A template for change? De-risking the transition to CDIO*

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ABSTRACT: *This paper provides a case study on how an established, mature engineering faculty, with a large population of students can make the successful, high risk, step change transition towards the delivery of CDIO objectives: "Graduating engineers who can conceive-design-implement-operate complex value-added engineering systems in a modern team-based environment" (Crawley et al, 2011). The successful results of the project demonstrated the effectiveness of the systems thinking and CDIO approach, and endorsed this as the basis for a major change strategy. Not only did it demonstrate the quality of all the students on the course, their potential and commitment to engineering, but it also demonstrated willingness of the faculty to take a risk and to embrace change. The project scenario opened up an otherwise overlooked teaching resource: that of practitioner lecturers with many years of experience of implementation and operation of major projects. These skills were essential to the scoping, design, planning and implementation of the project as well as giving the backdrop of best practice from industry. Auckland's experience of introducing a major step change may be used as a template for other universities who may wish to follow Auckland's example. This project shows the value of a hearts and minds approach to change as it brought together students, staff and best practice under a multidisciplinary systems thinking and CDIO approach; all united in the interests of reconstructing Christchurch.*

KEYWORDS: Systems thinking; teamwork; 21st century; engineering education.

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1 INTRODUCTION

The University of Auckland adopted, in 2011, a project-based learning experience for its 535 final-year engineering students. The aim was to introduce the faculty to a systems thinking and a CDIO (conceive, design, implement, operate) approach. The project scenario – "The Reconstruction of Christchurch" following the earthquake disaster earlier in the year – provided an ideal platform and a unique catalyst for change.

This was a high risk step change in teaching and learning methodologies. It brought together the faculty and students from all engineering disciplines. Students were divided between 20 groups of 26/27 students. Each group worked as a coherent team selecting their project manager, technical experts, and final presentation speaker. The project ran for a full week, instead of normal academic activities. It demanded intense "full on" activity from the start, with scheduled progress meetings and interim deliverables. "Light touch" guidance was provided by mentors assigned to each group.

Systems thinking, CDIO and management advice was provided by three seasoned practitioners, all of whom had run major engineering projects in the commercial world.

Note, "full on" can be described as high energy and total commitment from all members of the team; and "light touch" can be described as the provision of guidance and advice only as and when required by students, as distinct from regular reviews and progress meetings dictated by staff mentors.

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1.1 The challenge for the profession

Many leading authorities now believe that engineering has, over time, become subservient to other professions. The role of the professional engineer as a dominant, decision making figure in society has diminished and, in some cases, with disastrous results. The reasons for this are many and varied but one contributory factor is the focus on single specialised disciplines arranged in isolated swim lanes during formative university years. This continues to be an artificial environment as the practical application of engineering is multidisciplined and increasingly complex requiring business and financial skills as well as technical breadth (Lathem et al, 2011; McNair et al, 2011; Adams et al, 2011; Stevens et al, 2008). In addition, the most important element of all is people and the means to integrate and energise their work through inspirational leadership and professionalism; working as a team "to get things done". It requires engineers who can "inspire", "lead" and "integrate" as well as "engineer".

This means that successful engineers, who aspire to be leaders, need to master the dynamics of this complex and challenging new world as early as possible in their careers particularly if they want to compete for top jobs against accountants, lawyers and administrators. Employers are increasingly expecting these broader based professional skills as the standard profile for new recruits. Extended graduate training schemes, which once sought to bring raw recruits "up to speed", are becoming a thing of the past. Students, many of whom are now expected to take out substantial loans as an investment in their own education, are expecting higher standards. They are conscious that the job market is tough and they recognise that they need something "extra" to make them more attractive to prospective employers.

All this places new demands on universities to deliver something more in keeping with the needs of industry and the career aspirations of graduates. Unfortunately, there is evidence, as cited by Adams et al (2011), that engineering education is holding onto approaches to problem solving and knowledge acquisition that are out of alignment with professional practice. In particular the focus may be more on acquiring technical knowledge than on preparing for professional practice (Stevens et al, 2008).

1.2 The challenge for universities

Many universities are beginning to recognise these new demands and the need to take engineering education to another level (see, for instance, the numerous examples cited by Lathem et al, 2011). They have begun to explore how different disciplines can be integrated and managed together with leadership and teamwork to form robust, fully integrated solutions which meet the complex needs of today's society. CDIO is one such initiative, as is project-based learning.

There are significant differences between the way engineering is currently taught and the way it is applied in practice. The approach, the skills, and the capabilities required to deliver an effective, representative "real world" student experience is very different from the lecture theatre and the research laboratory. The scale of the changes required can be quite significant and requires considerable commitment to "make it happen". It includes student immersion in practical representative project scenarios which:

- logically integrate a whole range of engineering and non-engineering disciplines in the quest for optimal "best fit" solutions to large scale, complex problems
- deliver practical experience of leadership and organisational skills
- include social, ethical and financial factors in decision making and trade-offs
- win support for compelling, innovative solutions through advanced advocacy and communication skills.

The transformation required to establish such a change, make it successful and overcome the many risks, is as much about "hearts and minds" as it is about mechanical changes to content, the curriculum and the realignment of staff schedules. In reality, as the Appendix shows, there are more institutional barriers resisting change and reform than there are enablers propelling it forward. The challenges of change become more acute where the university is dominated by a research led agenda.

1.3 Incremental versus a step approach to change

Under these circumstances an incremental approach might seem easiest as it follows the line of least resistance. However, the pace of change can be slow and painful with each and every step. The benefits which justified the original investment of time and effort can be slow to materialise. Under these circumstances prolonged resistance and organisational inertia can wear down the most determined resolve. Fresh new initiatives can fade and fall by the wayside. The status quo becomes inevitable and graduating engineers continue to be disadvantaged against their peers in other professions.

There is a powerful argument that says a step change might be more effective, providing instant, recognisable results. Instinct says that the risk might be much higher and prospects for success much lower. Auckland has shown that the opposite is true and a step change has proven to be far more effective.

2 THE UNIVERSITY OF AUCKLAND EXPERIENCE

2.1 Auckland's strategy for change

Initially, Auckland was no different in facing many of these challenges. The risk of a step change seemed formidable particularly with over 535 students enrolled in each year of its undergraduate program. It had, however, already reached the point, where it wanted to proceed with a systems approach, as well with as scenario-based projects. After a series of presentations by Professor Keith Robinson, based on his experience at University College London (UCL) in the UK (Robinson, 2011), the Dean of the Faculty of Engineering at Auckland had endorsed the changes required and the Executive Committee, comprising all the Heads of Department, had bought into the program.

Figure 1 provides a summary slide of the systems thinking approach adopted by the faculty. Its aims and objectives are the same as CDIO. The figure represents a summary set of core principles developed by Keith Robinson after a long career managing major projects. His experience suggests that each of these principles has to be interpreted for each new project and for each new system under consideration. His experience, supported by other practitioners, also suggests that if any stage is missed out or if short cuts are taken; failures and suboptimal performance are the inevitable result. These principles then form the key processes which students are encouraged to follow as they work through the scenario.

The professional development courses, run for all undergraduates in years 1 to 4, had been identified as the means of delivering the new systems approach.

2.2 Committing to a step change

An incremental approach would have taken four years to flush through the faculty, starting initially with year 1 and finishing with year 4, four years later. As this seemed a long time to sustain a change program, the decision was made to go for a step change. Once committed, the faculty was keen to get started. A strategy was agreed such that the new systems approach would be adopted simultaneously by the entire faculty in each of the four years of the degree course. This would be accompanied by a series of scenario-based projects designed to represent a "real world" major project experience. A change management team was appointed and work began on the detailed plans necessary to implement the strategy.

2.3 What made Auckland's change strategy different

2.3.1 The event

The earthquake in Christchurch in February 2011 changed the game completely. The change management team quickly recognised that this represented a major opportunity to accelerate the whole change process. This unique event became the focus of a project for year 4 and the "Reconstruction of Christchurch" project was born.

In some respects the accelerated program for year 4 alone represented an even higher risk. There was clearly a danger that if it failed it would put the whole balance of the change program across all four years in jeopardy. The change management team recognised this and were determined that this, the lead systems project, would become a demonstrable

Figure 1: The systems thinking CDIO approach.

success; paving the way for the more comprehensive change program which would follow.

Timeliness was critical to maintaining topicality. The first window of opportunity appeared during the first week of August and all lectures for year 4 were cancelled, allowing a dedicated week for all 550 students to participate in groups of 25. The week itself would be preceded by four lectures on the systems thinking approach together with some special briefings for the 20 project managers that the students would elect.

It was recognised that a reconstruction plan was in New Zealand's national interest and once the project was announced, everyone – faculty staff and students – wanted to join in and contribute. It accelerated what was already a well-planned change process into a cause, a hearts and minds "mission". Even so, the subject alone was not necessarily enough to achieve complete transformational success.

2.3.2 The change management team

The dominant critical component was the change management team. The team had already been working closely together in the planning process and had discussed a number of possible project scenarios. However, they recognised that Christchurch had the potential to capture hearts and minds in a way which no other "contrived" scenarios could achieve. The August deadline, the accelerated program, and the additional risk which it represented meant an even more intense scenario planning process.

The development of a scenario script began instantly and it quickly became clear that each member of the team had essential skills which were entirely complementary. Three of the five were seasoned, senior players from industry who understood the world of major projects and could translate the circumstances at Christchurch into a digestible, multidisciplinary scenario in a way which the university's academic staff, with less industrial experience, would have found "challenging" if not impossible.

The five essential components to success were as follows:

1. The enforcer, Rob Kirkpatrick. Rob understood the faculty and knew all the key players. His uncompromising style pushed through approvals and changes to the time table and delivered handpicked staff "volunteers" to help and assist students during the project week. People turned up to meetings and briefings. Actions were completed. Or else!
2. The logistician, Heide Friedrich. Bearing in mind that over five hundred students were to take part – 20 teams of 25 students – the logistics challenges were significant. This is where Heide's skills came to the fore. She had the knack of getting things done efficiently and effectively. No loose ends, no missed deadlines. Room bookings, communications, meetings, technical support, actions, were all taken care of in a professional manner, not just during the planning phase, but throughout the scenario week itself. Heide also looked after feed-back and the all-important evaluation process.
3. The expert, Keith Robinson. Keith brought considerable experience of running scenarios at UCL and was able to help shape the game by developing both the scenario and the overall plan. His experience added confidence and a sense of what was achievable in the time available. In addition he provided the essential systems thinking approach. This was the essential CDIO "glue" which joined all the multifaceted aspects of the project together. It also provided the means of developing a solution to a very complex scenario in just a week from a standing start. Prior to this the students had not had any experience of group work or exposure to a systems approach. The timetable was such that only four "Systems Thinking" lectures were possible before scenario week.
4. The wise one, Colin Nicholas. During the development of the scenario it became clear that Colin had the knack of asking the right question at the right time. This maintained balance and an objective sense of direction. Colin also saw the issues from a student point of view and it was imperative to take this into account. Asking 500 students to get in for a 7am briefing was just one example. Colin had the answers as well as the questions.
5. The sponsor, Gerard Rowe, Associate Dean (Teaching and Learning). The role of sponsor is critical and Gerard, acting as the Dean's representative, maintained academic rigour and guided the team whenever new policy needed to be reinforced and change endorsed. Gerard's unwavering support gave the implementation team licence to do what was necessary "to make it happen".

2.3.3 A detailed plan

The entire change operation was underpinned by a carefully crafted plan to achieve a CDIO lifecycle. This is summarised below:

- A well-developed scenario containing a mix of politics, economics, insurance; a mix of demographics, health and local issues; an overview of stakeholder agendas; an overview of the scale of the destruction; a technical briefing, initial survey results; and soil mechanics and the potential for future tremors.
- A suggested plan based on the systems thinking approach.
- A list of deliverables.

- A series of four lectures on the systems thinking approach.
- A special briefing for the students who were to become the project manager for their group (20 groups of 25 in total).
- A special briefing for staff tutors and mentors to explain their role and how they could help.
- A special briefing to students on presentation skills and advocacy.
- Support and surgeries throughout the project week.
- Analysis of interim deliveries.
- Feedback on progress and midcourse corrections.
- Evaluation criteria and a marking system (which included a peer review critique).
- A dedicated final afternoon such that all 20 teams could present for four minutes in front of an invited external VIP guest, a member of the Auckland City Council.
- A celebratory party afterwards.

2.4 Characterising Auckland's success

The fact that students were put in charge of their own project and had to make judgements and decisions with imperfect data produced a new sense of maturity and confidence. They began to behave like professionals rather than students constrained by "compliance".

Reviewing their output against the official reconstruction report, issued just a few weeks later, showed that the students had done extremely well. Some might say that their solutions were more robust and sustainable than the official report. It showed the benefits of a systems thinking approach, ie. a CDIO approach verses that of more monochromatic view of the town planners and the architects involved in the official report.

Systems thinking and CDIO experience suggests that the "official" approach could to lead to a sub-optimal reconstruction program and escalating costs; something Auckland's students were keen to avoid.

2.4.1 Hearts and minds

Once the Christchurch project had been launched and was under way, the enthusiasm and energy of the students was overwhelming and everyone involved was caught up in the excitement and the spirit of adventure. Staff members who had been sceptics became converts. Students who had been suspicious became enthusiasts. The atmosphere at the final presentations was electric and it was clear that the students had been through a very special, very unique, "once in a lifetime" learning experience. Knowledge became deeply ingrained. The benefits of experience and wisdom understood.

It was clear that the experience had united them in adversity in a way that no other form of learning can deliver. Lifetime bonds and friendships were formed. In some cases it is true to say that the project was a life changing experience: that is what it is all about.

Given that the students had started from "zero" with no previous group work or systems tuition they achieved a huge amount in just a week. Their performance and capacity to adapt and to learn was extraordinary. They could not have responded better to this remarkable challenge.

2.4.2 Learning outcomes

The above is a condensation of the essential "hearts and minds" achievement of the transformation. Of necessity, it is expressed in emotional terms because that is what drove things forward and motivated all those who were involved. People were energised and engaged.

The learning outcomes are expressed in a more moderate language. Such is the norm in a paper of this nature and it serves to highlight that successful change goes well beyond a clinical scientific approach. The results of this project show that it's hearts and minds, and experience and leadership, that make a difference and carry the day.

Graduates of the 2011 Christchurch scenario:

- took away an intense practical experience of how to apply systems techniques to a complex, real world problem involving a number of disciplines
- gained a better understanding of leadership style and team working and its critical importance in managing major projects and business as a whole
- began to understand the social, economic, environmental and political drivers which form the working environment for every engineering project
- experienced the sense of excitement, achievement and self-satisfaction which only comes through cooperation and working successfully together as an organised group. This unique and fulfilling result can only be achieved through scenario-based learning. There is no substitute for actually doing it.

These learning objectives can only be achieved successfully if the whole exercise is professionally planned and executed by people who have experience of running successful projects operations at this level. The whole aim is to make the scenario as realistic and as authentic as possible.

All the evidence suggests that the "Reconstruction of Christchurch" project at Auckland had fulfilled the CDIO objectives: "graduating engineers who can conceive-design-implement-operate complex value-added engineering systems in a modern team-based environment".

2.5 What made the change successful?

It was the change management team and the unique, altruistic aims of the project, "The Reconstruction of Christchurch", that made the real difference. It took the faculty's strategy from "competent and professional" to "transformational and inspirational". In addition, the following are put forward as key aspects of the scenario's success:

- It was professionally organised. All the details affecting both the student experience and the mentors support had been carefully thought through in advance. For the same reason, the scenario had credibility and realism and purpose that the students could buy into. The change management team were very closely coordinated and communicated well. There were no mixed messages or confusion passing down to the students or the supporting team. Queries were handled quickly and efficiently.
- The project week was managed in real time and this allowed any problem areas to be fixed very quickly. For example, one team had not elected a particularly strong leader and this was picked up on the first day and corrected on the second, allowing the team to improve its performance and move forward.

The following section presents some individual testimonials as well as results of the student survey feedback (figures 2 and 3).

2.6 Testimonials and feedback

Our class survey had a high response rate of over 99%. Figure 2 shows the overwhelming support of the students, when rating the learning experience they were exposed to. Figure 3 shows the word cloud, based on the keywords students were asked to give to the learning experience. Example quotes and survey results are presented below.

Staff quotes:

- "I never thought this would work but now I'm totally convinced this is the future."
- "Overall, though, I warmed to the whole exercise, and felt that it was certainly a useful introduction for the students to working in large teams."
- "As academics we all love our subject, think the students should be studying it full-time, compete like hell with each other for the attention of the students. Yet 'real-life' engineering is so much more like what they did last week. A problem/ challenge without an obvious solution but subject to constraints – time, money, knowledge, and the requirement to work with others as part of a team. So I say a really excellent way of giving the students a taste of how they will find engineering practice."

Student quotes:

- "This [scenario] is the most worthwhile thing I've done in four years at Uni."
- "We had fun, worked hard, pulled together an awesome project. Almost everyone got into this project and worked very hard. We even managed to have fun at the same time."
- "This was one of the best group experiences I have had. All the sub-groups are extremely self-driven, motivated and diligent."
- "The group dynamics- will miss working together!" (in response to the question of what will you remember most from this scenario?).

3 CONCLUSIONS AND OBSERVATIONS

Auckland's experience shows that under the right conditions, with the right kind of planning and

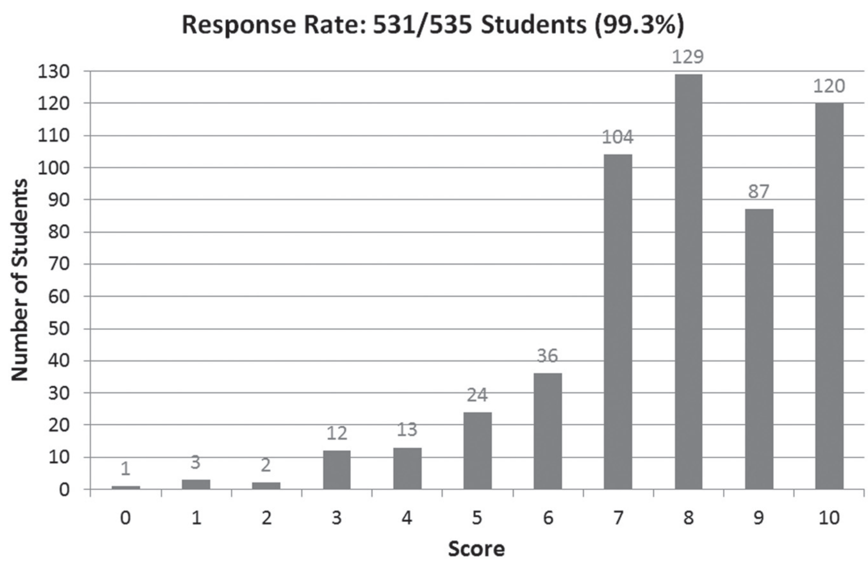

Figure 2: Response of students to the following question "Would you rate the systems scenario as a worthwhile learning experience? (score 0- 10 where 0 is low and 10 is high)".

Figure 3: Word cloud generated from feedback from all 535 students for the following question "Use 5 key words to summarise your overall experience on this scenario". The more frequently a word was used, the more prominently it is displayed.

guidance when led by experienced practitioners, who are accustomed to managing large teams in transition, a step change can, indeed, "deliver" transformation quite dramatically. It can create a hearts and minds transformation which takes on an enthusiasm and impetus all of its own. Under these circumstances change becomes infectious, inevitable and irreversible.

For many universities this is a challenging proposition and the whole concept may seem a "bridge too far". Yet, it becomes possible to think of Auckland's positive experience as a template for change. Faced with similar circumstances and the institutional barriers to change, Auckland made it work. Its more radical approach might enable like-minded, forward thinking universities to migrate much more easily to a teaching model which is uniquely suited to the 21st century.

It became clear, even before the final presentations, and the formal feedback that the whole week had become an outstanding success. The final presentations and the celebrations afterwards merely confirmed what everybody had sensed during the week. Total success. The faculty had never seen a response quite like it. After an event like this there was no going back to the old agenda. The faculty was totally committed to moving forward. Systems thinking CDIO approach had become accepted as part of the faculty overnight. It moved from something ethereal on the periphery of the curriculum to something firmly embedded in it and core to the faculty's future plans.

Since then, things have moved forward. At the time of writing, the curriculum of the design/professional development courses in years 1-4 are all being modified to accommodate major projects. System thinking, and the principles of CDIO, are being taught in each year and tutorials have been modified to accommodate the new agenda.

The faculty has chosen not to repeat the "Reconstruction of Christchurch" theme. That will be forever cast as something very special: a one-off experience, falling as it did so close to the event itself. The 2012 projects are just as challenging and just as topical. They are designed to stimulate students and capture their energy and their imagination just as much as the "Reconstruction of Christchurch" theme. It will take them from near obsessive concerns about the minutiae of engineering detail to an understanding of the broader issues which make the real difference between success and failure on major projects. It gives them an understanding of best practice in CDIO and hopefully the confidence to question and challenge to bring wayward projects back on track. In time it will give them the ability to lead with distinction.

3.1 Some reflections from the implementation team

We have spent some time analysing the roots of success and the limitations of our study and pondering the "what if we had done this" scenarios. One conclusion is that it would not have been possible with academics who have little or no experience of running major projects at the helm. The skills of implementing and delivering successful major projects are essential in creating and making such a scenario realistic and workable. These skills are different from those of managing research.

We have discussed this conclusion with colleagues, thinking that it might be an unpopular conclusion to draw. The response surprised us. They agree that they could not have conceived and planned the scenario or executed it in the same way that we did. There is clearly a message here. Large complex projects require people with that kind of experience to design and run them if students are to buy in to them and engage in the way that is required for transformational success**.**

Two possible limitations were identified. Firstly, while our aim was to create an interdisciplinary team experience, we can't exclude the possibility that in some of the student groups this was operationalised as multidisciplinary teamwork (McNair et al, 2011), in which groups of team members represented different traditional disciplines. The sheer size of our project groups (26/27) made this a fairly remote possibility. Secondly, the faculty members involved in mentoring the student groups were mostly self-selected because of their known interest in systems engineering. Thus the challenges we observed may be different (and possibly even greater) in interdisciplinary projects for which staff mentoring was not a voluntary activity (McNair et al, 2011).

3.2 A template for others?

In thinking about the Auckland experience, and the way that this single project has transformed the entire faculty – from classic specialised swim lane, to a multidisciplinary systems thinking (CDIO) approach – could it provide a step change template for others? We believe the answer is "yes", a similar approach could be adopted provided the same (or very similar) conditions were present. Top of the list, of course, is the systems thinking and big project experience necessary to design and deliver a scenario of this complexity and gravitas.

Auckland, through its experience of a well-run project based on a systems approach, has been transformed and can now claim to be in a strong, if not unique position to help and support others who wish to embark on a similar journey.

3.3 A possible template

We regard the following as essential components for success:

- Choose a project of national significance to engage, excite and to win hearts and minds. It must be a credible, representative CDIO scenario which takes on board all the complex issues associated with a real project at this level.
- Use an experienced team of practitioners with systems thinking and big project experience from industry to plan and execute.
- Develop a detailed, well prepared plan to coordinate the complex logistics involved and to engender confidence in students and support staff.

3.4 Do not try this at home, kids

Although this paper promotes the Auckland experience as a template for success it is not the whole story. Even with this as a template there are still challenges and risks for the unprepared. Much is embedded in the detail and this paper has not allowed us to catalogue all the advice we would like to give. We are happy to pass on this knowledge and experience as part of a series of bilateral initiatives and we would encourage all those who are contemplating a change to contact us.

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APPENDIX: CHARACTERISING THE BARRIERS TO CHANGE

It is generally accepted that managing change is almost always universally difficult. It is said that 75% of change projects fail (Haines et al, 2004).

Universities are no exception and some would say that universities seem to be particularly difficult with many built in institutionalised barriers to change. Some of these barriers are cultural, some organisational. It certainly seems to take something exceptional to move from one state to another.

Some of these barriers are characterised here:

- Academic staff are generally wedded to their specialist areas. This is reinforced by a reward and recognition system which focuses on research rather than teaching "outcomes". "Outcomes" in this instance means creating mature young professional engineers who are "fit for purpose", capable of competing with other professions for top jobs where they are just as capable in leadership and business skills as they are in engineering science. The latter might sound highly desirable and very altruistic, but it often takes second place to a glowing departmental research assessment and the prospect of promotion based on research. This is a very significant real barrier.
- Students like certainty. Their aim is to get a degree. They have much work to do to achieve this, especially on engineering courses it seems. Their efforts and priorities are dedicated almost exclusively to activities which earn marks or credits. They like certainty and the comfortable precedence of past papers. They are suspicious of anything new since that may jeopardise their ability to predict and manage outcomes. They are deeply suspicious of group work where they feel their own efforts, however diligent, might not be rewarded with an A+. Student opposition can be seen as a barrier.
- Timetables are fixed many months in advance and seldom allow flexibility. Mainstream courses, electives and course options form an interlocking mass which is difficult to decouple and restructure. Availability of suitable lecture theatres and breakout rooms are often at a premium. The larger the class size the more acute the problem. Changing the logistics becomes a real barrier particularly where a faculty has to share resources with others and where the automated timetabling system is suboptimal.
- Accreditation can be an issue where ever something "new" is being introduced. There is an internal system to satisfy and external bodies to convince. This takes time and energy. The more radical the change the more effort is required to change from the status quo.
- Engineering academics, who have little experience of practising in industry, fail to recognise that successful engineering is as much about people as it is about "science". Indeed, management and business is often shunned as not being "real" engineering. This attitude passes on quickly to students who often develop an aversion to "management". This is in stark contrast to senior figures in government and industry who recognise that success is about leadership, teamwork and the soft people skills. Introducing more "management" at the expense of "engineering science" therefore becomes a real turf war barrier.
- University culture allows more individual freedom than most organisations. Non-participation and resistance is tolerated and, perhaps, even encouraged as part of an "intellectual" debate. This makes whole scale transformation even more difficult as alignment between the parties is essential to implement successful change.
- Good leadership and teamwork are contact sports. Leadership skills or experience cannot be gained from a book or off the internet. Likewise, building successful teams cannot be achieved without engaging face to face. Both require face time and human interaction. It is in our DNA. Yet many universities lack the seasoned, industrial management expertise which is critical for developing these skills effectively in students.

The absolute focus on research-led league tables has the unintended consequence of incentivising professional researchers and not professional engineering practitioners with a desire to teach. Under these circumstances it is not surprising that engineers are losing ground.

KEITH ROBINSON

Prof Keith Robinson (FAPM FRSA) is an accomplished business leader with over 35 years' experience leading a variety of companies, major projects and change programs at board level. He was on the Board of the Association of Project Management and a visiting Professor at University College London before joining the University of Auckland in 2011, where his main interest is "systems thinking" and pioneering 21st century education for engineers.

HEIDE FRIEDRICH

Heide Friedrich graduated in Civil Engineering from the Technical University of Berlin, Germany (2002), and obtained her PhD in Hydraulic Engineering from The University of Auckland, New Zealand (2010). She worked at large-scale construction sites in Berlin and Taiwan before coming to New Zealand and starting her academic career. Since 2006 she has been teaching in the areas of hydraulic engineering, fluid mechanics, and professional and sustainable studies. She is currently Lecturer in the Department of Civil and Environmental Engineering. Her main research area focuses on river mechanics and sediment transport studies. In 2011 she coordinated the professional development course, under which umbrella the Systems Thinking project, herewith presented in the paper, was introduced. Heide is a member of the International Association for Hydro-Environment Engineering and Research.

ROB KIRKPATRICK

Rob Kirkpatrick obtained his BE Hons in Chemical & Materials Engineering in 1972 and a PhD in Engineering from UMIST, Manchester, UK, in 1975. His almost 40-year career covers a wide range of executive functions in the refining and petrochemical industry, both globally and in New Zealand. He has a long history in the New Zealand energy sector. For the past few years, he has been teaching design at the University of Auckland, and in more recent years made an important contribution by developing systems thinking as a form of engineering practice and teaching tool for students. He has proven to be adept at linking the classroom to practice. Students value very highly his holistic, multi-faceted and interdisciplinary project-based teaching. For many years, Rob served as the Chair of the Auckland Grammar School Board. He was recently (2013) elected a Fellow of IPENZ for his contribution to the advancement of engineering practice and education.

COLIN NICHOLAS

Colin Nicholas graduated from the University of Auckland with an ME degree in 1969 and spent the next 33 years in consulting structural engineering. His work involved planning, designing and project managing construction of industrial and commercial buildings, industrial support structures and bridges. In 2004, Colin joined the University of Auckland as a teaching fellow delivering practical engineering to final year students. He has managed and assisted courses in professional issues over many years and has an intense interest in creating a graduate with broad skills. He is a member of ICE, IStructE and a fellow of IPENZ.

GERARD ROWE

Gerard Rowe completed his BE, ME and PhD (in Electrical and Electronic Engineering) at the University of Auckland in 1978, 1980 and 1984, respectively. He joined the Department of Electrical and Computer Engineering at the University of Auckland in 1984, where he is currently an Associate Professor, and serves as Associate Dean (Teaching and Learning) within the Faculty of Engineering. He is a member of the Department's Radio Systems Group and his (disciplinary) research interests lie in the areas of radio systems, electromagnetics and bio-electromagnetics. He was the joint recipient of the 1993 IEE Electronics Letter Premium Award for the papers "Assessment of GTD for Mobile Radio Propagation Prediction" and "Estimation of Cellular Mobile Radio Planning Parameters Using a GTD-based Model" which he co-authored. Over the last 29 years he has taught at all levels and has developed a particular interest in identifying and correcting student conceptual misunderstandings, and in curriculum and course design. He has received numerous teaching awards from his institution. In 2004 he was awarded a (National) Tertiary Teaching Excellence Award in the Sustained Excellence in Teaching category, and in 2005 he received the Australasian Association for Engineering Education award for excellence in Engineering Education in the Teaching and Learning category. Gerard is a member of the IET, the IEEE, the Institution of Professional Engineers of New Zealand (IPENZ), ASEE, STLHE and AAEE.