Enhancing Industry Exposure, Discovery-Based and Cooperative Learning in Mechanics of Solids

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BACKGROUND
Mechanics of Solids is a second year undergraduate subject, undertaken by both Civil and Mechanical engineering students at the University of Technology, Sydney (UTS). Mechanics of Solids has been delivered for many years in a traditional format with lectures and problem solving tutorials. As part of a national Australian project "Enhancing Industry Exposure in Engineering Degrees", UTS in partnership with other universities and industry partners in Australia has sought industry involvement to engage students with the real-world challenges of engineering practice.

PURPOSE
The main objective of this project is to design, develop and implement learning modules in Mechanis of Solids that integrate industry exposure to provide context for the concepts included in this subject.

DESIGN
The project consisted of six guest lectures by industry representatives on topics related to typical Mechanics of Solids subject matter and two seminars on using MDSolids software.
Students completed a collaborative assignment aligned with one of the industry presentations. Their reports and presentations were assessed on assessment criteria which included contextual understanding, judgement, effective collaboration and creativity, and their perceptions were captured to evaluate the impact of industry engagement in this subject.

RESULTS
One of the major benefits of this project was students' better understanding of engineering practice. There were also positive effects on students' motivation for learning engineering.

CONCLUSIONS
This paper reports the major findings, outcomes and challenges for implementing enhancing industry exposure approach in Mechanics of Solids subject at UTS. The main finding of this research concluded that this project is very valuable to both students as it promotes exposure to real-world engineering challenges. The students' exposure to real and substantive challenges improves their contextual understanding, plus their judgement, practice based planning, teamwork, and initiative learning skills.

KEYWORDS
Industrial exposure, motivation, MDSolids and Mechanics of Solids

Introduction and background

An aim of engineering education is to develop students' knowledge, skills and attitudes so that as engineers they can engage with opportunities that contribute to a well-functioning society (Rychen & Salganik, 2003). A skills shortage is reported for engineering in Australia (The Senate, 2012) where engineering graduates need to gain professional experience in employment prior to being recognised as independent engineers. Contributing factors are that the average graduation rate of enrolled students in bachelor of engineering degrees at Australian universities is about 65% (Godfrey & King, 2011); significant gaps between the capabilities of graduates and the skills required in engineering sectors (S. A. Male, 2010); and that many engineering graduates do not work in engineering roles (Tilli & Trevelyan, 2010).

Engineering practice is poorly understood by both students and their academic teachers (Trevelyan & Tilli, 2007). At many Australian universities there are few academics with recent industry experience (Cameron & Reidsema, 2011). Despite the efforts of many educators, engineering education is largely shaped by a focus on engineering science (Sheppard, Macatangay, Colby, & Sullivan, 2009), rather than applications and practice. Consequently, before any exposure to practice, students are expected to learn theory without context or relevance. Many students find this difficult and not highly motivating to their learning. Furthermore, this approach does not reinforce the breadth of capabilities necessary for engineering practice, particularly its critical socio-technical dimensions (Faulkner, 2007; Fletcher, 1999). As a result, students are likely to have misperceptions about engineering practice, and develop professional identities that are inconsistent with practice.

Enhancing Industry Exposure in Engineering Degrees

As part of a national Australian project "Enhancing Industry Exposure in Engineering Degrees" funded by the Australian Government, University of Technology, Sydney (UTS) in partnership with other universities and industry partners in Australia has been focusing on engineering practices that includes some technical presentations and also site visit conducted by the people in industry to engage student with engineering challenges.

The main objective of this project is to provide students with more comprehensive understanding of engineering practice as a socio-technical activity and to develop motivation for learning of engineering through real-world problems (S. Male & King, 2013). In addition, learning through understanding context and connections is improved. The national project also tends to help students prepare for and transition into graduate employment. Moreover, this project is defined to design, develop and apply the perception of integrating industry exposure in mechanics of solids for students' deep learning. It promotes cognitive learning among students via moving smoothly from the existing teaching model to an enhanced practice based learning model. Finally, it aims to develop reflective practice skills to improve learning and support life-long learning and create a sense of belonging to the profession (S. Male & King, 2013).

On the other hand, industry partners participated in the project obtain visibility and loyalty among students and graduates and develop relationships with university researchers potentially leading to future collaborations, access to university resources such as laboratories, libraries, and experts. Moreover, it provides opportunities to work with future graduates and to identify potential graduate recruits. Staffs have opportunities for professional development through the experience of engaging with students (S. Male & King, 2013).

The first step was to identify a subject from within engineering. Since other universities participated in the project have targeted different engineering disciplines, a subject within Civil and Mechanical engineering disciplines was selected for the project conducted at UTS to engage its industry partners from the construction sector. 48331 Mechanics of Solids is a

second year undergraduate subject, undertaken by Civil, Environmental, Mechanical and Mechatronic engineering students at UTS and was nominated for the project. The challenge was to incorporate contextual industry experiences into this early stage subject. The project team included a research assistant as project conductor, the academic subject coordinator, Deputy Head of the School of Civil and Environmental Engineering and the Faculty's Associate Dean of Teaching and Learning. The project consisted of six guest lectures by industry representatives on topics related to the subject matter of Mechanics of Solids and two seminars on using MDSolids software. A questionnaire was used to elicit feedback from students in regard to their learning experience in the project. This paper reports the major findings, outcomes and challenges for implementing the project.

Mechanics of Solids at UTS

The objectives of this subject are to enable students to: acquire fundamental understanding of the behaviour of structural components commonly used in engineered structures and machines; develop skills to model and analyse the behaviour of structural and machine components subjected to various loading and support conditions based on principles of equilibrium, kinematic compatibility and material constitutional relationships. Mechanics of Solids has been taught using a traditional format based on a series of lectures, solving problems on the board and text instruction. The material has changed negligibly over the time that it has been taught, but the general topics have remained nearly unchanged for decades. Table 1 details the subject information.

Table 1: Subject information of Mechanics of Solids at UTS

Semester	Spring 2013 (July-Nov)
No. of students in the subject	274
required (core) subject of	Civil, Environmental, Mechanical, and Mechatronic Engineering
undertaken in	third semester of study in the degree

Project delivery process

The activities of the project at UTS included:

- To invite professionals and organise industrial presentation sessions utilising our industrial partners in different engineering disciplines
- To introduce MDSolids software as learning tool for important concepts in Mechanics of Solids
- To organise site visit to UTS construction sites to experience real-world problems
- To promote graduate attributes including team work, innovation, critical thinking, analysis data, research etc in the presentations and group assignments
- To consult with students regarding the group assignment
- To evaluate the group assignments of slides, research report, hand calculation verification using MDSolids and physical models
- To prepare and analyse feedback survey of students
- To collect and analyse feedback from academic colleagues and industrial partners.

Industrial presentations

Senior managers and engineers from different engineering fields such as structural engineering, geotechnical engineering, water engineering and material engineering were selected as ideal targets to contribute context to Mechanics of Solids material. A balance of people from different fields of engineering related to Mechanics of Solids were invited. The industry partners who participated in the project include Atlantis Corporation, Sika,

Geofabrics, Arup, SMEC and Lend Lease as shown in Table 2. These companies provided professional engineers to present to students to familiarise them with real-world problems using the fundamental concepts typically included in a Mechanics of Solids curriculum, and lead the students through the actual challenges involved in solving the problem. Figure 1 a illustrates an example presentation.

The professionals were identified through exiting collaborative research projects or our Industry Partnering Unit and were recruited by invitation through the project team members. These identified individuals were asked to deliver a 30 min presentation at the end of one of the six lectures as listed in Figure 1a. Table 2 lists industry presentations and partner details.

Table 2: Industry presentations and partner details

Presentation topic	Organisation	Presenter	Description
The new engineering challenges	Atlantis Corporation	Manager	A holistic environmental approach to engineering challenges
Material selection for engineering design	Sika Australia	Production Engineer	Concrete and polymers as construction materials, stress-strain and ductility in material selection
Engineered Geosynthetic	Geofabrics	Teaching support engineer	Geosynthetic Solutions and their applications and material properties
Flexural members	Arup	Senior Structural Engineer	Analysis of flexural member and Plasticity, Inelastic bending, strain-stress distribution and composites
Material selection for engineering design	SMEC Australia	Senior geotechnical engineer	Stresses on inclined planes, principle stresses and transformation of plane stresses
Site visit to UTS new engineering building	Lend Lease	Site manager	Stress-strain, flexural member and design of structures

MDSlids web module

Mechanics of Deformable Solids (MDSolids) developed by Prof. Timothy Philpot at Murray State University, Kentucky, USA was used as a tool for independent learning, as shown in Figure 1b, in line with discovery-based and co-operative learning methodologies. In this subject, students were most interested in understanding the particular assignment problems assigned by their lecturers. MDsolids can support students in understanding and solving those questions. In the process, students' problem solving skills are developed by providing an intuitive interface. Meanwhile, an easy-to-use means of investigating a number of problems and variations is provided and students' are guided to the important factors affecting various problems types (Philpot; Philpot & Hall, 2005).

Several outstanding features of MDSolids are: 1) versatility, where MDSolids has routines pertaining to all of the topics taught in a typical Mechanics of Solids course, 2) ease-of-input, where MDSolids provides graphic cues to guide users in entering data. The illustrations can be easily adjusted, 3) visual communication, each MDSolids routine features a picture or plot that graphically depicts important aspects of the problem, 4) text-based explanations, where many of the MDSolids modules provide extra explanations to describe in words how the calculations are performed which can help students develop the procedural knowledge needed to solve the problems (Philpot; Philpot & Hall, 2005).

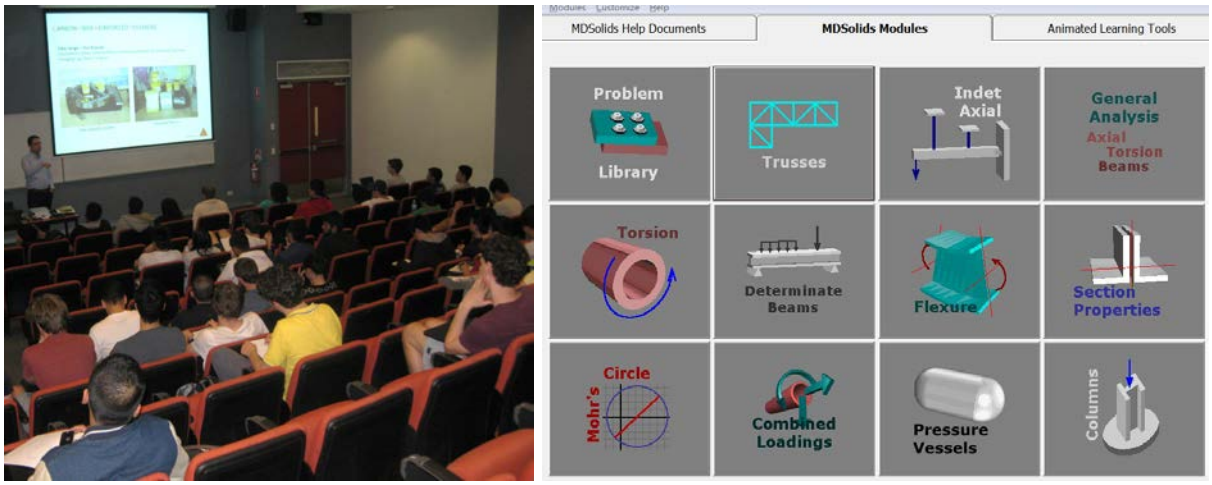

Figure 1: (a) Industrial presentation by Sika Australia and (b) MDsolids Modules

Details of MDSoilds seminars covering stress-strain, internal force diagrams, stress transformation, flexural members, plasticity and buckling are illustrated in Table 3.

Table 3: MDSoilds presentations details

Seminar topic	Organisation	Presenter	Description
MDSolids module 1	UTS	Academic	Introduction to the package and its abilities
MDSolids module 2	UTS	Academic	Mohr circle, transformation of plane stresses and flexural members

Site visit

A visit to the UTS new engineering and IT building construction site located in Sydney was arranged and a group of fifteen students had an opportunity to interact with real project clients as well as members from the project's construction team and project management consultants as depicted in Figure 2. The site visit helped students to gain experience of a real project, discovering the challenges of engineering practice including the site constraints, environmental conditions, and project requirements. Students were required to reflect on these via completion of a site visit report.

The site visit took 1.5 hours to inspect half of the 14 levels in the building including the structural elements, machines, equipment and materials used in the construction. A site manager reported on construction activities and challenges to all participants in the construction process. The building with a total cost of $ 276 million will accommodate approximately 500 staff and 4300 students.

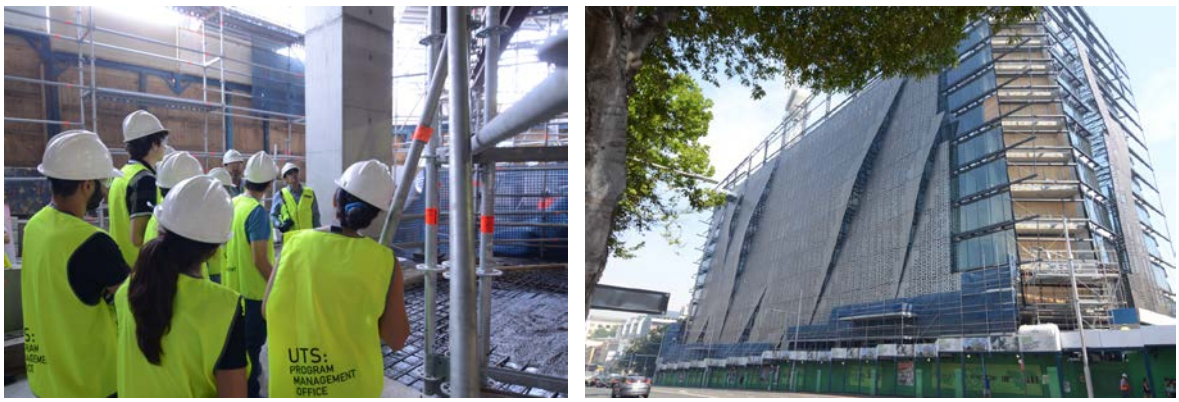

Figure 2: Visit to the UTS new engineering and IT building construction site

Collaborative assignments

Students worked in pairs to submit their assignment in the form of a report, power point slides, poster, short film or prototypes. Students were allowed to choose any research topic relevant to the presentations by industry partners or Mechanics of Solids subject incorporating local and global engineering practices, engineering applications and engineering science. Moreover, it could be in the form of industry based case study with appropriate details and discussion, or a site visit report related to disciplines discussed in Mechanics of Solids. Alternatively, it could be verification of the answers of homework assignment problems using a MDSolids web-module.

Consultation sessions assisted students to enhance the quality of the assignments. The assignments were assessed based on assessment criteria including contextual understanding, judgment, effective teamwork and creativity. The assessment counted as 5% towards the final mark in the subject, with a bonus 10% to be added based on performance in the project.

Upon completion of the presentations at the end of this semester, around 70% of the students (190 out of 270) submitted their group assignment aligned with one of the industrial presentations.

Evaluation of outcomes and findings

At the conclusion of the semester students were surveyed to collect their reflective observations and recommendations. The survey consisted of closed response and open-ended questions and was implemented through online survey software. 35 students out of 274 students (approximately 13%) contributed to the feedback survey. The students' feedback was analysed to identify and report the suggestions for improvement to the project.

The details of the number of participants and their average marks are listed in Table 4.

Table 5 represents participation of students in different sessions out of 35 students that contributed to the feedback survey.

Table 4: Numbers of students submitted reports and their marks

Topic	Description	Students No.	average mark (out of 15)
MDSolids	MDSolids web module	62	11.2
Geofabrics	Engineered Geosynthetic	33	11.4
Sika	Material selection	17	9.9
Atlantis	New engineering challenges	15	11.2
structures	Flexural members	12	12.6
site visit	Site visit to UTS sites	7	14.4
materials	Engineering Material	6	12
miscellaneous	-	38	12.3
		total = 190 out of 274 (70%)	Ave = 11.85 out of 15

Table 5: Participation of students in the sessions (out of 35 students of feedback survey)

Answer Options	Response %	Response Count
ATLANTIS: The new engineering challenges	34.4%	11
SIKA: Material selection for engineering design	40.6%	13
GEOFABRICS: Engineered Geosynthetic Solutions	34.4%	11
ARUP: Flexural members	18.8%	6
SMEC: Geotechnical Challenges & Solutions	9.4%	3
MDSolids web-module	56.3%	18
Site visit	6.3%	2

Students were asked to identify the best aspects and the improvements needed for the project. Their perceptions of the best aspects of the project are listed in Table 6. Another finding was that students would have preferred the industry presentations to be scheduled outside of normal lectures.

Table 6: Students' responses to open-ended survey questions

Best aspects of the project:
Ability to personally ask questions to engineers in question and answer sessions
Better understanding of the subject by exploration of MDSolids
Presentation of real-world engineering practices
Better understanding of real-world problems of the fields of Civil and Mechanical engineering
Industries proximity to students and vacation job opportunity with the industry partners
Learn how the forces and mechanics problems in this subject relate back to the big picture
The improvements needed for the project:
Make the group assignment should be more clear
Make the delivery of the project more interesting
Polish the industry presentations to make them shorter and more concise
Invite more industry partners coming from Mechanical and Mechantronic engineering

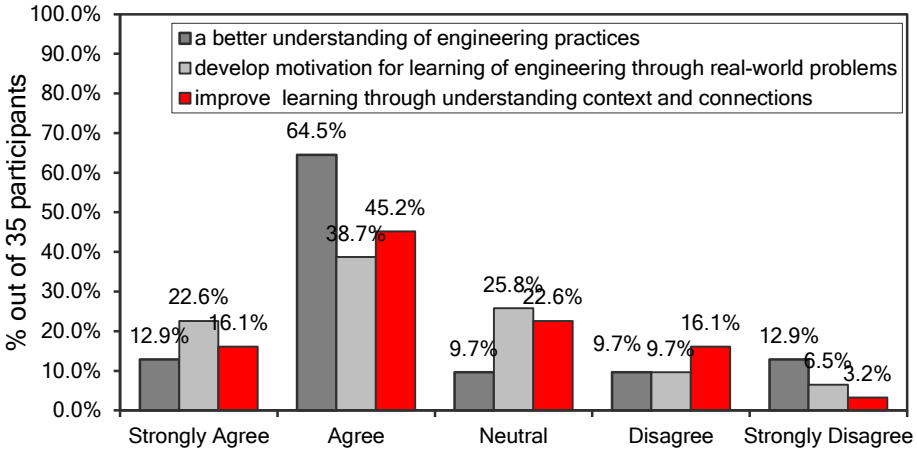

Figure 3: Students' opinions on the influence of industry presentations on different matters

Figure 3 represents generalised student feedback based on satisfaction with the influence of industry presentations on (a) their better understanding of engineering practices, (b) their motivation for learning of engineering through real-world problems and (c) improving learning through understanding context and connections. As evident from Figure 3, 65-80% of the students agreed that the industry presentations and site visit improved their understanding of engineering practice, learning through understanding context and connections whilst the project developed their motivation for learning through real-world problems.

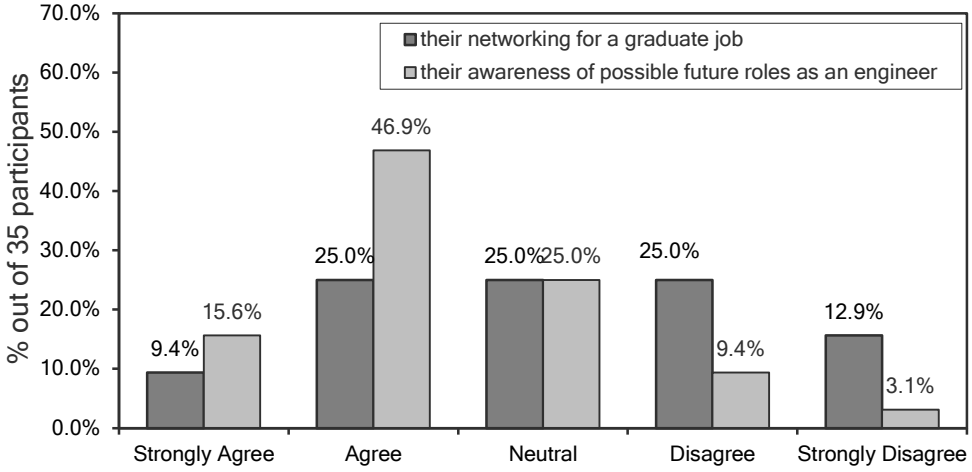

Figure 4: Students' opinions on the influence of industry presentations on their networking for a graduate job and their awareness of possible future roles as an engineer

Figure 4 shows students' opinions on the influence of industry presentations on their networking for a graduate job and their awareness of possible future roles as an engineer. It is clear that the way the project was delivered was not entirely positively received by the students in terms of networking for a graduate job. This is not so surprising when we recall that Mechanics of Solids is a second year subject and so for some students graduation is still mentally a long way off. Despite their reflections on the influence of industry presentations on their networking for a graduate job, 60% of the students agreed that the industry presentations had influenced their awareness of possible future engineering roles.

Figure 5 depicts students' opinions on the influence of MDSolids on their problem solving skills. 65% of students agreed that MDSolids is a helpful tool to assist them to bridge the gap between the subject materials and their application in solving assignments in Mechanics of Solids.

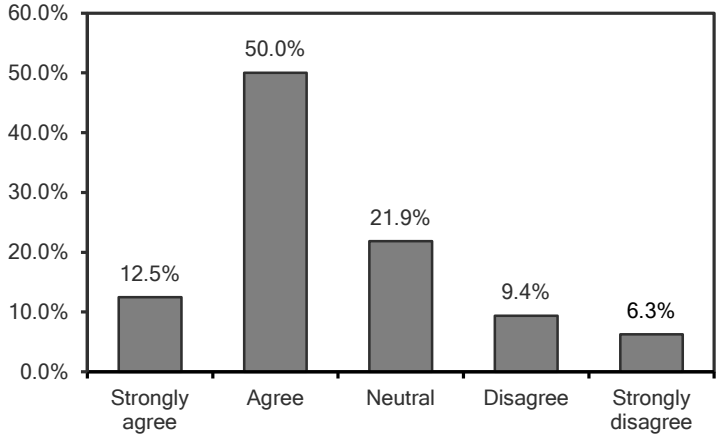

Figure 5: Students' opinions on influence of MDSolids on their problem solving skills

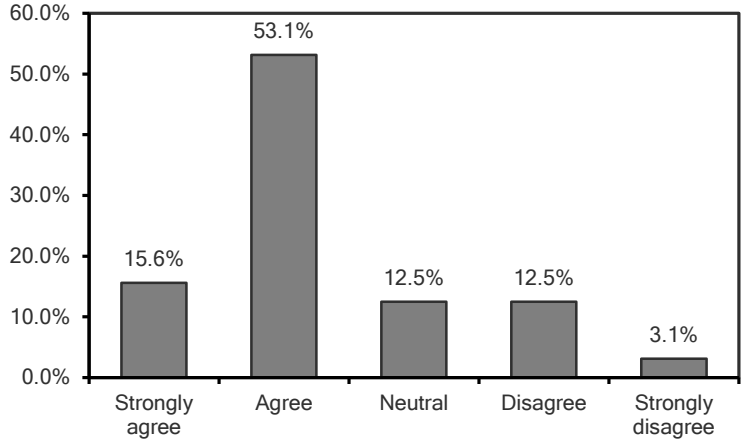

Figure 6: Students' opinions on their overall satisfaction with the quality of the project

Generally students welcomed the opportunity of enhancing industrial exposure in engineering subjects. They clearly made this comment on the evaluation questionnaires where 70% of students responded strongly agree or agree as illustrated in Figure 6. However, the way the project was delivered was not entirely positively received by 25% of the students. Hence, it is necessary to investigate what features adopted in delivering this project were most disliked by students and consider them in future implementations of the project.

Plans for continuing use of the project

The project was not run in Autumn 2014 but there are plans for its reintroduction into the subject in Spring 2014 and beyond. A key reason includes the teaching staff, and their capacity and motivation/willingness to take on the responsibility. Moreover, like many institutions, the Faculty is progressively revising delivery modes across subjects.

Furthermore, this project has been disseminated into an earlier stage subject with a similar industrial presentation on truss members of the Central Park (Broadway, NSW) building delivered in the Engineering Mechanics subject. The MDSolids has been installed on UTS computers and we are using it in Mechanics of Solids and Engineering Mechanics subjects.

Conclusions

This paper reports the outcomes and challenges for the project "Enhancing Industry Exposure in Mechanics of Solids subject at UTS". It successfully demonstrates that industry exposure can be contextually included in a relatively early stage of a Civil or Mechanical degree progam. The project was conducted as a series of eight industry presentation modules and MDSolids package seminars spaced throughout semester. Feedback from students has been analysed to evaluate achievement of the project's objectives.

One of the major benefits of this project is its impact on students' better understanding of engineering practice, students' motivation for learning of engineering through real-world problems and improving students' learning through understanding context and connections between theory and practice. In addition, utilising the MDSolids software package was found to be a helpful tool to assist students to cover the gap between the subject concepts and the application of them in solving homework assignments.

While there was enthusiasm for enhancing industry engagement in Mechanics of Solid subject at UTS, improvements for future offerings may include:

1) Collect feedback from the industry presenters; 2) Greater diversity of invited industry partners from Mechanical engineering and 3) The industry presentations should be polished to make them shorter and more concise.

References

Cameron, I., & Reidsema, C. (2011, 5-7 December). *Australian engineering academe: a snapshot of demographics and attitudes.* Paper presented at the 22nd Annual Conference of the Australasian Association for Engineering Education, Fremantle, WA.

Faulkner, W. (2007). "Nuts and Bolts and People": Gender-Troubled Engineering Identities. *Social Studies of Science, 37*(3), 331-356.

Fletcher, J., K. (1999). *Disappearing acts: gender, power and relational practice at work*. Cambridge, MA: MIT Press.

Godfrey, E., & King, R. (2011). Curriculum specification and support for engineering education: understanding attrition, academic support, revised competencies, pathways and access. Strawberry Hills NSW: Australian Learning & Teaching Council.

Male, S., & King, R. (2013). Best Practice Guidelines for Effective Industry Engagement in Australian Engineering Degrees.

Male, S. A. (2010). Generic Engineering Competencies: A Review and Modelling Approach. *Education Research and Perspectives, 37*(1), 25-51.

Philpot, T. A. MDSOLIDS: SOFTWARE TO BRIDGE THE GAP BETWEEN LECTURES AND HOMEWORK.

Philpot, T. A., & Hall, R. H. (2005). The role of MDSolids in international mechanics of materials education. *International Journal of Engineering Education, 21*(2), 350-360.

Rychen, D. S., & Salganik, L. H. (2003). *Key Competencies for a Successful Life and a Well-Functioning Society*. Cambridge, MA: Hogrefe & Huber.

Sheppard, S. D., Macatangay, K., Colby, A., & Sullivan, W. M. (2009). Educating Engineers: Designing for the Future Field Book Highlights and Summary. Retrieved from http://www.carnegiefoundation.org/sites/default/files/publications/elibrary_pdf_769.pdf

The Senate. (2012). The shortage of engineering and related employment skills (Education Employment and Workplace Relations Committee, Trans.). Canberra, ACT: Commonwealth of Australia.

Tilli, S., & Trevelyan, J. P. (2010). Labour Force Outcomes for Engineering Graduates in Australia. *Australasian Journal of Engineering Education, 16*(2), 101-122.

Trevelyan, J. P., & Tilli, S. (2007). Published Research on Engineering Work. *Journal of Professional Issues in Engineering Education and Practice, 133*(4), 300-307.

Acknowledgements

'This project has been developed by UTS supported by the Australian Council of Engineering Deans (ACED) with funding from the Australian Government Department of Industry, Workplace Innovation Program. The project was conceived as a response to a recommendation to ACED by the National Resources Sector Workforce Strategy Taskforce'.