A high-school teacher's perspective of first-year engineering

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***Abstract**: To be successful in first-year engineering courses, undergraduates must engage in active, self-directed and peer-group learning. The university atmosphere, structures and courses are all set up to encourage and promote this. This paper reports on the results of in-depth fieldwork research carried out at the University of Auckland engineering school into its first-year courses. This entailed an experienced high-school physics teacher taking a break from high-school teaching for one year and examining the transition from high-school physics to first-year courses in some detail. The focus was on the peer assessment, problem-solving and feedback that are used in lectures, tutorials and clinics to promote effective and sustainable learning. The models that emerged place a great importance on the ability to solve problems and use feedback effectively.*

Introduction

Learning, or in this case academic learning, could be described as an enduring change in behaviour, or the capacity to behave in a considered and rational manner which results from practice and other forms of individual experience and social interactions (Schunk, 2009). Achieved by the process of constructing knowledge and skills, where the individual is an 'active processor of information' (Roth and Roychoudhury, 1994). Furthermore, Nunes and McPherson (2003) proposed that academic learning is much more than mere passive reception and acquisition of knowledge. Rather viewing adult learning as a process which is controlled by the individual. Whereby, the construction of knowledge is active, self-directed and gained through experience. In particular it is widely described in adult learning theories, that individuals take an active control of their learning in social and physical contexts and this includes experiential learning. This is explained by constructivist theories of learning.

However, in teacher-centred learning environments such as high-school, students view the learning of physics as the receiving of knowledge from teachers (Anderson et al, 1996). That is concepts and principles are external to the student and are received through a process of teaching. Predominantly transferred and controlled by the teacher. This objectivist theory of learning (Roth and Roychoudhury, 1994) is consistent with students' epistemologies and views of knowing and learning physics. Where, many students in high-school focus on memorization rather than understanding the material.

It is clear that the modes of learning in higher education differ greatly from this. Rather than just rote-learning as used in high-school, there are other more effective modes of learning. Firstly, active learning is one of these dominant modes at university. According to Amenkhienan and Kogan (2004), (with references there within) higher learning outcomes, positive personal development and increased students motivation is the result of active participation in their own learning processes. Clearly, this is a deep approach to learning and therefore has an important impact on individual development, empowerment and academic performance. Moreover adult students take a more active role in the construction of understanding the material that is presented in courses, by practicing important discipline-specific skills. Obviously it is important that students use a range of approaches and strategies to actively engage with the material.

Secondly, self-directed learning (e.g. Stolk et al (2007) with references there within) is another important mode that emerges from adult learning theories. This is where individuals take complete control of their learning experiences. Through this type of personal learning, adults diagnose their learning needs and formulate a wider range of approaches to meet these, by seeking out and generating experiences to construct the appropriate knowledge and skills. Consequently the key is for effective and sustainable learning to occur students need to receive and use feedback effectively.

In summary, adult learning theories main principle is that people learn by controlling individual behaviours to create their knowledge and skills. Achieved through personal experiences with others, and feedback from self-generated learning experiences. Therefore first-year students need to view themselves as their own teachers and constructively evaluate their own learning needs in order for effective and sustainable learning to occur in higher education. Hence the hypothesis is that at university, these predominant modes of adult learning (active and self-directed) form the basis of the teaching and learning programs. This paper will illustrate the key themes that emerged from fieldwork research from the first-year engineering course at the University of Auckland that supports this.

Research methods and methods of analysis

The principal data sources for this study were observations made through non-participation of lectures, tutorials and student study areas. However, this included some participation in tutorials and clinics (peer tutoring). Additional data, was 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 at the University of Auckland. Further, examination of relevant documents (such as, course books, electronic resources and assignments) for further evidence that triangulated claims or assertions made in informal interviews of academic staff and communications given to students. For example, teaching staff emphasised that students should take responsibility for their own learning not only through lectures and tutorials, but also through course material, projects, electronic resources and assignments.

The observational data gathered are presented first, and the themes identified, and then examined in more depth using the focus group interviews and other evidence. Also, included in the research findings below are the adult learning theories as described in the introduction section that relate to these emerging themes. We will describe the general goals and learning intentions that emerged from the year-one courses at the school of engineering, followed by students learning experiences, and then expectations and behaviours. Then, finally conclusions are made.

Research findings

First-year course goals

The general teaching and learning outcomes that are described from this study of the first-year engineering courses are the discipline-specific skills and generic skills. These outcomes are supported by the University of Auckland profile mission statement that describes need for both specialist knowledge and general intellectual and life skills. All the courses in the first-year are taught by engineering staff. And through this, students engage with the discipline-specific skills (including knowledge and problem-solving) and generic skills (including active, self-directed and peer-group learning). For example, one of the goals of the first-year engineering course is to develop students' skills to solve problems by producing clear, structured and effective solutions. Hence most of the learning activities and assessments in the course are focused on this outcome. As is described in this paper, this is achieved through the practice of solving problems. But also includes participating and contributing to their peer-group through generic skills. That involved both individual and peer assessments.

Students learning experiences

Overall the general goal of first-year engineering course at the University of Auckland is to show students the 'way into' the subject via lectures, tutorials, assignments and projects. This will be described by the following section and is modelled on Figure 1 below, showing how first-year engineering students are engaged in active, self-directed and peer-group learning.

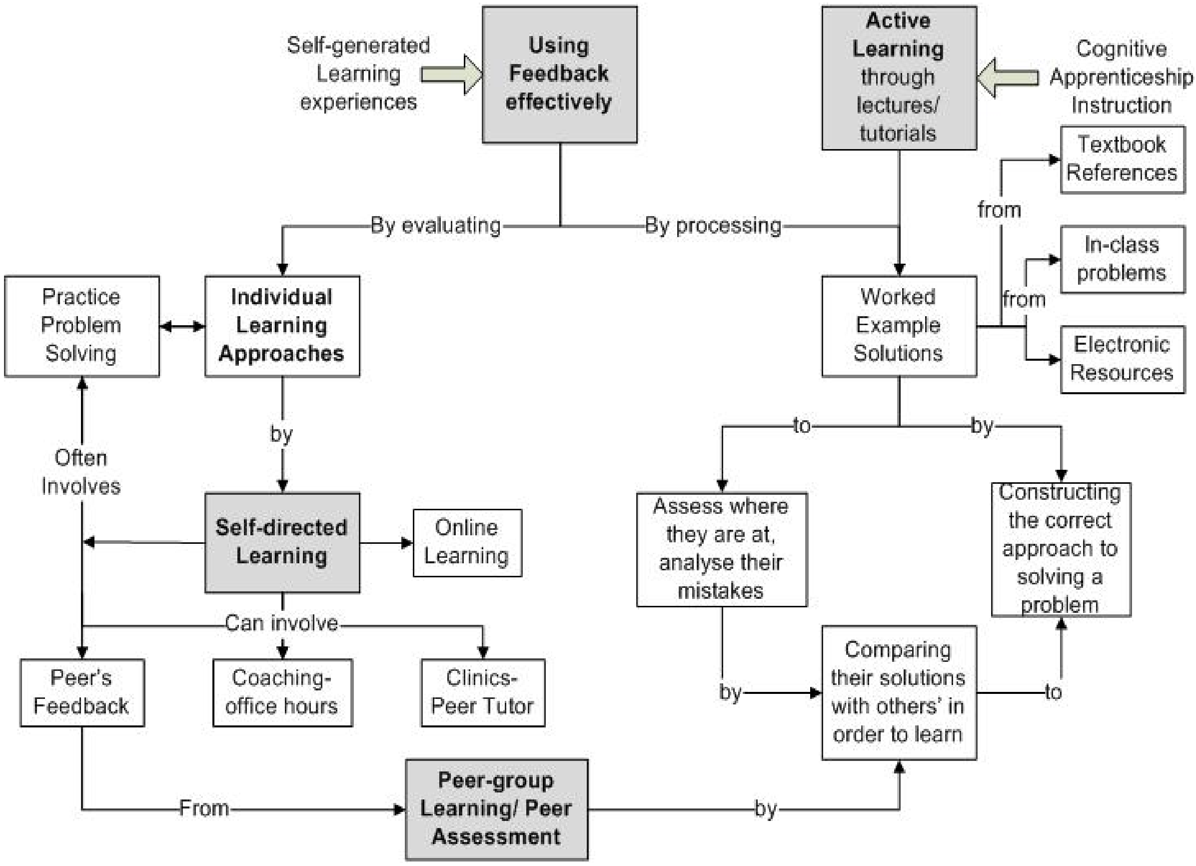

Figure 1: Using feedback effectively

Active Learning

The discipline-specific skills are delivered primary through lectures. Typical lectures where presented with computer presentations, containing all the essential information, which are organised and presented in a smooth, straightforward manner. Also in many cases this included the use of document cameras to highlight important material and/or solve problems in the course books. Whereby, students embraced the material, as observed by their active involvement with the lectures and tutorials by practicing to learn. Other evidence emerged from first-year students when discussing what makes lectures more engaging, comments like: 'I think it is the way it has been taught (rather than the content). When the lecturer is a general enthusiast about what they are teaching you then it is so much easier to learn. And get interested yourself'. Clearly lectures and tutorials support active learning of discipline-specific skills as described in the introduction.

As previously described, 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 Figure 1 above. This is characterised by modelling and coaching. For example, lecturers where continually involved in modelling the problem-solving process in lectures. Making the whole process of problem-solving visible by thinking aloud through worked example solutions by explaining why the different steps are taken. Following this students actively solve problems in-class either individual or in pairs, whereby coaching and feedback was given as and when required. In other words, through cognitive apprentice instruction, active learning is supported in both lectures and tutorials.

Through effective instruction, students' are guided and encouraged to actively construct the correct approach to solving problems by comparing solutions with not only their instructors and peers in order to learn how to learn. For example, tutorials involve small group discussions that enable students to evaluate and process their individual learning approaches. Whereby, tutors typical give guidance and coaching on difficult concepts. This is consistent with the cognitive apprenticeship instruction model. In particular, tutorials explore the different approaches and strategies used in solving problems.

Also, students are actively promoted to use worked example solutions from electronic resources, and textbook references, along with in-class problems to gain important feedback on their learning needs as modelled in Figure 1. This was further supported by communications via emails from course organisers encouraging participation in clinics (peer tutoring) and coaching by lecturers during office hours, where they are able to get assistance on specific problems and/or concepts, if they have any misconceptions. Obviously this is very useful for development of effective and sustainable learning because this increases the opportunity to receive and use feedback. Since individuals 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 are vital in assisting the construction of knowledge.

Self-directed Learning

Self-directed learning as suggested by Stolk et al (2009) is an important outcome of engineering curricula, and this was indeed the case. As this form of learning is encouraged and promoted throughout the course. For example, students are guided to the actively use textbooks that are relevant to the course material. Encouraging this by using page references from the course textbook in lectures, also other books that could be used for back ground reading and attempting more problems. Another important element in this was the coaching that takes place by lecturers and peer tutoring through clinics. Furthermore, for tutorials, problems were expected to be attempted before attending these lessons was commonly reinforced. And as described in Figure 1, self-directed learning often involved practicing more problems. The importance of directing their learning also emerged from the focus group interviews. With the following comment made about the lectures and tutorials. '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'.

Courses supported effective feedback from self-directed learning for students to find their 'way into' the engineering discipline as previously described. Specifically, they process and evaluate feedback given on learning and problem-solving as modelled in Figure 1. Through this self-evaluation of their individual learning approaches, they meet needs by directing their learning. Comments made in focus groups interviews supported this view: 'In school I personal used only one approach. But in university, because I was developing, I tired maybe four or five different learning approaches until I find the right one. I think it depends on the person. But I think general everyone has their individual learning methods.' Clearly, students actively meet their individual learning needs by processing and evaluating approaches by using feedback effectively. Certainly this supports the hypothesis where students take the initiative and control of their own learning as in adult learning theories.

All of the above points are clearly based on students needing to have as much contact time as they can to help in the construction of domain-specific skills. And this is clearly the intention of the first-year course. Through this individual's take a lot more control over their learning, as opposed in high-school that involves more direct instruction. From focus group interviews, students made further comments about self-directed learning such as: '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 total up to you whether you sink or swim'. This again reflects the importance that they view themselves as their own teachers, building on and extending their pre-existing knowledge, skills and approaches.

Peer-group Learning

It is evident that from the points above, that for students to develop effective and sustainable learning personal experiences need to be intentional, voluntary and purposeful, through an active process rather than a passive one. For example, peer-group learning that takes place in student study areas supports this. Clearly, student-to-student social interactions are an intended outcome of first-year courses. Whereby, students engage with peer-groups to aid their social and cognitive development. Cronje and Coll (2008) suggested that when first-year students need assistance, they would go to "fellow students" in the first instant. This 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 and evaluating on their own ideas and the ideas of others to make meaningful connections.

Furthermore, by interacting with peers, individuals are able to clarity and extend their current understanding through the articulation of thinking and ideas, in a social context. This is supported by Nunes and McPherson (2003), who suggested that knowledge is influenced by not only individual experiences but also social interactions. Also, comments made in focus groups interviews included the motivated to learn that comes from these types of social interactions: 'Yes I do (learn from peers). Not just like with random people from the class. I have a couple 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 actual do something'. Clearly feedback between peers from social interactions is an important element to learning at university.

Peer-Assessment

Another 'way into' the subject was through effective feedback from formative assessment. In particular, the theme that emerged was the use of both self and peer-assessment through group work projects and assignments. In the case of peer-assessment, this clearly enhances effective and sustainable learning. As suggested by Trahasch (2004), this form of assessment "yields positive gains and aims to integrate learning and assessment". Through observations and comments from students' this was clearly the case. For peer-assessment on problem-solving the responsibility was with individuals to give specific descriptive feedback to their peers by marking solutions from a common scheme. By comparing their solutions and making judgements with others enabled them to find gaps in their knowledge and problem-solving skills. Allowing them the opportunity to assess where they are at, and analyse their mistakes as in Figure 1. This also increased individual participation and contribution through these social interactions. Overall this form of peer-assessment was motivating students since they received effective feedback, which enables them find their 'way into' the process of problem-solving. As students can revisited discipline-specific skills.

Online Learning

Finally, online learning from the electronic resources emerged as another important element. Managed by lecturers but the experiences students' gain is dependent on what they activities they chose to engage with. The idea is that they use the electronic resources online to repeatedly return to course material, problem-solving solutions and/or hints on how to solve problems so they meet their individual learning needs, as modelled in Figure 1. This also included practising problem-solving skills through online assessments. As reported in Turney et al (2009), there is a clear benefit to students. In particular, those that are struggling with the transition from high-school to university, find that online learning enhances individual development.

Expectations and behaviours

As previously stated, in higher education, individual students assume the major responsibility for personal learning and development by engaging in generic skills (including active, self-directed and peer-group learning) through experiences. The following points' summaries the expectations of students entering the school of engineering at university from high-school that emerged from this study:

- Takes initiative (active and self-directed learning) in using a variety of resources to meet learning needs, by processing and evaluating experiences. Individual construction of knowledge.
- Contributes freely to others' learning and development (peer-group learning and peer-assessment) and through social interactions, and dialogue. Co-construction of knowledge.

This is the clear difference between high-school and higher education. It emerged that the responsibility for learning in the first-year engineering course are 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 behaviours reflect this.

Conclusion

The first-year courses at the school of engineering aim for students to be active and directed in their learning. Whereby, they are guided to actively to meet their learning needs. 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 to take control of their study by making choices to support their learning and 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.

With the social foundation of learning clearly established and there are many contexts that supported this formally and informally. The first-year engineering students are involved in 'a community of practice'. Where, individuals interact with ideas, materials, instructors, and peers in order to create a collective understanding. Rather than simply receiving knowledge individual as in teacher-centred learning environments at high-schools. Through this social cognitive theory of learning, interactions, knowledge, expertise and skills deepen. The overall implications for instructors are that many first-year students are a work in progress and as such they should explore and evaluate different approaches and strategies for learning. In particular they need to go beyond rote-learning to use multiple modes of learning. And view the process of observing, participating and contributing as learning.

References

Amenkhienan, C. A., & Kogan, L. R. (2004) Engineering students' perceptions of academic activities and support services: factors that influence their academic performance. *College Student Journal*. 38(4), 523-540

Anderson, J.R., Reder, L.M., & Simon, H.A. (1996) Situated Learning and Education. *Educational Researcher*. 25(4), 5-11

Bates, A. W. (2000). *Managing technological change: Strategies for college and university leaders.* San Francisco: Jossey-Bass.

Cronje, T., Coll, R. K. (2008) Student perceptions of higher education science and engineering learning communities. *Research in Science & Technological Education.* 26(3), 295-309

Nunes, M. B., & McPherson, M. (2003). Constructivism vs. Objectivism: Where is difference for designers of e-Learning Environments? *Proceedings of the 3rd IEEE International Conference on Advanced Learning Technologies*

Roth, W-M., & Roychoudhury, A. (1994). Physics Students' Epistemologies and Views about knowing and learning. *Journal of Research in Science Teaching.* 31(1), 5-30.

Schunk, D.H. (2009). *Learning Theories: An Educational Perspective.* New Jersey: Pearson Education, Inc

Stolk, J., Martello, R., & Geddes, J. (2007). Work in Progress-Building autonomous students; Modeling curricular approaches for lifelong learning, 37th ASEE/IEEE Frontiers in Education Conference (pp 20-21). Milwankee, WI

Trahasch, S. (2004). From peer Assessment Towards Collaborative Learning, *34th ASEE/IEEE Frontiers in Education Conference* (pp16-20). Savannah, GA

Turney, C.S.M., Robinson, D., Lee. M., & Soutar, A. (2009). Using technology to direct learning in higher education. *Active Learning in Higher Education*. 10(1), 71-83.

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