transition from high-school to university, and the teaching environment must support and encourage students to develop these skills.

Learning has been described as an enduring change in behaviour, the capacity to behave in a considered and rational manner which results from practice and other forms of individual experience and social interactions[3]. Constructivist theories maintain that learning is much more than mere passive reception and acquisition of knowledge, rather learning involves the learner actively processing information and constructing knowledge and skills[4, 5]. Ideally learners, particularly as they approach adulthood, should exercise a fair degree of control over their own learning and the social and physical context in which it takes place.

However, in teacher-directed learning environments, such as the majority of high-school classrooms, students often view the learning of physics as the receiving of knowledge from teachers[6]. In this objectivist theory of learning, concepts and principles are seen as being external to the student and are transmitted to students via a process of teaching controlled by the teacher[5]. Perhaps as a consequence of this view of what constitutes learning, many students focus on memorization rather than on understanding the material.

It is clear that the preferred modes of learning for adult learners are not memorization and rote-learning. Other modes are essential. Firstly, active learning can produce enhanced learning outcomes, positive personal development and increased student motivation[7]. Ideally, students should take an active role in understanding the material that is presented in courses, by practicing important discipline-specific skills, using a range of approaches and strategies to actively engage with the material and construct their knowledge. This is a deep approach to learning, and has an important impact on individual development, empowerment and academic performance.

Secondly, self-directed learning becomes more important as learners transition into adulthood[8]. Ultimately, individuals are required to take complete control of their own learning experiences, diagnosing their learning needs and formulating a wider range of approaches to meet these by seeking out and generating experiences to construct appropriate knowledge and skills. As a corollary, for effective and sustainable learning to occur, students need to receive and use feedback effectively.

It is hoped that, at university, these predominant modes of adult learning (active learning and self-directed learning) do form the basis of the teaching and learning programs. Even first-year students, ideally, should view themselves as their own teachers and constructively evaluate their own learning needs. This paper will illustrate the key themes that emerged from fieldwork research in the first-year engineering course at the University of Auckland and will present the extent to which preferred learning modes were in evidence.

Research methods

The teacher's focus was on the peer assessment, problem-solving and feedback that are used in lectures and tutorials to promote effective learning and encourage students to take responsibility for their own learning. His field research involved both inductive and deductive approaches and verification of the emerging models. The data were gathered by participant and non-participant observations, surveys, the perusal of documents, and informal interviews and focus-group discussions. A number of more formal interviews and focus-group discussions were also recorded, transcribed and analyzed. Models (conceptual frameworks) were then constructed to reflect the actions of students and the interactions that students have with their lecturers and tutors. The result was a comprehensive view of what is expected of first-year engineering students from a high school teacher's perspective.

The principal data sources for this study were observations made through non-participative attendance in lectures, tutorials and student study areas. However, some limited researcher participation in tutorials and clinics also took place. Additional data, used for the purpose of triangulation and verification, came from the analysis of focus-group interviews with first-year engineering students and dialogue with engineering lecturers and tutors. Similarly, further data from the examination of relevant documents (such as course books, electronic resources and assignments) were also used to corroborate claims or assertions made in informal interviews of academic staff and communications given to students. For example, teaching staff in lectures and tutorials emphasized that students should take responsibility for their own learning, and this message also came through in course materials, projects, electronic resources and assignments.

The researcher was aware that his presence in the class could well impact on student behaviour. However, he was present from the first lecture and subsequently attended all lectures. He also attended a number of different tutorial classes and spent some time seated in student work-areas. On a relatively small number of occasions the researcher did take on a more active role, helping students with their work or assisting in the delivery of the material in some tutorial sessions. This long-term presence gave the students time to accept the researcher and, ultimately, any behavior modifications produced by his presence would have been minimal. Such long-term involvement also enabled a wealth of data to be collected. From these fieldwork observations a number of themes emerged and these were explored further during focus-group interviews with the first-year students.

In what follows the observational data gathered are presented first, the themes are identified, and then the themes are examined in more depth in the light of the focus-group interviews and other evidence. Also revisited in the research findings and related to these emerging themes are the adult learning theories described in the previous section.

First-year course goals

The general teaching and learning outcomes associated with the first-year engineering courses include both discipline-specific skills (including knowledge and problem-solving) and generic skills (including active, self-directed and peer-group learning). The realization of these outcomes is made more likely by the fact that all the first-year courses are taught 'in-house' by engineering academics. Further perusal of documents reveals that these outcomes are supported by the University of Auckland's mission statement, which describes the need for both specialist knowledge and general intellectual and life skills.

As an illustrative example, one of the goals of the first-year engineering course is to develop the students' problem-solving skills by producing clear, structured and effective solutions. Hence many of the learning activities and assessments in the course are focused on this outcome. As may be expected, this is achieved through the practice of regularly solving problems. This even happens routinely in lectures: during lectures the lecturers model problem-solving themselves, set the students problems to solve, and then go over the solutions. The students also regularly take part in guided peer-marking exercises in tutorials, in which each student marks the work of a fellow student. In this way the students also contribute to the development of generic skills within their peer-group.

Student learning experiences

Overall, the goal of the University of Auckland's first-year engineering courses is to show students the 'way into' engineering via lectures, tutorials, assignments and projects. Electrical and Digital Systems, based on its high student success rate, would appear to be largely achieving this goal: in 2009, 93% of enrolled students passed the course, with 2% dropping out and 5% not achieving sufficiently well in the assessments. The key findings are modelled in Figure 1 below, showing how first-year engineering students are engaged in active, self-directed and peer learning. These learning modes are described in subsequent sections.

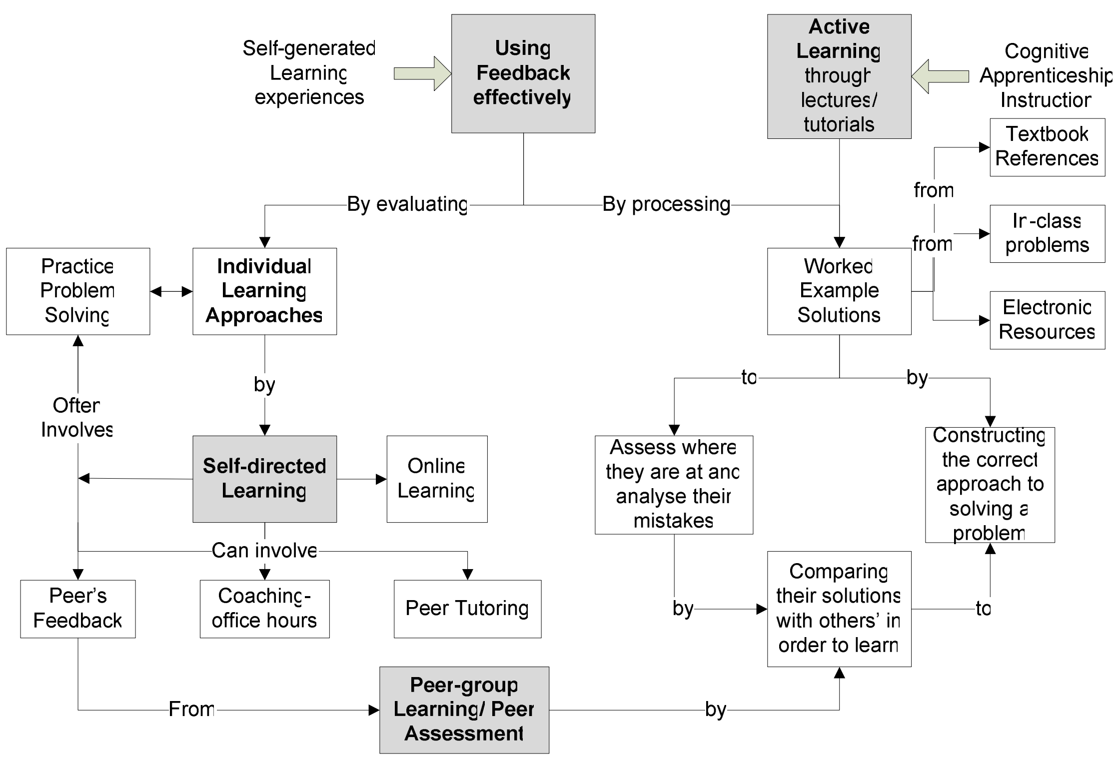

Figure 1: Modes of learning

Active Learning

The discipline-specific skills were delivered primarily through lectures. In many cases, lectures involved computer presentations. Document cameras were also frequently used by the lecturers in highlighting important material and solving problems in the write-on course-books. Lectures contained all the essential information, and were judged by the high-school teacher to be presented in an organized and clear manner. The organization was exemplified by the course-books which students brought to each lecture. These contained the theory in outline form, problems for both lecturers and students to work during lectures, learning objectives for each lecture, textbook references to further reading for each topic, and homework questions for each lecture (some of these questions were stated in the course-book itself, while others were referenced from the prescribed text). Student feedback in response to the question "In this course what was most helpful for your learning?" supported the above judgement: "Course books. Both are awesome. Very well set out, relevant information, easy to read and learn, bang on", "The course books were very well set out, and I really liked the questions in the book as doing them helped me understand the content better", "the lectures were organised and presented the material in an excellent way", "The lecturers very clearly explained what we were covering and what we needed to know. I found it all very organised and it helped me to sort out the material nicely in my head", "how clearly everything was laid out and explained", "The lecture objectives are very good in a way we know what we are supposed to gain and should know from the lectures. The course books have a good layout where it is simple to read and understand. It also helps when the lecturers point out the main points", "This was the most organised course I have taken this year. Both course books... were laid out in a manner that was very tidy and easy to study from".

In lectures, students were regularly given problems to solve, after which the lecturer would work through the problem, in this way both presenting a solution and modelling good problem-solving techniques. It was observed that students embraced this approach, as shown by their active involvement in lectures and tutorials. Survey feedback from students also supported this observation: "the way of looking at examples in class and going through them was a great help in aiding my understanding and knowledge", "I really REALLY appreciated the worked examples and practice questions", "The course-books are set out in a good way - the way that we have breaks during the lectures to do the exercises are a great way to learn", "How we did problems during class while going through the answer with us, helped with the understanding".

As previously noted, one of the key goals in the first-year engineering course is to develop problem-solving skills from an engineering perspective. The theme that emerged to support this was the use of cognitive-apprenticeship instruction, as modelled in Figures 1 and 2. This theme was characterised by instructor modelling and coaching: lecturers and tutors were continually involved in modelling the problem-solving process in lectures and tutorials. The instructors made the whole process of problem-solving visible by 'thinking aloud' as they solved problems: producing solutions step-by-step and explaining and discussing why each step was taken. Following this modelling, students actively solved problems in-class either individually or in pairs, and instructors provided coaching and feedback when required. Thus, through cognitive-apprentice instruction, active learning of discipline-specific skills was supported in both lectures and tutorials.

Through effective instruction, students were guided and encouraged to actively construct the correct approach to solving problems by comparing their solutions with both their instructors and their peers in order to learn how to learn. For example, tutorials involved small-group discussions that enabled students to evaluate and process their individual learning approaches. Tutors regularly provided guidance and coaching on the concepts that students found difficult. In particular, tutorials explored the different approaches and strategies used in solving problems. All this is consistent with the cognitive-apprenticeship instruction model. The much smaller size of tutorials (around 40 students) compared to lectures (around 300 students) provided tutors and students with an opportunity to interact on a more personal level with each other. Students certainly appreciated and made good use of this opportunity, as indicated by student responses to the question "In this course what was most helpful for your learning?": "The tutorials were a good opportunity for me to ask questions about the course material, the tutor provided good and helpful feedback", "The tutorial was most helpful as the tutor was able to explain concepts to the class, reinforcing what was learnt in lectures", "The tutorials as they gave regular feedback on how we were doing in the course as well as the opportunity to ask questions and gain a more in-depth knowledge on what was being taught and what was expected of us", "The tutorials were really helpful. I liked it when the calculations were done in front of the class step by step", "The tutorials were very helpful..., my tutor, in particular was fantastic. He was clear and concise with his explanations and encouraged students to air any queries or concerns about the topic".

Students were also actively encouraged to use worked-example solutions from electronic resources and textbooks, as well as in-class problems, to gain important feedback on their learning needs, as modelled in Figure 1. This was further supported by email communications from course organisers encouraging participation in clinics (peer tutoring by more senior students) and 'office hours' (coaching by lecturers). In these clinics and 'office hours', students were able to get assistance with specific problems and/or concepts. The provision of clinics and 'office hours' was very useful for the development of effective, adult learning because it increased the opportunities for students to receive and use feedback. Since students are busy trying to make sense of multiple sets of facts, concepts, principles and skills during the course of a normal day's work at university, many sources of information and assistance are vital in assisting the construction of knowledge.

Self-directed Learning

Self-directed learning is an important outcome of engineering curricula[7], and this form of learning was encouraged and promoted throughout the course. For example, students were guided to actively use textbooks that were relevant to the course material. This was done by giving page references (for both theory and problems) to the course textbook in lectures, and by mentioning other books that could be used for background reading and as sources of more problems. The in-house-developed online resource OASIS was also used for skills practice and assessments, providing students with an incentive to practice their skills and with instant feedback when they did so. Another important element in developing self-directed learning was the coaching that took place in tutorials and clinics. Problems were expected to be attempted before attending tutorials, and this expectation was regularly reinforced. Overall, the students were expected to work through many problems in their own time, sourced from course-books, textbooks, and online resources such as OASIS. The importance of self-directed learning also emerged from focus-group interviews: "I think that everyone learns differently, so it's up to each individual. Some people I know just go to lectures and go through the notes and just know the stuff. Others like me learn a lot better if I practice and do more by hands on learning… It is down to how each individual learns". Self-directed learning can be nurtured effectively in a number of ways, and this investigation identified some of these ways as: peer feedback, coaching from instructors, and comments on graded tests. Hints and constructive comments were clearly valued by all students. All these elements helped guide the students to plug any gaps in their knowledge and understanding.

Courses supported effective feedback from self-directed learning. Specifically, students processed and evaluated feedback given on learning and problem-solving as modelled in Figure 1. Through this self-evaluation of their individual learning approaches, they met their needs by directing their learning appropriately. Comments made in focus-group interviews supported this view: “In school I personally used only one approach. But in university, because I was developing, I tried maybe four or five different learning approaches until I found the right one. I think it depends on the person. But I think in general everyone has their individual learning methods.”

To meet their individual learning requirements, students need to use feedback effectively as they process and evaluate their work, and construct their domain-specific skills. Clearly, therefore, in order to maximize feedback, it is important for the students to have as much contact time as they can. The first-year course does provide opportunities for considerable contact time through lectures, tutorials, clinics and ‘office hours’. Further feedback was provided by OASIS online assignments, pen-and-paper tests, peer-marking exercises, and practical work.

Throughout the course, individuals were required to exercise considerable control over their learning. By comparison, students commented in focus-group interviews that high-school classes involved much more direct instruction: “You go to class and learn stuff. But at university, no one makes sure you do it. You need to motivate yourself. At school, if you don’t do the work you get told off. But here, you will get zero. It is totally up to you whether you sink or swim”, “Coming from a school [high school] that is very structured it has been very different. Of course you have that big degree of freedom and I think it is more pronounced when you come from a structured environment. We had uniforms and I had to keep my hair short and everything. Because of that, I was almost overwhelmed to start with, as there is a lot less time spent in class and that. A lot less homework that is compulsory. And so it is as predicted it is up to you to commit to doing the work. But personally I find it a lot more enjoyable because it is more up to you.” Some students managed the transition well: “The transition was pretty smooth but I found that leaning was more independent. And I really had to research myself and find out how things work rather than asking lecturers or something like that.” Others were slower to realize that they needed to develop new ways of learning and made a less-auspicious start: “I don’t have strategies so far because I don’t concentrate that much. I go to the lectures and they go through things once and they go through it pretty fast. Not like high-school. Where they take one week to explain stuff you can get it already. And you can get good results. So like I wasn’t that good last semester and I am going to catch up. I don’t have a plan yet. But I just have to do all the work that they give us. The work they give us today I will have to do it tonight.” The above comments reflect the importance of students viewing themselves as their own teachers, building on and extending their pre-existing knowledge, skills and approaches.

Peer Assessment

Another ‘way into’ the subject was through effective feedback from formative assessment. In this context, the theme that emerged was the use of both self- and peer-assessment in group-work projects and assignments. One important initiative here was the implementation in 2009 of peer-assessment exercises. These were conducted fortnightly in tutorials. Prior to "peer-marking tutorials", students were asked to write solutions to specified questions. At the start of the tutorial these solutions were collected by the tutor who re-distributed them amongst the students. A detailed marking scheme was then displayed and the tutor guided the students through it as they marked the work of one of their peers. The markers were required to award marks, write short explanatory notes where marks had been lost, and also write their name, as marker, on the solutions. After marking, the solutions were returned briefly to their authors for checking, and then collected again by the tutor. After the tutorial, a teaching assistant checked that each student had genuinely attempted both answering the questions and marking the answers and providing feedback. Those that had done so were awarded one percent towards the final course grade. The scripts were returned to the students at the next-week's tutorial.

By making judgements of the solutions of others, receiving feedback about their own solutions, and comparing their solutions with those of their peers, students were able to find any gaps in their own knowledge and problem-solving skills. Prior to the introduction of peer-marking exercises, tutorial attendance midway through the semester was typically around 30%; in 2009 with the advent of peer-marking exercises, attendance was consistently very high, around 90%. Overall this form of peer assessment was very motivating for students and greatly increased student attendance at tutorials. These student comments from focus-group discussions summarize the situation well: "Peer assessment is an excellent way to motivate students to do electrical study. With the challenging course of Engineering and many students having other commitments, it is an excellent way for students to keep on track with what's happening in lectures and doing some amount of study so as to gain 1%", "Firstly, it forces you to do some work and secondly, you get to know how the examiner is wanting you to answer the question. And that is really important because that's how you get really good marks in the exams. Sometimes you know the stuff but not how to answer the exam."

All the quantitative and qualitative data collected in this study indicated strongly that student learning was enhanced by peer assessment. The survey comments from students certainly supported this assertion: "I like the peer-marking exercises as it taught me to set out my working properly in steps", "The peer-marking tutorials were definitely very helpful as having to do them meant that I had to understand the course material then instead of leaving it until right before the tests/exams etc. It was also helpful to see how other students answer questions and to see model answers for these questions and how they would be marked", "the peer reviews made me do the problems and helped me understand the concepts", "I think the peer marking exercises were a good idea and stopped me from getting behind", "Peer review made it possible to understand what is really expected from us by the markers and it was nice to see how well we were doing in the course".

Social interactions in tutorials and in common work-spaces also increased individual participation and contribution. The main theme that emerged was that students were exposed to and could learn other ways of solving problems, thus extending and strengthening their individual knowledge. Tutorials and peer-marking activities are modelled in Figure 2. As suggested by Trahasch[9], peer- assessment "yields positive gains and aims to integrate learning and assessment".

Peer-Learning

Teaching and learning environments make use of explicit and deliberate peer learning[10]. This peer learning can take many forms, such as peer monitoring, peer assessment (as described previously), peer tutoring, cooperative learning, and peer-group learning. Peer tutoring and cooperative learning are widely utilized by first-year engineering courses at the University of Auckland. However, getting feedback from one's peers is an effective learning activity which occurs implicitly and vicariously as well as explicitly and deliberately at most universities. Therefore this investigation also explored peer-group learning carried out in the student study areas: it was apparent that this was occurring without any direct instruction to do so. However, it should be noted that student-to-student social interactions are an intended outcome of first-year courses.

Ideally, learning should be sustainable: students should learn how to learn, and take responsibility for their own learning. For this to happen, personal learning experiences ultimately need to be intentional, voluntary and purposeful, involving active rather than passive processes. Peer-group learning that takes place in student study areas supports such learning experiences. Through these interactions, students engage with peer groups to aid their social and cognitive development. It has been suggested[11] that when first-year students need assistance, they typically go to "fellow students" in the first instance. This peer learning occurs when students are self-directed and motivated to learn the course material. Specifically, individuals involved in such groups give each other feedback by reflecting on and evaluating their own ideas and the ideas of others to make meaningful connections. By interacting with peers in a social context, individuals are able to clarify and extend their current understanding through the articulation of thinking and ideas. All the above became quickly apparent in the course of making non-participative observations in the busy student study areas frequented by first-year students, giving support to the notion that knowledge is influenced not only by individual experiences but also by social interactions[12]. Comments made in focus-group interviews revealed the motivation to learn that comes from this type of social interaction: "Yes I do [learn from peers]. Not just like with random people from the class. I have a couple of mates who want to do well, so we work on assignments, study for tests and learn together. I like to stay at university and do that, because if I go home and sit down, I don't do any study. So if I stay at university with my mates who are studying as well, I actually do something", "If I have a question, I first go with my buddies and first of all we will discuss it. After we discuss we go into individual work where we work out problems ourselves. Then after we have done that we come back and compare our answers. And see if there are any differences. If there is then we discuss again and see where our problem occurred. And if we can't figure out where and why then we will take it to a tutor or lecturers. So for me I like to study with a partner. Then I like to discuss things. I think that I find that way easier to understand and learn. This is not a formal thing. It is just me and my mate because we already know each other from high-school, he's doing the same subjects as I am and we just find it easy to discuss things between us. But study groups are good as well, but... For me it was an informal, rather than formal study group I think." Clearly feedback between peers from social interactions is an important element of learning at university. However, some students did express a preference for solitary study, even while they acknowledged the advantages of working with others: "I definitely do study by myself more often, just to figure stuff out. A lot of time like doing assignments and stuff like that, if you work as a group it makes it sort of quicker and easier. But when you need to learn something and you are not too sure I would prefer to do it myself", "Otherwise I sometimes talk to my father who is an engineer. Then the student drop-in centre I have used a couple of times. But in general I like to figure things out myself. Because if I can understand it in my own head, then it is better than copying someone else's understanding of it".

In the peer-tutoring that occurred during tutorials and clinics, the typical focus was on problem-solving. Fieldwork research revealed that tutors typically engaged students in how engineers go about solving problems: explaining when to apply concepts and principles and showing how to produce clear, structured and effective solutions. These activities supported self-directed learning as outlined previously. These activities are modelled in Figure 2. Interestingly, in the student study areas, it was observed that students would not only check that the correct answer was reached, but also discuss different ways of achieving the same solution. Robust interactions happened because there was often some uncertainty and debate about what was the best method, or even the correct answer, and so students frequently had to justify their theoretical frameworks and methods to others. However, in tutorials when the tutor was present students more frequently focussed on getting the correct answers rather than extending and elaborating on their knowledge in the ways outlined above. Perhaps this was because they assumed that the tutor would always provide them with the best methods and the correct answers, thus reducing the need for discussion or debate.

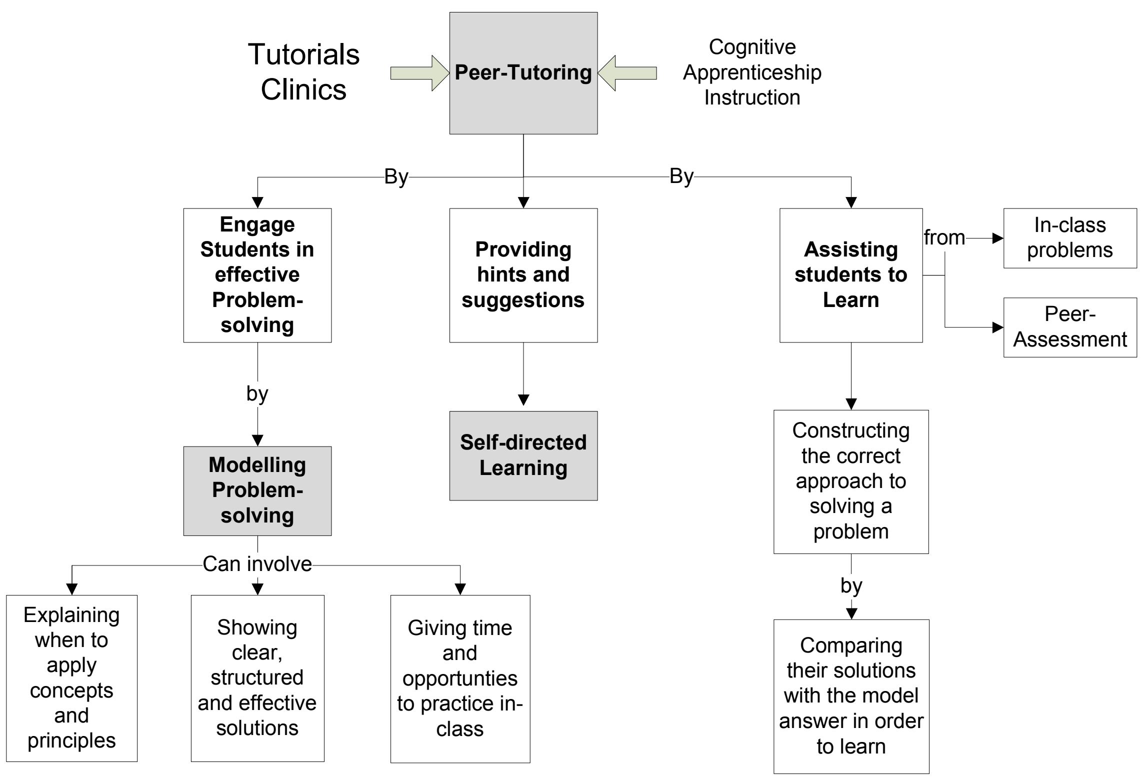

Figure 2: Tutorials and Clinics

Online Learning

Online learning provides a clear benefit to students[13, 14]. In particular, students who are struggling with the transition from high school to university find that online learning enhances individual development. Perhaps unsurprisingly, online learning did emerge as another important facet of student learning in year-one engineering. In particular, when asked “In this course what was most helpful for your learning?” students frequently mentioned OASIS (Online Assessment System with Integrated Study): “OASIS is really helpful in terms of more questions to practice for tests/exam/pure learning”, “OASIS and tutorials helped me put my knowledge to the test. Also allowed me to understand how and why things worked the way they did”, “OASIS and peer marking are great tools of learning”, “OASIS is amazing - in terms of having the questions and answers right there, and always changing”. This last comment refers to the fact that students can use OASIS to practice many numerically different versions of the same question.

Clearly, how students use online learning is affected by their learning styles and their strategies for learning new material[15] and, while the online learning was largely managed by the lecturers, the experiences the students gained were dependent on what activities they chose to engage with, and the extent to which they did engage with them. It was the instructors’ intention that students would use the electronic resources online to repeatedly return to course material, problem-solving solutions and/or hints on how to solve problems so as to meet their individual learning needs, as modelled in Figure 1. OASIS online assessments that contributed a total of 10% to the course grade also motivated students to practice problem-solving skills and learn from the virtually-instant feedback provided. Support for online learning also emerged in the peer-assessment activities when some students requested that the model answers be made available online as well as in the tutorials. Many students were keen to view these solutions in their own time. Of course students must be self-directed to make the most of this source of knowledge.

Expectations and behaviours

In higher education, as previously stated, individual students need to assume the major responsibility for personal learning and development of generic skills (including active, self-directed and peer-group learning) by engaging in a range of experiences. This study determined that what is expected of students entering the Faculty of Engineering at the University of Auckland can be largely summarized under the following two headings:

- Individual construction of knowledge: students should take the initiative (active and self-directed learning) in using a variety of resources to meet learning needs by processing and evaluating experiences.
- Co-construction of knowledge: students should contribute freely to the learning and development of others (peer-group learning and peer-assessment) through social interactions and dialogue.

The above indicates the difference between high-school and higher education. From this study it emerged that the responsibility for learning in the first-year engineering courses is clearly with individual students. As stated by a first-year student: “At school if you didn’t know the concepts straight off, the teacher would kind of help you, and just slow down a bit. But here it’s like you are kind of expected to learn it by yourself. If you are struggling you have to do it on your own time”. Much of what first-year engineering students learn is from self-generated learning experiences and their behaviors reflect this. Instructors should and do reinforce the behaviors that they want repeated. Individual and co-construction of knowledge are two such behaviours.

Conclusions and implications

The year proved to be most rewarding for all those involved. The teacher gained valuable insights into the University’s engineering degree program, a program in fact taken by many of his students. The teacher is now also well-placed to disseminate his findings to the broader high-school-teacher community. The university lecturers received insightful feedback on their programs, and some program improvements have already been implemented as a result.

It was found that the Faculty of Engineering teaching staff support and encourage first-year students to be active processors of knowledge. They are guided to actively meet their learning needs and fill any gaps they might have in their knowledge. The students are typically engaged in peer, active and self-directed learning. The University of Auckland provides the environment, opportunity, support, space, resources and time for effective and sustainable learning to occur. This is achieved when individual students take control of their study by making choices that support their learning and by developing well informed, organized study habits. Students are given significant ‘personal thinking’ time so they can participate and contribute but they must be proactive to make the most of these opportunities.

A social foundation for learning is also clearly established, and there are many contexts which support this foundation, both formally and informally. The first-year engineering students are involved in ‘a community of practice’ in which individuals interact with ideas, materials, instructors, and peers in order to create a collective understanding, rather than simply to receive knowledge individually as they might in teacher-centred learning environments like those sometimes found in high schools. Through this social cognitive model of learning, interactions, knowledge, expertise and skills deepen.

One key implication for instructors is that many first-year students are a ‘work-in-progress’ and, as such, they need to explore and evaluate different approaches and strategies for learning. In particular the students need to go beyond rote learning, use multiple modes of learning, and learn to regard the processes of observing, participating and contributing as learning too. The teaching climate must reinforce the requirement that students should teach themselves. The learning environment must be such that students are supported and guided to make the critical transition to ‘involved and self-directed learners’.

There are also important implications for high-school teachers. It was found that first-year engineering students are regularly engaged in peer, active and self-directed learning. Also, the models that emerged place great importance on the ability to solve problems and use feedback effectively. Further, it is clear that there are both generic skills (involving peer, active and self-directed learning) and discipline-specific skills (involving knowledge and problem solving) that are required from students in order for effective and sustainable learning to take place. More efforts should therefore be made in high schools to develop the skill sets relevant to these modes of learning.

Given that students rely on learning from their peers to find their ‘way into’ the engineering discipline, they need to become effective teachers themselves. Therefore, peer learning should be an important part of most, if not all, first-year engineering courses. Peer-assessment should be a regular way of marking problem-solving activities. Thus students would become more effective learners and teachers, and they would also gain important skills in communicating to others effectively. For peer assessment to realise its full potential, all parties involved, academic staff, teaching assistants and students, need appropriate training. Others forms of peer learning also should be utilised, such as cooperative learning and peer monitoring.

It has become clear that, when students find they can meet their own learning needs, they become more effective learners. Further, they are more likely to use deep rather than shallow approaches. For educators in higher learning, tapping into the social foundation of learning is the best way to achieve these deep-learning approaches. First-year students, starting from the first day of their university instruction, should be guided away from dependent learning and towards independent learning. Instructors should emphasize from the beginning and throughout the course the value of working with others in the co-construction of knowledge. In fact, direct instruction on how to get the best out of first-year engineering courses is vital over the first few months of the academic year. Instructors should view students as 'future engineers' and instruct them accordingly.

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