An adaptive e-learning community of practice for mechanics courses in engineering

Final Report 2013

Partner institutions and team members:
The University of New South Wales
Associate Professor B. Gangadhara Prusty (project leader)
Dr Zora Vrcelj
University of Wollongong
Professor Tim McCarthy
University of Tasmania
Mr Robert Ojeda
University of Technology, Sydney
Ms Anne Gardner

Report author:
M. Asif Khawaja (project officer)

Associated Institutions:
RMIT University, The University of Melbourne, University of Western Sydney

Reference group members:
Dr Robin Ford, Dr Roger Hadgraft, Associate Professor Tom Molyneaux

Consultative group members:
Dr Carol Russell, Dr Nadine Marcus

http://adaptive-mechanics.eng.unsw.edu.au
Support for the production of this report has been provided by the Australian Government Office for Learning and Teaching. The views expressed in this report do not necessarily reflect the views of the Australian Government Office for Learning and Teaching.

With the exception of the Commonwealth Coat of Arms, and where otherwise noted, all material presented in this document is provided under Creative Commons Attribution-ShareAlike 3.0 Unported License http://creativecommons.org/licenses/by-sa/3.0/.

The details of the relevant licence conditions are available on the Creative Commons website (accessible using the links provided) as is the full legal code for the Creative Commons Attribution-ShareAlike 3.0 Unported License http://creativecommons.org/licenses/by-sa/3.0/legalcode.

Requests and inquiries concerning these rights should be addressed to:
Office for Learning and Teaching
Department of Industry, Innovation, Science, Research and Tertiary Education
GPO Box 9880,
Location code N255EL10
Sydney NSW 2001
<learningandteaching@deewr.gov.au>

2013
ISBN: 978-1-921916-73-1
Acknowledgements

Support for this project was provided by the Australian Government, Office for Learning and Teaching, previously known as the Australian Learning and Teaching Council (ALTC), under the Grant No. CG10-1586.

UNSW was the host institution and the team would particularly like to thank Anne Simmons (Head of School, School of Mechanical and Manufacturing Engineering.), David Clements, (Associate Dean, Faculty of Engineering), Stephen Marshall (Director, Learning & Teaching), Helen Dalton (Learning & Teaching), and Richard Henry (Deputy Vice-Chancellor) for their support.

We acknowledge the contribution of Dr. Dror Ben-Naim, Shaowei Ho and Zack Belinson who served as Project Officer, Software Developer and Portal Developer, respectively, right from the start of the project, leading the AT development team. They had to leave their positions in August 2011 as a result of initiating the spinout company ‘smartsparrow’, but supported the project till the end. We also appreciate the excellent work of Shing Y Kong and Jay Sul, for their useful contributions to the development of ATs.

The project team would like to acknowledge all the academic staff who attended workshops and seminars over the course of the project, and students who participated in the evaluation of ATs and provided the survey data.

Finally, we would like to thank the students throughout the period from 2006 to-date who helped design and develop the ATs under the supervision of B. Gangadhara Prusty, especially Owen Ho (UG Honours student, 2007), Shaowei Ho (UG Honours student, 2008), C K Yau (UG Honours student, 2009), C W Chan (UG Honours student, 2010), Zhao Ang (UG Honours student, 2010), Jesse Whelan (UG Honours student, 2011) and Gim Soh (Taste of Research student, 2012).
List of acronyms used

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AeLP</td>
<td>Adaptive eLearning Platform</td>
</tr>
<tr>
<td>AI</td>
<td>Artificial Intelligence</td>
</tr>
<tr>
<td>ALTC</td>
<td>Australian Learning and Teaching Council Ltd</td>
</tr>
<tr>
<td>AT</td>
<td>Adaptive Tutorial</td>
</tr>
<tr>
<td>CMS</td>
<td>Content Management System</td>
</tr>
<tr>
<td>CoP</td>
<td>Community of Practice</td>
</tr>
<tr>
<td>FBD</td>
<td>Free Body Diagram</td>
</tr>
<tr>
<td>ITS</td>
<td>Intelligent Tutoring system</td>
</tr>
<tr>
<td>LMS</td>
<td>Learning Management System</td>
</tr>
<tr>
<td>OLT</td>
<td>Office for Learning and Teaching</td>
</tr>
<tr>
<td>TC</td>
<td>Threshold Concept</td>
</tr>
<tr>
<td>UMelb</td>
<td>The University of Melbourne</td>
</tr>
<tr>
<td>UNSW</td>
<td>The University of New South Wales</td>
</tr>
<tr>
<td>UoW</td>
<td>University of Wollongong</td>
</tr>
<tr>
<td>UTAS</td>
<td>University of Tasmania</td>
</tr>
<tr>
<td>UTS</td>
<td>University of Technology, Sydney</td>
</tr>
<tr>
<td>UWS</td>
<td>University of Western Sydney</td>
</tr>
<tr>
<td>VAF</td>
<td>Virtual Apparatus Framework</td>
</tr>
<tr>
<td>XML</td>
<td>eXtensible Markup Language</td>
</tr>
</tbody>
</table>
Executive summary

This project set out to explore the use of online eLearning Adaptive Tutorials in engineering courses and to develop a Community of Practice (CoP) for Mechanics courses in engineering departments or schools at various Australian universities. The project involved a team of engineering academics from several Australian universities including The University of New South Wales (the lead university), University of Wollongong, University of Tasmania, University of Technology, Sydney, RMIT University, The University of Melbourne, and University of Western Sydney. The research focused on mechanics courses and drew upon the data gathered from academics and students at the partner universities.

Teaching fundamental threshold concepts to students in the large classes of 1st and 2nd year engineering mechanics courses is an ever challenging task. High failure rates, potentially due to students not grasping “threshold concepts”, is a continuing concern, as is demand for targeted methods to overcome the situation. Despite many studies and techniques used to identify reasons and to improve learning performance, the problem still persists.

The deliverables for project included (i) develop 12 Adaptive Tutorials (ATs) covering identified core threshold concepts, (ii) incorporate Adaptive Tutorials into the course syllabi at partner institutions, (iii) conduct 2 staff training workshops, (iv) develop a web-based community portal featuring all Adaptive Tutorials, accessible to all universities within Australia, and (v) develop comprehensive support material for students and teachers. All these objectives have been achieved.

The ATs were trialled with over twelve hundred engineering mechanics students in two separate studies over a period of three years from 2009 to 2011. The students were surveyed each time after they used the tutorials. Both qualitative and quantitative analyses including student surveys, ANOVA tests and t-Tests were completed to examine relationships between study variables.

Students’ overall self-reported ratings showed positive relationships between their use of ATs and their course satisfaction. We found significant overall positive relationships between number of ATs and the course grades throughout the three years, especially for high performing students. Low performing students showed significant performance improvement when number of ATs was increased from two in 2009 to four in 2010, but showed significant performance deterioration when the number was increased from four in 2010 to eight in 2011. These findings will enable implementers to adapt their use of ATs accordingly.

The project makes the following recommendations:

1. Retain the focus on developing students’ understanding of threshold concepts
2. Create further Adaptive Tutorials for engineering mechanics
3. Use the results of this study when planning strategies for implementing Adaptive Tutorials
4. Continue to promote the Community of Practice for Engineering Mechanics
5. Incorporate other elearning resources for mechanics in engineering
6. Create and implement Adaptive Tutorial technology for other engineering courses and disciplines.
# Table of Contents

Acknowledgements ..................................................................................................................... 3  
List of acronyms used .................................................................................................................. 4  
Executive summary .................................................................................................................... 5  
Table of Contents ........................................................................................................................ 6  
Tables and Figures ...................................................................................................................... 7  

Chapter 1: Introduction .............................................................................................................. 8  
  1.1 Background ............................................................................................................... 8  
  1.2 Scope ...................................................................................................................... 11  

Chapter 2: Project Outcomes and Impacts ............................................................................... 13  
  2.1 Project Approach and Methodology ...................................................................... 13  
  2.2 Achievement of Projected Outcomes .................................................................... 41  

Chapter 3: Dissemination .......................................................................................................... 45  
  3.1 Activities and Outcomes ......................................................................................... 45  
  3.2 Usable Project Outcomes ....................................................................................... 47  

Chapter 4: Linkages ................................................................................................................... 49  

Chapter 5: Project Evaluation ................................................................................................... 50  
  5.1 Evaluation Process .................................................................................................. 50  
  5.2 Evidence of Project Impact ..................................................................................... 51  

Chapter 6: Recommendations .................................................................................................. 53  
  6.1 Retain focus on developing students’ understanding of threshold concepts ....... 53  
  6.2 Create further Adaptive Tutorials for engineering mechanics............................... 53  
  6.3 Reconsider the strategy for implementing Adaptive Tutorials .............................. 53  
  6.4 Promote the Community of Practice for Engineering Mechanics......................... 53  
  6.5 Incorporate other elearning resources for engineering mechanics....................... 54  
  6.6 Create and implement AT technology for other engineering disciplines .............. 54  

References ................................................................................................................................ 55  

Appendix A: Publications .......................................................................................................... 57  
Appendix B: Samples of Distribution Material ......................................................................... 64  
Appendix C: Survey Questionnaire ........................................................................................... 67  
Appendix D: Evaluation Report ................................................................................................. 70  
Appendix E: Community of Practice Web Portal ...................................................................... 72
Tables and Figures

Tables

Table 1. Outcomes in Original Project Proposal ................................................................. 13
Table 2. Engineering Academics as members of the Community of Practice ..................... 16
Table 3. Proposed List of Threshold Concepts ................................................................. 17
Table 4. Final List of Threshold Concepts .......................................................................... 18
Table 5. Training Workshops conducted on the use of ATs ............................................... 21
Table 6. Assessments for the Mechanics of Solids course ............................................... 23
Table 7. Summary of Contexts used in FBD Analysis ...................................................... 26
Table 8. Descriptive analysis for Block Test component .................................................. 27
Table 9. Descriptive analysis for AT test component ........................................................ 29
Table 10. Descriptive analysis of Final exam component ................................................... 29
Table 11. Distribution of students with a WAM Cut-off = 65 ............................................. 30
Table 12. Thematic analysis of student feedback for 8 ATs ................................................ 35
Table 13. Number of comments about effectiveness of FBD ATs and mean scores .......... 36
Table 14. Reasons given for effectiveness or suggestions for improvement ....................... 36
Table 15. Summary of the use of ATs at various institutions during 2011 ............................ 52

Figures

Figure 1. A conversational framework for the project and its pedagogical evaluation .... 10
Figure 2. Project Stages and Sources of Input .................................................................... 14
Figure 3. The AT Analyser uses Solution Trace Graphs to visually analyse students’ solution-traces through the problem state-space ................................................................. 15
Figure 4. Screenshots of ATs in Engineering Mechanics .................................................... 18
Figure 5. Initial Storyboard or Mock-up for Free Body Diagram Tutorial .......................... 19
Figure 6. Screenshot of authoring window for Free Body Diagram Tutorial ....................... 20
Figure 7. Adaptive Tutorial Development Process and the Roles involved ......................... 20
Figure 8. Free Body Diagram Tutorial and its Configuration file ....................................... 21
Figure 9. Staff Training Workshops at RMIT, Melbourne (left) and UTS, Sydney ............... 22
Figure 10. Free Body Diagram tutorial question implemented at 4 different university contexts and student responses ............................................................... 25
Figure 11. Student performance in 2nd year Mechanics of Solids course .......................... 27
Figure 12. Average Block Test Scores in Mechanics of Solids course for three years ......... 28
Figure 13. Average Lab Scores in Mechanics of Solids course for the three years .......... 28
Figure 14. Average AT Scores in Mechanics of Solids course for 3 years .......................... 29
Figure 15. Average Final Exam Scores in Mechanics of Solids course for the three years .......................... 30
Figure 16. Average Before-Final-Exam Scores for Low vs. High Performing Students .... 31
Figure 17. Average Final Exam Scores for Low vs. High Performing Students ................. 31
Figure 18. Average Total Course Scores for Low vs. High Performing Students ............... 32
Figure 19. Students’ Average Course Scores against their Individual WAMs ................. 32
Figure 20. Percentages of Low Performing Students able to improve against their WAMs ... 33
Figure 21. A sample of student responses in 2009 ........................................................... 34
Figure 22. Student responses to questions about the last two tutorials in 2011, for lower and upper half of final exam scores ............................................................... 34
Figure 23. Distributions of time taken and marks for one of the final two ATs ................. 36
Figure 24. Free Body Diagram Results for Context 1 ......................................................... 37
Figure 25. Home page of Web-based Community Portal for Engineering Mechanics ...... 42
Figure 26. Final Project Workshop and Portal Launch at UNSW, Sydney ........................... 46
Chapter 1: Introduction

1.1 Background

The aim of this project is to address long-standing and persistent challenges in engineering education. Its approach is to use ideas from the field of Artificial Intelligence (AI) to provide intelligent e-learning tools that are adaptive to student’s learning performance.

University is a major place of growth and development in both the professional and personal life of a student. When students enter university, they bring a wide range of abilities, maturity, and confidence, and have a similarly wide range of attitudes towards their studies. This is particularly evident when students encounter the large classes of 1st and 2nd year engineering foundation courses in engineering mechanics. In typical engineering schools these demanding studies comprise up to 25% of 1st year and up to 40% of 2nd year. Failure rates of up to 50% are common in introductory mechanics courses in engineering, which has been an issue of continuing importance and concern (Goldfinch, Carew, & Thomas, 2009; McCarthy et al., 2010). Many initiatives have been aimed at identifying reasons for the high failure rates, and finding ways of addressing the problem – both by individual engineering mechanics teachers and, increasingly, by the community of engineering educators. Because of their importance, some of these initiatives have been supported by Engineering Schools, some by Universities and others by national bodies like Australian Government’s Office for Learning and Teaching (OLT), previously known as Australian Learning and Teaching Council (ALTC).

Previous studies on learning in engineering mechanics in Australia indicate that many students experience substantial difficulties, but offer relatively little explanation of the underlying causes of these difficulties (Dwight & Carew, 2006; Goldfinch, Carew, Gardner, et al., 2008; Goldfinch, Carew, & McCarthy, 2008; Goldfinch et al., 2009). 21st century students need more explanation and understanding of the course than the traditional book-and-board can provide. Most students expect learning outcomes from the course to be clear, simple, easy, and achievable. Whether this is possible or not, they do expect more flexible ways of learning and demonstrating engineering expertise than chalk-and-talk instruction can offer (Hadjraft, 2007). These students are as keen as students ever were to link subject matter with engineering reality and want opportunities to visualise the subject matter through experiments or similar exercises which develop clear understanding of different components of the course of engineering.

Students can learn the basic skills with the development of a coherent approach to computer-assisted learning and assessment (Hadjraft, 2007). Participating in hands-on or interactive activities can improve the students’ motivational levels in learning (Jorgenson, 2005; Kessissoglou & Prusty, 2009; Paris, Yambor, & Packard, 1998). Moreover, research suggests that students benefit from an interactive learning environment in which they can have some control of their learning experiences (Mayer & Chandler, 2001). Computer-based games that have been developed for the students in Statics and Mechanics of Materials courses (Philpot et al., 2003) were successful in both improving student performances and dramatically increasing engagement and motivation levels.

There are many online educational resources available so it should therefore be possible to locate resources suitable to learning specific skills and make them available to students “on demand” so that they can learn the skills they need as they arise from the project tasks. Towards that end a recent project explored existing online learning resources in the area of Engineering Mechanics (Goldfinch & Gardner, 2010). The researchers carefully evaluated freely available online resources and catalogued them into a database. The aim of the database is to encourage students to be proactive in improving the quality of their learning.
Another alternative is to provide students with lots of worked out problem solutions to study, interspersed with some problems to solve – taking advantage of the “worked example effect”. This reduces the cognitive overload associated with large amounts of unfamiliar problem solving for less knowledgeable learners, but allows students to stay motivated (Sweller & Cooper, 1985). An online learning environment provides an ideal opportunity to expose students to a wide array of worked out problem solutions to study, with the option of easily changing the values of variables without altering the concepts being demonstrated.

To help analyse the quantitative and qualitative data available through current project, we can be guided by the comprehensive body of recent cognitively guided research summarised by (Sweller, Ayres, & Kalyuga, 2011) that is relevant to online instructional design. The instructional techniques suggested by this empirically supported body of literature all rely on us not overloading our students’ available information processing capacity.

In particular, we should be aware of the expertise reversal effect (Kalyuga, Ayres, Chandler, & Sweller, 2003), where instructional techniques that work best for inexperienced learners, may lose their effectiveness or even be worse for more experienced learners. Instructors, by virtue of their role, are more knowledgeable in the domain in which they are teaching. Sometimes we as instructors inadvertently assume the method that would be best for us to extend our own knowledge in the domain, would also be best for our students. Unfortunately this is not always the case. For instance, inexperienced learners need comprehensive extra information and practice in a domain. But how the extra information is presented is not neutral in terms of processing load, and if it is unfamiliar it may need extra resources to process. The instructional format in which this information is presented therefore becomes critical to ensure effective learning.

In contrast, those experienced in the domain may find the extra information redundant and a waste of cognitive resources (see (Chandler & Sweller, 1991) for a detailed explanation of the redundancy effect). Instead, more experienced learners may benefit from solving unfamiliar problems and trying to tie all the information together in new and unfamiliar ways. In contrast, extensive problem solving for novices is cognitively overwhelming and students would be better off studying many worked out problem solutions interspersed with a few similar problems to solve (see (Sweller & Cooper, 1985) for a description of the worked example effect). We thus need to be aware of the knowledge levels of our students when designing instructional content. In particular, we need to try and not overload the less knowledgeable learners with too much new and non-essential information, but rather focus on what is essential for learning. We do not want to overwhelm student’s limited cognitive resources with information that is redundant to acquiring the basic mechanical threshold concepts. Multimedia technologies that adapt to each learner’s current status offer a solution to this difference in requirements. Long-term goals for the use of the technology also include being able to use students written or spoken language in real time to assess the current cognitive load level and so adapt instructional content accordingly (see (Khawaja, Chen, & Marcus, 2010, 2012) for a description of how we may eventually be able to do this). Existing resources adapt content based on whether students get the answers to questions right or wrong.

There is a wide variety in the types of online resources available and there is certainly no shortage of them, but almost invariably, they implicitly reduce the role of the teachers who use them to simply pointing students to them; they are rarely built in such a way that teachers can adapt them to their specific needs. So the problem with existing online resources is that they do not track in detail where students are going wrong and also that they are difficult to adapt to specific students or teachers’ needs. Pedagogical aspects of the content are tied to the worldview of the producer, and teachers who wish to use them must either accept things as they are, or adjust the context and breadth of instruction they would by assisting them to select learning resources best suited to their needs.
ideally desire. The problem is not too acute when covering topics that are fundamental to any specific disciplines, as one can argue that typically, there is little variation in the teaching of this type of topics. But the nature of higher-education is such that teachers are established researchers in the field and often feel they “own” the discipline’s knowledge. They often want more pedagogical control over the activities they dictate to their students. They also want to be able to tie the new knowledge into students existing knowledge and context. Students also come from varying backgrounds and have different starting points in their knowledge bases.

Also, though there are a number of initiatives by Universities around the world to use online educational resources and tools, there are not many tools available with the ability to provide instant, intelligent (relevant and appropriate) feedback that is adapted to the learner’s knowledge level while maintaining a teacher’s reflection and adaptation with minimum effort.

We also do not yet fully understand when and how best to use multimedia instructional technologies and this is currently a topic of extensive educational research. A useful overview of this challenge is provided by framing the learning technologies as part of a conversation between teacher(s) and student(s) (Laurillard, 2002). Figure 1 shows how the conversational model might apply in the context of this project.

![Figure 1. A conversational framework for the project and its pedagogical evaluation](image)

In traditional teaching methods the teacher would interact with the student in person. Learning would be measured through formal assessment as well as direct conversation with tutors. With the adaptive e-learning tutorials, the teacher sets up an online activity in which a large number of students work individually through simulated application of some core concepts. The students learn from automated feedback and hints based on their responses, so eventually their understanding of how to use the concepts comes closer to that sought by the teacher. The adaptive e-learning platform logs and analyses all student responses, so the teacher is able to monitor student learning and then to identify and deal with common conceptual problems, either through the adaptive tutorial or through other teaching.

This project involved supporting the development of a community of practice among users of the ATs across several Australian universities. The aim was that individual teachers would benefit from sharing their understanding of the conceptual challenges in the discipline, and in particular on some key threshold concepts (Meyer & Land, 2002, 2005). They would then
An adaptive e-learning community of practice for mechanics courses in engineering

The project evaluation therefore addressed three questions:

1. How did the events and activities in the community of practice support teacher use of the tutorials?
2. Are there significant measurable changes in student learning outcomes as a result of introducing the ATs?
3. What is the student perception of the value of the ATs for their learning?

The tangible project outcomes include the ATs created and used, the events organised and the resources produced together with data obtained from the teachers in the project team who took part in semi-structured interviews on their experience of designing, using and analysing the adaptive tutorials.

Changes in student performance following the introduction of ATs were evaluated by analysing the grades obtained in various assessment tasks. This was particularly effective in one of the classes involved in the project where an increasing numbers of ATs had been introduced by the same teacher over a period of three years, using similar assessments. This made possible a longitudinal quantitative study. Teachers of other classes were also able to report on changes in their students’ performance.

Student perceptions of the tutorial were gathered by short surveys after each tutorial. Responses to multiple choice questions could then be compared quantitatively across different tutorials and contexts. Students were also invited to offer text comments to expand on their responses. Qualitative analysis of these comments gives further insight into the students’ learning experiences.

One aim of the community approach to developing and using the ATs is that it will lead to a better shared understanding of the common cognitive challenges facing undergraduate students of engineering mechanics. Specifically, the project aimed to provide some practical tools for researching and improving student learning in the discipline. In particular, the inherent difficulty for teachers in identifying threshold concepts in engineering mechanics may be partly overcome by the ability to track learning patterns in detail across large numbers of students.

1.2 Scope

This project focused on complementing and building on earlier work that aimed to improve learning outcomes in engineering mechanics in Australian university engineering degree programs. Its context was large diverse groups of students, many of whom need more than traditional “book and board” teaching methods to engage them in learning. Based on the successful pilot study and evaluation at The University of New South Wales (UNSW), the project set out to explore the use of online eLearning Adaptive Tutorials (ATs) in engineering courses and to develop a Community of Practice (CoP) for Mechanics courses in engineering departments or schools at various Australian universities. The project involved a team of engineering academics from the partner Australian universities, who agreed to adopt ATs into their teachings. The partner universities were The University of New South Wales (the lead university), University of Wollongong, University of Tasmania, and University of Technology, Sydney. Three other universities also participated in the project as associated members including RMIT University, The University of Melbourne, and University of Western Sydney. The research focused on mechanics courses and drew upon data gathered from academics and students at the partner universities.

There were four main objectives. Firstly, to develop a community of like-minded engineering academics from wide range of universities who would like to incorporate ATs in
their mechanics courses in order to improve their students’ learning performance. Secondly, to identify and develop ATs that will help in teaching the threshold concepts involved in engineering mechanics foundation courses in 1\textsuperscript{st} and 2\textsuperscript{nd} years where consist of hundreds of students. Thirdly, to develop and make available to the engineering community a web-based community portal that would feature all the ATs, and be supported by published pedagogical research and information on using them. And fourthly, to collect and record data from students and teachers’ use of the ATs and to analyse the data for the impact of the technology on the students’ learning performance.

The typical Australian university engineering departments involved in this project ranged from large metropolitan universities like UNSW, which has Australia’s largest Faculty of Engineering and has a high proportion of overseas students in the undergraduate studies, to small regional universities with a higher proportion of local students from rural backgrounds, such as the University of Tasmania. The lead university already had close contacts at each of these universities with academics responsible for teaching 1\textsuperscript{st} and 2\textsuperscript{nd} year mechanics courses and who have an interest in using eLearning technologies in their courses, which provided a good basis for setting up research activities.

Various research approaches were utilised to identify and investigate threshold concepts and the factors that impacted students’ learning in engineering mechanics. The factors investigated comprised issues at various levels including threshold concepts, ATs, eLearning technology, students, course curriculum, and university levels. We used both qualitative as well as quantitative analyses methods to investigate the factors impacting students’ learning.
Chapter 2: Project Outcomes and Impacts

This project involved the development of 12 Adaptive Tutorials for key threshold concepts (TCs) in engineering mechanics, targeting first and second year engineering mechanics students in Australian universities. The outcomes originally proposed for this project, and the extent of their realisation are listed in Table 1. These outcomes have been delivered through the research, development, and evaluation approaches originally proposed, with only minimal modifications.

Table 1. Outcomes in Original Project Proposal

<table>
<thead>
<tr>
<th>Projected Outcome</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing 12 Adaptive Tutorials covering identified core threshold concepts, accessible to all the universities within Australia through web-based portal.</td>
<td>Achieved</td>
</tr>
<tr>
<td>Incorporating Adaptive Tutorials into the course syllabi at institutions where members of the OLT project team are teaching.</td>
<td>Achieved</td>
</tr>
<tr>
<td>Conducting 2 staff training workshops open to academics at all Australian engineering faculties.</td>
<td>Exceeded</td>
</tr>
<tr>
<td>Developing a web-based community portal where all Adaptive Tutorials are featured, accessible to all the universities within Australia for their use, along with published pedagogical research on using them.</td>
<td>Achieved</td>
</tr>
<tr>
<td>Developing comprehensive support material including a user-editable ‘how-to-use’ guide and user manual that will support the teacher usage of the portal and the tutorials.</td>
<td>Achieved</td>
</tr>
</tbody>
</table>

As indicated in Figure 1, these practical outcomes are underpinned by a pedagogical evaluation to establish the impact of the ATs on student learning – both in terms of measured student performance in assessments and in their feedback on the experience of using the ATs.

2.1 Project Approach and Methodology

The project approach and research methodology was based around the plan presented originally in the research proposal and summarised in Figure 2. This section describes how each of the stages of the project was carried out, the analyses, the findings, and how these findings led to the proposed recommendations.

2.1.1 Adaptive Tutorials and the Adaptive eLearning Platform

Adaptive Tutorials (ATs) are eLearning modules where an Intelligent Tutoring System (ITS) adapts the instruction level (difficulty, feedback and activity-sequence) to learners, based on their individual performance. From a pedagogical point of view, ATs are similar to teaching laboratory activities and are analogous to the concept of Tutorial Simulations as described by (Laurillard, 2002). They can be described as a pragmatic hybrid between instructivist and constructivist educational theories, trying to strike a balance between guided and discovery learning. ATs are typically guided, featuring a detailed explanation that leads students through the interaction, while offering adaptive, remedial feedback in response to misconceptions. ATs are also interactive, enabling students to investigate a phenomenon or a problem in a hands-on manner, thereby encouraging discovery learning.
Figure 2. Project Stages and Sources of Input
The Adaptive e-Learning Community of Practice for Mechanics Courses in Engineering

ATs exhibit three types of adaptation:

1. students receive feedback that is adapted to their specific misconceptions
2. sub-activities (questions, tasks) are also sequenced adaptively based on their performance
3. the content of the activities (examples, questions) and the feedback is adapted in response to general patterns in student responses.

The third level of adaptation is what distinguishes the work on ATs from other ITS research.

The Adaptive eLearning Platform (AeLP) is a web-based implementation of Virtual Apparatus Framework (VAF) (Ben-Naim, Marcus, & Bain, 2007). The VAF’s premise is that teachers should be able to develop ATs in a way that is analogous to how they develop laboratory activities. In other words they need not be concerned about building the software or understanding exactly how it works, but rather they should be able to import prefabricated “apparatus” into a learning environment, and then author lesson-plans that guide students through interaction with the apparatus. The AeLP is used to build ATs using VAF.

The AeLP incorporating ATs has been in use since 2006 at The University of New South Wales deployed via the institutional online learning management system. To date, more than 40 different ATs have been incorporated into the syllabi of 10 major courses (each with 50–700 students) at various departments, and accessed by over 5000 students a year (Ben-Naim, Marcus, & Bain, 2009; Prusty, Ho, & Ho, 2009; Velan et al., 2009).

Adaptive Tutorials are not “launch and forget” projects. Once ATs are developed, teachers use the AT-Analyser, which creates visual traces of student performance, (see Figure 3) to scrutinise their students’ interactions during the ATs, and to adapt the AT content as needed based on their students’ demonstrated misconceptions. By visualising patterns in student responses in the ATs, the AeLP helps teachers gain a better understanding of where their students are having problems with key concepts that they need to progress to more complex learning tasks. ATs can then be easily updated to address any misconceptions.

This creates a powerful educational experimentation environment where hypotheses about students’ learning can be evaluated, adapted and then shared and published. Teachers thus become ‘action researchers’, confirming or disproving their hypotheses about the best way to help their students learn (Ben-Naim, Marcus, & Bain, 2008; Ben-Naim et al., 2009).

![Figure 3. The AT Analyser uses Solution Trace Graphs to visually analyse students’ solution-traces through the problem state-space](image-url)
2.1.2 Building an Adaptive eLearning Community of Practice for Engineering Mechanics

One of the main objectives of the project was to build a Community of Practice (CoP), a community of like-minded engineering educators in Australia and provide them with a common platform to allow them to work collaboratively and develop ATs to use in their teachings to enable them to improve the overall students’ learning performance. There is a growing recognition of the importance in using the CoP approach for teacher professional development, and especially, to support teachers and educators in reflecting on their practice, in a collaborative and supportive environment (Schlager, Fusco, & Schank, 2002). Such an approach fits well with the desire to increase the adoption of ATs by emphasising on reflection and adaptation.

To achieve this, we involved a team of enthusiastic engineering academics, who agreed to adopt ATs into their mechanics courses in engineering, from a range of Australian universities including The University of New South Wales, University of Wollongong, University of Tasmania, University of Technology, Sydney, RMIT University, and The University of Melbourne. The tasks to be completed by this CoP involved identifying Threshold Concepts for mechanics courses in engineering and development, use, and dissemination of a set of ATs. One of the important tasks to be performed by the CoP was also to identify and design the adaptations to be performed by the ATs.

Table 2 lists the engineering academics and researchers that were involved in the project and who formed the Community of Practice for the above identified objectives:

<table>
<thead>
<tr>
<th>Engineering Academic</th>
<th>University</th>
<th>School/Department</th>
<th>Responsible for Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. B. Gangadhara Prusty</td>
<td>UNSW</td>
<td>Mechanical and Manufacturing Engineering</td>
<td>MMAN2400 (Mechanics of Solids 1) and MMAN 1300 (Engineering Mechanics 1)</td>
</tr>
<tr>
<td>Dr. Zora Vrcelj</td>
<td>UNSW</td>
<td>Civil and Environmental Engineering</td>
<td>CVEN1300 (Engineering Mechanics for Civil Engineers)</td>
</tr>
<tr>
<td>Dr. Timothy McCarthy</td>
<td>UoW</td>
<td>Civil, Mining &amp; Environmental Engineering</td>
<td>ENGG101 (Foundations of Engineering)</td>
</tr>
<tr>
<td>Dr. Roberto Ojeda</td>
<td>UTAS</td>
<td>Maritime Engineering &amp; Hydrodynamics</td>
<td>Mechanics of Solids</td>
</tr>
<tr>
<td>Mrs. Anne Gardner</td>
<td>UTS</td>
<td>Civil and Environmental Engineering</td>
<td>48321 (Engineering Mechanics)</td>
</tr>
<tr>
<td>Dr. Roger Hadgraft</td>
<td>UMelb</td>
<td>Civil Engineering</td>
<td></td>
</tr>
<tr>
<td>Dr. Tom Molyneaux</td>
<td>RMIT</td>
<td>Civil Engineering</td>
<td></td>
</tr>
<tr>
<td>Dr. Robin Ford</td>
<td>UNSW</td>
<td>Mechanical and Manufacturing Engineering</td>
<td></td>
</tr>
<tr>
<td>Dr. Carol Russell</td>
<td>UWS</td>
<td>Teaching Development Unit</td>
<td></td>
</tr>
<tr>
<td>Dr. Nadine Marcus</td>
<td>UNSW</td>
<td>School of Computer Science and Engineering</td>
<td></td>
</tr>
</tbody>
</table>
2.1.3 Identifying Threshold Concepts in Engineering Mechanics

Threshold Concept (TC) is a term used to describe basic knowledge and understanding of the core concepts of a given subject that once understood, transform a person’s perception of the subject irreversibly (Meyer & Land, 2005). High failure rates in engineering mechanics suggest that students may be struggling with the TCs. Once acquired, TCs can seem simple and self-evident, yet without them students will be unable to progress to more complex analyses. Students who fail in engineering mechanics are usually sticking on one or more of these concepts. Because discipline experts have made the conceptual leap years ago they often find it hard to identify why many students are struggling with apparently simple tasks involving TCs (Davies, 2006; Meyer & Land, 2005). For the non-expert learner, TCs are “troublesome knowledge” in that they may initially seem counter-intuitive (Meyer & Land, 2002; Perkins, 2006). A student who is persistent and motivated will eventually reach a breakthrough in understanding. But unless students see the point of the exercise they are unlikely to spend the required time on task to reach the breakthrough point.

Ideally, to provide context and help with TCs a student and teacher would have an extended “conversation” in which the teacher sets activities for the student, observes the student responses to the activity, and then adjusts the explanations and activities accordingly. Where there are large diverse classes and therefore limited scope for individual responses to students, one solution is to mediate the conversation through technology as illustrated in Figure 1 (Laurillard, 2002; Prusty, 2010).

This project aimed at developing and providing that technology, which can support both students and teachers in their learning and teaching of the TCs, respectively. The objective of forming a Community of Practice (CoP) of engineering educators was to identify the core knowledge components for the engineering mechanics courses. Several tentative TCs were identified originally in project proposal as listed in Table 3, which were to be collaboratively discussed with the members of the CoP. After several meetings, discussions and consultations with the mechanics educators in engineering from collaborating universities, students and other team members, some of the proposed concepts were removed and few new ones were identified for this project (Table 4). In selecting these TCs, several factors were considered including how a large number of students are tackling common engineering mechanics tasks, and where significant numbers are having difficulty with the concepts required to do these tasks, and how and when the online tutorials could be adapted to suit the students learning of those TCs.

<table>
<thead>
<tr>
<th>Threshold Concept</th>
<th>Suitable for Engineering Mechanics Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resultant of Forces, Moments, and Couples</td>
<td>Statics</td>
</tr>
<tr>
<td>3D Force Systems</td>
<td>Statics</td>
</tr>
<tr>
<td>Trusses</td>
<td>Statics</td>
</tr>
<tr>
<td>Friction in Machines</td>
<td>Statics</td>
</tr>
<tr>
<td>First and Second Moment of Area</td>
<td>Statics</td>
</tr>
<tr>
<td>Internal Forces in a Beam</td>
<td>Mechanics of Solids / Statics</td>
</tr>
<tr>
<td>Shear Force and Bending Moment</td>
<td>Mechanics of Solids</td>
</tr>
<tr>
<td>Stress and Strain Fundamentals</td>
<td>Mechanics of Solids</td>
</tr>
<tr>
<td>Combined Loading</td>
<td>Mechanics of Solids</td>
</tr>
<tr>
<td>Generalised Hook’s Law</td>
<td>Mechanics of Solids</td>
</tr>
<tr>
<td>Mohr’s Circle for Stress in 3D</td>
<td>Mechanics of Solids</td>
</tr>
<tr>
<td>Mohr’s Circle for Strain in 3D</td>
<td>Mechanics of Solids</td>
</tr>
</tbody>
</table>
Table 4. Final List of Threshold Concepts

<table>
<thead>
<tr>
<th>Threshold Concept</th>
<th>Suitable for Engineering Mechanics Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free Body Diagram</td>
<td>Statics</td>
</tr>
<tr>
<td>Trusses (two force members)</td>
<td>Statics</td>
</tr>
<tr>
<td>Centroids</td>
<td>Statics</td>
</tr>
<tr>
<td>Friction in Machines</td>
<td>Statics</td>
</tr>
<tr>
<td>Mechanics Fundamentals</td>
<td>Mechanics of Solids</td>
</tr>
<tr>
<td>Torsion</td>
<td>Mechanics of Solids</td>
</tr>
<tr>
<td>Shear Force and Bending Moment</td>
<td>Mechanics of Solids</td>
</tr>
<tr>
<td>2D Mohr’s Circle</td>
<td>Mechanics of Solids</td>
</tr>
<tr>
<td>3D Mohr’s Circle</td>
<td>Mechanics of Solids</td>
</tr>
<tr>
<td>Projectile Motion</td>
<td>Dynamics</td>
</tr>
<tr>
<td>Impulse and Momentum</td>
<td>Dynamics</td>
</tr>
<tr>
<td>Work and Energy</td>
<td>Dynamics</td>
</tr>
</tbody>
</table>

2.1.4 Developing Adaptive Tutorials Covering the Identified TCs

Once identified, the TCs were to be incorporated into the Adaptive Tutorials (ATs) - the web-based, interactive, adaptive elearning tools. The ATs were targeted at students undertaking engineering mechanics courses in their 1st and 2nd year of engineering. The objective of this tool was not only to target the teaching of mechanics concepts and theories, but to do so in an engaging, interactive, and interesting manner. Essential criteria for the tool included: visually engaging graphics, user-friendliness, high interactivity, and the ability to produce adaptive feedback in response to a learner’s actions and responses.

These ATs, based on “virtual apparatus” simulations, had to provide two advantages: (a) students could spend time working through the tutorials and get immediate feedback on how well they are able to understand and apply basic concepts and (b) teachers could track how students are performing in these tutorials in detail, and pinpoint areas where teaching needs to be adjusted. We implemented 12 ATs in the 1st and 2nd year mechanics courses to cover all the identified TCs. Figure 4 shows screenshots of some of the ATs developed and implemented.

![Figure 4. Screenshots of ATs in Engineering Mechanics](image-url)
implementation of these ATs at various universities on the students’ course satisfaction and overall performance.

The ATs are complex software modules and required careful design and production. As most of the aspects of the identified TCs could be visualised, the development of tutorials required much consideration to enable the effective communication of ideas by means of animation and simulation to provide visually and controllably rich content. The AT development process involved storyboarding, learning objective development, authoring, deployment, and teaching, as described below:

**Storyboarding:** It is the process of creating a series of illustrations that are to be displayed in sequence for the purpose of pre-visualisation of the tutorials. It determines the scope, context, layout, flow of questions, outcome of the student’s response and feedback for each question, the function and appearance of each required learning objective. This is the most time-consuming process as it needs to be as detailed as possible to cover and facilitate creation of the learning objectives. Teachers and educational software developers play their important role during this process. Figure 5 shows an example of a partial storyboard for Free Body Diagram AT.

![Figure 5. Initial Storyboard or Mock-up for Free Body Diagram Tutorial](image)

**Learning Object Development:** Learning objectives are the desired results to be achieved from attempting an AT. The learning objectives for each AT are determined from the course outline of a mechanics course. To achieve each learning objective, several Learning Objects (LOs) are designed using the Adobe Flash CS3 software. Then Adobe Flex Builder 3 software is used to develop various types of user-interfaces for an AT. After that by means of a programming language called Actionscript 3.0, the created LOs are programmed to be controllable from the Adaptive eLearning Platform (AeLP). The educational developers and other software developers are involved in this process.

**Authoring:** This is the process of creating the actual ATs by the teachers (academics) to cover a specific TC using the already created LOs or ‘virtual apparatus’ through the AeLP platform. Teachers are able to author, test and publish the AT through the AeLP platform. This process involves teachers, educational developers and other professional software developers. Figure 6 shows a screenshot of the authoring window for the Free Body Diagram AT.

**Deployment:** Once the required AT is designed and authored, it is deployed for use by the academic. The deployment involves embedding the tutorial into the Learning Management System (LMS) of the university for the relevant course. The teacher and the educational developer play their part during this stage.

**Teaching:** Once deployed, the teacher (academic) uses the AT in his/her course during their teaching and is able to adapt the AT and its content as s/he feels appropriate for students’ effective learning.
Throughout the term of the project, the ATs have undergone several development, design, and overhaul stages to improve their quality, content, and user-friendliness adaptable and compatible with the new version of AeLP platforms. To give the academics full flexibility and control over the behaviour of the ATs, all tutorials are built to be easily configurable using a simple eXtensible Markup Language (XML) configuration file, where a teacher can define different values to change the properties and behaviour of a tutorial. Figure 8 shows an example of the Free Body Diagram Tutorial and its corresponding configuration file.
2.1.5 Staff Training on using ATs

Effective implementation of the ATs at UNSW and other collaborating universities would not have been possible without adequate training for the mechanics educators from all the universities. This was achieved through four dedicated training workshops, which were open for attendance to academics at all Australian engineering faculties. A set of online training and support material including user manual were also provided.

Training Workshops: We organised six workshops for the engineering academics, as summarised in Table 5, to train them on using the ATs in their engineering mechanics courses at their respective universities.

<table>
<thead>
<tr>
<th>Workshop</th>
<th>Date</th>
<th>Location</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Project Workshop</td>
<td>07/06/10</td>
<td>UNSW, Sydney</td>
<td>16 academics</td>
</tr>
<tr>
<td>2. Public Workshop</td>
<td>01/12/10</td>
<td>UNSW, Sydney</td>
<td>25 academics &amp; general public</td>
</tr>
<tr>
<td>3. Orientation Workshop</td>
<td>08/12/10</td>
<td>UTS, Sydney</td>
<td>7 academics</td>
</tr>
<tr>
<td>4. Project Workshop</td>
<td>14/02/11</td>
<td>RMIT, Melbourne</td>
<td>26 academics</td>
</tr>
<tr>
<td>5. Project Workshop</td>
<td>22/07/11</td>
<td>UNSW, Sydney</td>
<td>11 academics</td>
</tr>
<tr>
<td>6. Final Project Workshop and Portal Launch</td>
<td>13/02/12</td>
<td>UNSW, Sydney</td>
<td>15 academics</td>
</tr>
</tbody>
</table>

All the workshops were attended by the Project team members and the mechanics academics from the collaborating universities. During the workshops, the participants were provided with orientation of the project components and a hands-on training on the use of AT. The training also provided the opportunity to the participants to author their own ATs and understand the complete life-cycle process of the ATs from creating them to modifying, running them for their courses and finally enhancing them as per students’ feedback or discarding them if needed. Figure 9 shows photographs taken during 2 of these workshops.
Figure 9. Staff Training Workshops at RMIT, Melbourne (left) and UTS, Sydney.

Other Training and Support Material:
Before and during the workshops, the participants were provided with relevant printed training and support material. This included introduction to the workshop and the ATs, a list of possible frequently asked questions (FAQs) with detailed answers, instructions on how to use the tutorials and what to expect from the online platform, a list of issues and troubleshooting steps, and contact details of the support officer in case if they have any problems in using the ATs afterwards.

Besides the workshops and training material, the project team members, including the educational developers, also provided online remote support and offline help through emails to the collaborating academic staff during their implementation and use of the ATs for their engineering mechanics courses at their respective universities. Appendix B provides more details and samples of the training and support material used during the project.

2.1.6 Implementing the use of ATs in Mechanics Courses in Engineering

In view of the fact that many 1st and 2nd year undergraduate students struggle with basic concepts in mechanics courses, the lead project university (UNSW) has been involved since 2006, in developing and piloting a series of Adaptive Tutorials (ATs) within the School of Mechanical Engineering (Prusty et al., 2009) using the Adaptive eLearning Platform (AeLP) developed at the Faculty of Engineering, UNSW (Ben-Naim et al., 2007). The effective use of ATs at UNSW generated encouraging results with improving students’ course performance and satisfaction as well as giving teachers control of the learning process.

After the successful implementation at UNSW, this project extended the use of ATs in engineering mechanics courses to several Australian universities. In this section, we discuss how we implemented these ATs at various universities through a Community of Practice (CoP) approach. We also describe, as a representative case study, an integrated approach to implementing the ATs at UNSW and providing a learning environment for engineering mechanics courses. We also discuss how we developed various tools, components, and strategies.

By the end of year 2011, 10 out of 12 proposed ATs were piloted across universities in different first and second year mechanics courses and were evaluated both pedagogically and for technical usability. The objective was to evaluate:

(I) how different cohorts of students, in different contexts, engage with the ATs,
(II) how the ATs benefit learning of the key TCs in mechanics courses in engineering, and
(III) how easily and effectively the teachers are able to use the information
2.1.7 Pedagogical Evaluation

As part of this project under the Community of Practice approach, we implemented several ATs at the member institutions during semester 1 of 2011. We gathered feedback from all students using the ATs in that semester.

We carried out two complementary analyses of these data: comparison of student feedback on one AT across the four different teaching contexts, and comparison of student feedback from one class using eight different tutorials. Through staged implementation of the ATs, the pedagogical evaluation aimed to demonstrate how the tools can help students learn basic theoretical concepts, improve performance in assessments and add to overall student satisfaction with the courses (Prusty, 2010; Prusty & Russell, 2011).

Specifically, we evaluated a comprehensive implementation of ATs for the 2nd year Mechanics of Solids course at UNSW from 2009 to 2011. We also compared implementation of the Free Body Diagram adaptive tutorial, across 4 different university contexts in semester 1 of 2011.

Implementing ATs at UNSW in 2nd Year Mechanics of Solids Course:
The objective of the lecturer in teaching Mechanics of Solids (MMAN2400) at the School of Mechanical and Manufacturing Engineering, UNSW was to implement strategies to (i) keep students’ interest and (ii) improve students performance, taking into account the variability in their background. This was achieved by taking the following actions: (1) introducing online ATs for learning and assessment, (2) introducing a variety of laboratory experiments conducted by students with limited supervision, and (3) providing block tests (tests on a block of study) at every 3 weeks interval. The various activities and assessments were delivered in a well-balanced time schedule to keep the students motivated and maintain their interest in the course.

A summary of the various assessments given in the course over the years 2009 to 2011 is shown in Table 6.

<table>
<thead>
<tr>
<th>Type of Assessment</th>
<th>Reason for Assessment</th>
<th>Marks (100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block Tests (x4)</td>
<td>Four tests to assess basic knowledge in Solid Mechanics over 3 week period</td>
<td>28</td>
</tr>
<tr>
<td>Adaptive Tutorials (x2, 4, or 8)</td>
<td>On-line assessment and feedback</td>
<td>13</td>
</tr>
<tr>
<td>Laboratory Experiment (x4)</td>
<td>Laboratory based group work using experimental rigs</td>
<td>19</td>
</tr>
<tr>
<td>Final Exam</td>
<td>Harder questions on the entire course</td>
<td>40</td>
</tr>
</tbody>
</table>

The number of ATs implemented increased from two in 2009 to four in 2010 and eight in 2011. The idea to include more number of ATs was mainly due to provide more and better understanding of the key TCs, through more varied practice, customised feedback and interactive exercises. Other assessment components remained constant in number over the three years. Earlier studies indicate that the AeLP system is an effective tool for management and assessment of AT exercises for large class sizes, such as the Mechanics of Solids (Prusty & Ben-Naim, 2010). Furthermore, the system is web-based and interactive, providing integration of technology into the course and an enjoyable means of delivering the tutorial exercises in a real life context. Using this system, the students were able to progress using both customised lesson adaptation and assessment of key concepts. The answers for both the adapted lesson content and practice questions targeted key
components. Each student had identical questions but with different numbers being generated using a parameterised approach. Generic feedback was provided to the questions at every stage in terms of the type of error made or general concept being misunderstood.

Methodology for Implementation at UNSW
For the 2nd year Mechanics of Solids implementation, we carried out a longitudinal and mixed method study (Creswell, 2003) in order to collect both qualitative and quantitative data concerning the effectiveness of the assessment strategies including the use of ATs. Student surveys are credible assessment instruments to assess and evaluate student outcomes in engineering professional skills (Olds, Moskal, & Miller, 2005). A quantitative survey instrument (see Appendix C) was designed and administered as part of the online ATs to the students of Mechanics of Solids course (n = 930) at the end of each AT. In 2011 semester 1, more detailed qualitative data collection was added, students’ written responses to open-ended survey questions. The collected data was analysed for:

- tracking student use of the ATs in different years
- collecting survey data from students about their perception of the tutorials
- comparing patterns of assessment results for various years

In each class in which they were used, the ATs were integrated with cycles of assessment and feedback. Typically, they were available online to all students and were made part of the formal assessment making it compulsory for all students.

There are two particular hypotheses that we aimed to test:

1. Effects of change in the number of Adaptive Tutorials (ATs) on the students’ performance. We hypothesise that students who do more ATs in any year will get better scores in all course components than those students who do fewer ATs.

2. Effects of change in the number of ATs on the high and low ability students’ performance. We expect that although ATs will have a positive effect on all students’ course performance, students with a history of poorer performance in earlier study (weighted average mark, or WAM, under 65%) will benefit significantly more than better performing students (weighted average mark 65% or over).

Data Sample and Context
The study involved a total of 930 undergraduate 2nd year engineering students of the Mechanics of Solids course at The University of New South Wales (UNSW) enrolled in years 2009 (n = 303), 2010 (n = 295), and 2011 (n = 332). The students from the year 2009 served as a baseline cohort for comparison purposes. All students came from the School of Mechanical and Manufacturing Engineering at UNSW and were enrolled as full-time students.

Survey Instrument
The Student Survey Questionnaire (see Appendix C) was designed to measure the effectiveness of ATs for students’ learning performance. Using a five-point Likert scale, questions included items concerning effectiveness, ease of use, and user-friendliness of the tutorials. The questionnaire consisted of 5 quantitative questions, where students were required to rate the effectiveness of ATs and 2 qualitative open-ended questions to allow students to write their comments about the effectiveness of ATs.

Data Collection Procedure
Survey Questionnaires were administered as part of the ATs towards the end of each AT and at the end of the course. Besides survey questionnaires data, students’ performance on the ATs were also automatically marked and recorded. Students’ course performance on other assessment components, e.g. Block tests, Lab experiments, and Final exam, was also
manually marked and recorded.

**Implementing ATs at Collaborating Universities:**
Many ATs, especially the Free Body Diagram (FBD) ATs, were implemented in several different university contexts. The Project Team had identified Free Body Diagrams as one of the more fundamental TCs in engineering mechanics. It is a subtle concept; obvious if you grasp it and a complete mystery if you do not. Acknowledging the significance of this concept in the study of engineering mechanics, others have sought to develop interventions that target students understanding of Free Body Diagrams (McCarthy & Goldfinch, 2010), and studies focussing on the underlying concepts of FBD’s are nothing new (Hestenes, Wells, & Swackhamer, 1992; Lane, 1993). However, providing helpful feedback to those for whom the concept is a blur remains a challenge, particularly when managing large 1st and 2nd year undergraduate classes.

In 2011 semester 1, four of the teachers in the project team used the FBD adaptive tutorial. Figure 10 shows an example of how the AeLP analysis tools can be used to generate comparisons of common mistakes across different student cohorts. This enables teachers to combine and share information on how well students are learning the core concepts and what mistakes they make. In this case the figure shows the FBD of a rear wheel drive car that is pushing into a wall. The green arrows on the top-right corner represent a possible correct set of answers. The four figures below with red arrows show the range of incorrect answers submitted by students with colour intensity of the arrows indicating their distribution; the darkest being the most common incorrect solution.

Table 7 summarises the characteristics of the 4 contexts in which the FBD AT was implemented. After completing the FBD AT, all students provided feedback on their experience via a survey questionnaire with multiple choice and open-ended questions (See Appendix C).
Table 7. Summary of Contexts used in FBD Analysis

<table>
<thead>
<tr>
<th>Context</th>
<th>University type</th>
<th>Course</th>
<th>Students</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>metropolitan, ATN</td>
<td>1st year engineering mechanics for civil engineers</td>
<td>mainly mid-year intake and repeat students (main school-leaver cohort does this subject in semester 2)</td>
<td>revision exercise, for token marks, end of semester, 57/95 completed AT</td>
</tr>
<tr>
<td>2</td>
<td>regional</td>
<td>1st year introduction to engineering (statics, dynamics and fluid mechanics)</td>
<td>mixed cohort, some with limited maths background</td>
<td>required students who failed initial test to take tutorials, optional for others, 29/126 completed AT</td>
</tr>
<tr>
<td>3</td>
<td>metropolitan Go8</td>
<td>1st year engineering mechanics for civil engineers</td>
<td>mainly mid-year intake and repeat students (main school-leaver cohort does this subject in semester 2)</td>
<td>throughout semester, 84/101 completed AT</td>
</tr>
<tr>
<td>4</td>
<td>metropolitan Go8</td>
<td>2nd year mechanics of solids for mechanical engineers</td>
<td>main cohort, students who have successfully completed 1st year engineering mechanics</td>
<td>integrated into teaching and assessment, 10-12% of course marks, 299/326 completed AT</td>
</tr>
</tbody>
</table>

2.1.8 Data Analyses

In this section, we present the analyses of the data collected from the use of ATs at UNSW as well as other collaborating universities showing the effects of the use of ATs on the students’ learning performance and course satisfaction.

Use of Adaptive Tutorials at UNSW

Data was collected from several successive student cohorts in 2nd year Mechanics of Solids at UNSW, while ATs were being introduced. The results show the effects on the students’ score performance and course satisfaction. The findings presented here result from both quantitative and qualitative analyses.

Performance Data

As a preliminary review of student performance, a snapshot of the improved performance of the students in Mechanics of Solids course in 2nd year Mechanical Engineering at UNSW is presented in Figure 11. Since the first iteration of the revised Mechanics of Solids course in 2007, student numbers have almost doubled, student satisfaction rate has increased and student performance has improved (Prusty, 2011).
Comprehensive statistical analyses of the student course performance were performed on the course score data collected over a period of 3 years from 2009 to 2011 Mechanics of Solids course. As mentioned earlier, the students in this course were assessed through multiple assessment components of which ATs formed only a sub-component. Analyses presented here cover the various assessment dimensions for this course. The same lecturer taught the course in all 3 years and the structure and content of the course, remained similar other than the number of ATs introduced.

**Effects of change in number of ATs on students’ performance**

Our first analysis was to test the hypothesis that more ATs improve performance in all assessment components. We investigated whether students who got a chance to do more ATs in any year were able to perform better and get higher scores in their Block Test (BT) component for that year as compared to students who did fewer ATs in other years. As mentioned earlier that students for the MMAN2400 course in earlier years did fewer ATs than students in later years, specifically, they did 2, 4, and 8 ATs in years 2009, 2010, and 2011, respectively. Because the BT component marks were slightly different for each year, we converted students scores for each year to percentages in order to normalise any possible systematic score differences. Table 8 shows the results for BTs.

<table>
<thead>
<tr>
<th>Student Groups</th>
<th>Total Students</th>
<th>Sum of Averages</th>
<th>Average or Mean Score (%)</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>304</td>
<td>169.71</td>
<td>0.56</td>
<td>0.035</td>
</tr>
<tr>
<td>2010</td>
<td>295</td>
<td>170.57</td>
<td>0.58</td>
<td>0.038</td>
</tr>
<tr>
<td>2011</td>
<td>333</td>
<td>202.24</td>
<td>0.61</td>
<td>0.041</td>
</tr>
</tbody>
</table>

Analysis of the BT components showed that students in the later years, where there were higher number of ATs involved, secured higher scores on the average, in their respective BTs, as we had expected. This is shown in Figure 12.
To see whether this improved performance difference in BTs in the later years is statistically significant, we performed an ANOVA test on the BT data for the three years. The results showed there was a significant difference in the BT scores for the years 2009, 2010, and 2011 ($F=5.11$, $p=0.006$), showing that students in the later years scored significantly higher than students in earlier years. This does not tell us though in which year they performed significantly better than other years. Further analysis indicates that there was no significant increase in the student BT scores from year 2009 to 2010 or from 2010 to 2011. But there was a strongly significant overall increase in the BT scores between the years 2009 and 2011 (Independent one-tail $t$-Test, $t_c=1.64$, $t=3.17$, $p=0.001$). This shows that students’ overall performance in their Block tests improved over the years with increase in number of ATs.

We then analysed the Labs experiment component to see if students had a similar pattern of Lab scores as in their BTs. Like BTs, due to a slight difference in the marks allocated to Labs for each year, we converted students Lab scores for each year to percentages to normalise any score differences and performed a one-way ANOVA test to look for any differences in the Lab scores. Though, numerically, students in 2010 seem to be doing better by about 2.5% than students in 2009, we found no significant difference in the Lab scores for students in the three years 2009, 2010, and 2011, as shown in Figure 13. This tells us that students Lab exercise performance does not seem to be affected significantly over the years regardless of the change in the number of ATs.
Next, we analysed the students’ score performance in the AT component for the three years in the similar way. Table 9 shows a summary of the results for the AT test component:

<table>
<thead>
<tr>
<th>Student Groups</th>
<th>Total Students</th>
<th>Sum of Averages</th>
<th>Average or Mean Score (%)</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>304</td>
<td>248.17</td>
<td>0.82</td>
<td>0.055</td>
</tr>
<tr>
<td>2010</td>
<td>295</td>
<td>249.61</td>
<td>0.85</td>
<td>0.028</td>
</tr>
<tr>
<td>2011</td>
<td>333</td>
<td>259.32</td>
<td>0.78</td>
<td>0.038</td>
</tr>
</tbody>
</table>

We first performed a one-way ANOVA test to find any significant differences in the AT scores. We found a significant difference in students AT scores for the three years ($F=8.73$, $p=0.0001$), as depicted in Figure 14.

This does not tell us though that how different were the scores, in what direction they are and for what years they are significant. To further investigate this we performed one-tailed $t$-tests on the AT scores for the three years. We found that there was no significant difference in the students’ AT scores for years 2009 and 2010 (independent one-tailed $t$-Test, $t_c=1.64$, $t=-1.77$, $p=0.04$), i.e. their performance in ATs was similar. However, students in year 2011 scored significantly lower in their ATs than both student groups in years 2009 as well as 2010 (independent one-tailed $t$-Tests, $p=0.01$ and $p=0.000001$, respectively), as illustrated in Figure 13. This result was not as expected and is in the opposite direction of the results for the Block tests, where students significantly performed better in year 2011 compared to earlier years. Finally, we investigated the students’ final exam component score performance over the three years. Table 10 presents the descriptive analysis results showing that like AT component scores, students in the later years, especially in 2011, scored lower in their final exam component, also depicted in Figure 15.

<table>
<thead>
<tr>
<th>Student Groups</th>
<th>Total Students</th>
<th>Sum of Averages</th>
<th>Average or Mean Score (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>304</td>
<td>167.03</td>
<td>0.551</td>
</tr>
<tr>
<td>2010</td>
<td>295</td>
<td>161.56</td>
<td>0.547</td>
</tr>
<tr>
<td>2011</td>
<td>333</td>
<td>170.62</td>
<td>0.511</td>
</tr>
</tbody>
</table>
Once again, to see whether this lower performance difference in the later years is statistically significant, we performed a one-way ANOVA test on the normalised final exam scores for the years 2009, 2010, and 2011. The results showed a significant difference in the scores ($F=3.12$, $p=0.04$), showing that students in the later years scored lower in their final exams than students in earlier years. To confirm that this significant difference was due to the lower performance in year 2011, we performed a set of $t$-tests. We found that there was no significant difference in the performance of students of years 2009 and 2010 (independent one-tailed $t$-Test, $t_c=1.64$, $t=0.198$, $p=0.42$), i.e. their performance in final exams was similar. However, students in year 2011 scored significantly lower than both students in years 2009 as well as 2010 (independent one-tailed $t$-Tests, $p=0.01$ and $p=0.02$, respectively). These results tell us that as opposed to our original hypotheses, the higher number of ATs did not necessarily have a positive effect on the students overall course performance.

**Effects of change in number of ATs on the high and low performing students**

Previous analysis and results presented assumed that all students’ basic level of understanding and ability is similar. However, according to Cognitive Load Theory, students’ level of expertise interacts with format of instruction to affect what instructional method may be best suited for each cohort of students (Kalyuga et al., 2003). The instructional format that is best for more knowledgeable students, may not be as good for less knowledgeable learners. We thus decided to do a separate analysis comparing low vs. high performing students scores to find out how their performance is affected by the use of ATs and other test components. The second set of hypotheses was aimed at finding these effects of change in the number of ATs on the high and low performing students’ course performance. The ability of students was based on their WAM scores, which is the average course performance of the students for all the courses completed in their previous semesters or terms before doing the Mechanics of Solids course. A high performing student was determined with a WAM score of 65 or higher. Table 11 presents the distribution of high and low performing students for the three years.

<table>
<thead>
<tr>
<th>Table 11. Distribution of students with a WAM Cut-off = 65</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Total Students</td>
</tr>
<tr>
<td>High Performing</td>
</tr>
<tr>
<td>Low Performing</td>
</tr>
</tbody>
</table>
To analyse the effect of change in the number of ATs on the course performance of low vs. high performing students, we first separated the low performing students from high performing students based on their WAM cut-off of 65. We then compared the students’ score performance on course assessment components. To save some space here, we combined the three assessment components (i.e. Block tests, Labs, and ATs), which were conducted before the Final exam, together and compared the combined before-final-exam score performances. The results provided a new understanding of how change in the number of ATs and intensity of learning environment was affecting the students’ learning performance. We found that the use of various ATs was having a different impact on high performing students course performance as compared to low performing students, as illustrated in Figure 16.

![Figure 16. Average Before-Final-Exam Scores for Low vs. High Performing Students](image1)

Specifically, we found that high performing students were able to improve their before-final-exam score performance significantly from year 2009 to year 2010 (shown by Independent one-tail t-Test, \( t_c=1.65, t=-4.41, p<0.001 \)) and from 2010 to 2011 (Independent one-tail t-Test, \( t_c=1.65, t=-1.97, p=0.02 \)). On the other hand, the low performing students’ score performance for before-final-exam component was affected differently in that it did increase from 2009 to 2010 significantly (Independent one-tail t-Test, \( t_c=1.64, t=-4.07, p<0.001 \)) but for 2010 to 2011, their score performance did not improve. This result clarifies that in fact only the high performing students may actually be getting the benefit of increased and challenging number of ATs and that it is the low performing students who are being negatively impacted by the extended number of ATs (8 in year 2011). We then performed a similar analysis of the low and high performing students for their Final exam component performance only. Once again, we found that the use of various number of ATs was having a different impact on high vs. low performing students final exam score performance, as illustrated in Figure 17.

![Figure 17. Average Final Exam Scores for Low vs. High Performing Students](image2)
For the Final exam component, we found no statistically significant difference in the high performing students score performance (shown by one-way ANOVA, $F=1.79$, $p=0.16$), which tells that any variance in the number of ATs or complexity of the learning environment did not affect the high performing students learning performance. While for the low performing students, their final exam scores varied significantly (one-way ANOVA, $F=7.28$, $p<0.001$).

Specifically, we found that though for 2010 students final exam score improved a little as compared to 2009, their score performance for the year 2011 however, when there were the highest number of ATs implemented, decreased significantly compared to both the years 2009 and 2010 (independent one-tailed $t$-Tests, $p=0.01$ and $p<0.001$, respectively).

Further, we analysed the low and high performing students’ total course score performance in the similar fashion and results were very similar, as illustrated in Figure 18.

![Figure 18. Average Total Course Scores for Low vs. High Performing Students](image)

It is very clear from Figure 17 that there is no significant difference in the high performing students overall course performance (left), while there is significant difference in the low performing students’ total course scores (shown by one-way ANOVA, $F=6.46$, $p=0.001$). Independent $t$-Tests confirmed that low performing students were able to improve their course performance from 2009 to 2010 ($t_c=1.64$, $t=-3.37$, $p<0.001$), while their course performance was significantly impacted negatively from 2010 to 2011 ($t_c=1.64$, $t=2.72$, $p=0.003$).

One final analysis that we performed in order to compare the effects of the number of ATs on the low vs. high performing students, was to see how students have performed in the MMAN2400 course against their own individual WAMs. Figure 19 illustrates students course performance against their WAMs.

![Figure 19. Students’ Average Course Scores against their Individual WAMs](image)

As visible from Figure 19, for all the three years, all high performing students on the average, were able to get a higher course score against their own WAMs, which confirms that the assessment strategies used in the course, especially the use of ATs, have helped...
high performing students improve their course performance significantly. On the other hand, the low performing students course performance against their WAMs is different, in the different years. For both the years 2009 and 2011, when there were either too few number of ATs were involved (2009) or too many number of ATs were implemented (2011), the low performing students, on average, were not able to improve their course performance against their previous WAMs. While in 2010, when a moderate number of ATs were implemented in the course, the low performing students were able to enhance their course score against their previous WAMs.

Further investigation of the low performing students scores revealed that for the years 2009 and 2011, only about 40% and 34% of the low performing students respectively, were able to improve their overall course score against their individual WAMs. While for the year 2010, a significant 57% of the low performing students were able to improve their course score against their individual WAMs, as shown in Figure 20.

![Figure 20. Percentages of Low Performing Students able to improve against their WAMs](image)

**Student Feedback on Adaptive Tutorials**

The findings presented here result from both quantitative and qualitative analysis of student survey responses on their use of the tutorials.

**Feedback from 2nd Year Mechanics of Solids Students**

Figure 21 shows a snapshot of survey results from MMAN2400 Mechanics of Solids in 2009, showing that students would like to see many more ATs and that trend continues every year. It was this feedback that led to introduction of increasing numbers of ATs in 2010 and 2011.

The 2010 and 2011 surveys confirm that students believe the tutorials are helpful for their learning. Typical student comments:

- “Excellent tutorial. The tutorial has really furthered my knowledge of this topic. I would really like to see more of these tutorials. This tutorial has taught me the basic concepts and ideas I will need to undertake questions of a similar nature in the text book. Very helpful”
- “This tutorial was clear and helped me understand the concepts of Mohr’s circle to a much better degree than before. I highly recommend it.”

In 2011, the survey questions presented with the final two of eight ATs used during the semester specifically asked students whether the ATs had helped them learn key concepts. The majority responded positively, as shown in Figure 21. To find out how these responses relate to students’ performance in the only subsequent assessment, the final exam, we separated the group into two equal parts – half scoring 50% or below in the final exam and half scoring above 50%.
Qualitative Analysis of the Results
A thematic analysis of student feedback collected after each tutorial identified patterns of positive and negative comments that varied across the tutorials. The text responses were coded manually using NVIVO software. Table 12 summarises the number of comments on each of the major themes identified. Column 1 lists the themes, with negative comments shaded pink and positive shaded blue. The shading in the body of the table ranges from red for the most frequent themes to blue for least frequent. Student comments on this AT have already been used to provide an updated version, showing the value of the teacher feedback that this AeLP platform provides.
After the multiple-choice question on whether the ATs helped with key concepts, students were invited to enter a text comment on why. The analysis of these comments shows similar types of comment from better and poorer performers in the final exam, although the better performers made more and longer comments about how the ATs helped. The comments from better performers indicate that they are already familiar with the concepts. Typical examples are:

- “It requires us to use content already learned.”
- “Method of joints is used so regularly it was good for a refresher”
- “Easy and step by step.”

Poorer performers, however, more often note that they are beginning to forget some things, for example:

- “Method of joints, did it so long ago I almost forgot.”
- “It was a good brush up on things I’d started to forget.”

There are hardly any comments indicating that the tutorials were challenging, and many indicating explicitly that they were easy, or easy to follow. The reported time spent on these two tutorials, and the marks scored may also be significant. Figure 23 shows these data for one of the final block ATs in 2011.
Feedback from Students using the FBD AT across four Contexts

Table 13 describes number of students comments about the effectiveness of ATs for learning and their mean scores.

<table>
<thead>
<tr>
<th>Context</th>
<th>A : FBD-effective</th>
<th>B : FBD-ineffective</th>
<th>mean scores for students who completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context 1</td>
<td>22</td>
<td>30</td>
<td>33</td>
</tr>
<tr>
<td>Context 2</td>
<td>12</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Context 3</td>
<td>28</td>
<td>24</td>
<td>42</td>
</tr>
<tr>
<td>Context 4</td>
<td>145</td>
<td>58</td>
<td>61</td>
</tr>
</tbody>
</table>

The text comment patterns correspond well with the multiple choice responses showing the reasons given for effectiveness, ineffectiveness, and suggestions for improvements. A summary of these comments is presented in Table 14.

Table 14. Reasons given for effectiveness, ineffectiveness or suggestions for improvement

<table>
<thead>
<tr>
<th>Reason</th>
<th>FBD effective</th>
<th>FBD ineffective</th>
<th>FBD how to improve</th>
</tr>
</thead>
<tbody>
<tr>
<td>engaging</td>
<td>31</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>immediate feedback</td>
<td>23</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>understanding concepts</td>
<td>19</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>simple or easy to interactive</td>
<td>17</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>develops skills</td>
<td>12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>self-paced</td>
<td>10</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>saves time</td>
<td>9</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>flexible</td>
<td>8</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>revision or reinforcement</td>
<td>6</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>visual</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>real or practical</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>scaffolding</td>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>prefer other methods</td>
<td>0</td>
<td>23</td>
<td>1</td>
</tr>
<tr>
<td>confusing or hard to understand</td>
<td>0</td>
<td>22</td>
<td>10</td>
</tr>
<tr>
<td>not enough feedback</td>
<td>0</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>hard to use</td>
<td>0</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>frustrating</td>
<td>0</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>pointless or useless</td>
<td>0</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>time consuming</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>mistakes in tutorials</td>
<td>0</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>unfair</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>unengaging</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Students in contexts 2, 3, and 4, on average, found the FBD ATs helpful for learning. Both 1st year civil engineering cohorts were less enthusiastic in their comments than the other two contexts. The most positive response was from context 4 – a large cohort in their 2nd year of study, where the tutorials were integrated into the course assessment.

In context 1, students were offered the ATs as a revision exercise for nominal extra marks, whereas in context 3 the ATs were integrated with formal assessment.

The analysis of student comments corresponded well with the multiple choice responses, which indicates that those who chose to comment are a typical sample (i.e. not biased to those who liked or disliked the tutorials). Those students who found them helpful indicated that they were more engaging (e.g. used words like ‘fun’ and ‘interesting’). Immediate feedback seems to be particularly helpful. Some students did not find them helpful and said they preferred other methods, found them confusing or hard to understand, or wanted better feedback. Several of these students mentioned specific areas of the tutorials that could be improved.

Overall, the student perception of effectiveness corresponds with the scores for the tutorial. Not surprisingly, more of the 2nd year students (context 4) both found the tutorials helpful and gained higher scores on average.

This analysis indicates that, for this particular AT (on FBD), the subject and cohort appear to be more influential than the mode of use or the type of university. Entry qualifications are similar for both cohorts – ATAR>91. The 1st year regional university class and the large 2nd year metropolitan university classes in mechanical/general engineering both gave more positive responses. However, the 1st year ‘remedial’ context users score poorly, though they appreciated the tutorials.

The civil engineering student cohorts (contexts 1 and 3) both included a significant proportion of students who would be repeating the subject. The results may therefore indicate that those students are struggling with basic TCs underlying the free body diagram AT, which had not been catered for in the initial tutorial feedback. The frequent comments that the tutorial was confusing, hard or didn’t give enough feedback support this view. Further analysis of the solution trace graphs for these students may show exactly where there is a need for more detailed feedback.

Overall, for the FBD AT, we were able to show:
• The tutorial works well for 2nd year students, where it is reinforcing earlier learning and is integrated with assessment.
• 1st year student cohorts with a significant proportion of repeating students need more scaffolding and detailed feedback than the tutorial currently provides.

2.1.9 Discussion of the Results

The findings from the analysis of the Student Survey Questionnaire combined with the teachers surveys and interviews and the students’ course score performance have provided a complex mixture of information to help evaluate the Adaptive eLearning project and continue its implementation for engineering courses. The purpose of this research was to answer questions concerning the validity and effectiveness of the learning and assessment tools, especially the use of ATs, to determine their impact on students learning of the TCs and overall course performance.

Effects of change in the number of ATs on the students’ performance:
Students in the later years, where there were higher number of ATs (ATs) involved, secured higher scores on the average, in their respective Block Test (BT) components, as we had originally expected. This improvement in the BT scores could be attributed to more ATs being incorporated immediately before BT components, giving students a better understanding of the core course concepts before they attempt their BTs.

Regarding the students’ performance in the AT component itself, we found that students in year 2011 scored significantly lower in their ATs than both student groups in years 2009 as well as, which is not what we originally expected and is almost in the opposite direction of the results for the Block tests, where students significantly performed better in year 2011 compared to earlier years. We suggest what may have happened here is that students actually got overloaded and may have been presented with too many ATs. It appears that at some point having too much information to deal with becomes detrimental to learning. This can be explained by the redundancy effect, where having to process extra non-essential information is not neutral but actually has a negative effect on learning (Chandler & Sweller, 1991). It appears that including four ATs in the course supplements students’ learning, but increasing the number to eight ATs may indeed be too many for students to benefit from. Similarly, the Final exam scores in 2011, when there were many more ATs, were also significantly lower than in previous years. These findings provide further support for a redundancy effect (Chandler & Sweller, 1991), where having to deal with extra non-essential information may lead to less effective learning. More is not always better and at some point we may land up overloading students’ limited cognitive capacities. It appears that we reached this threshold when including 8 ATs in the course.

Effects of change in the number of ATs on the high and low performing students:
When we compared the course performance of high performing students (having a WAM >= 65) with the low performing students, we found that the use of various ATs was having a very different impact on high versus low performing students’ performance. Specifically, we found that high performing students were able to improve their Before-final-exam score performance between the years 2009 and 2011, while, the low performing students’ Before-final-exam performance did increase from 2009 to 2010, but not for 2011. This result clarified that in fact only the high performing students may actually be getting the benefit of increased and challenging number of ATs and that it is the low performing students who are being negatively impacted by the extended number of ATs (8 ATs in year 2011). These results are in line with an expertise reversal effect (Kalyuga et al., 2003), where the instructional format that is best for more knowledgeable learners, may in fact, be worse for less knowledgeable students. Eight ATs was still manageable for the high performing students, but became too much for the more novice students. The high performing students had more knowledge in the domain and so were able to deal with and benefit from the extra ATs. In contrast, at some point too much extra information became cognitively overloading for the low performing students. Interestingly, for the year 2010, where a
moderate number of ATs (4 ATs) were implemented, the low performing students showed significant improvement in their learning and hence in their course performance, compared to the previous year. It appears that dealing with too much extra information has led to a redundancy effect for the low performing students and may lead to less effective learning (Chandler & Sweller, 1991; Paas, Renkl, & Sweller, 2003). So, keeping the extra information to be processed by the students to a moderate level may enhance their learning performance, while too much extra assessment may cause an unmanageably high cognitive load.

Similarly, for the Final exam component as well as the total scores, the low and high performing students’ performances differed significantly in that for these components the high performing students’ performance did not change much for the three years but the low performing students’ performance fluctuated significantly. In particular we found that low performing students performance for the year 2011, when there were highest number of ATs implemented, decreased significantly as compared to the year 2010. On the other hand, in 2010 when there were moderate number of ATs involved, their score performance showed improvement compared to previous year of 2009. As with AT scores, this result emphasises the fact that the low performing students are being negatively affected by the increasing number of ATs in the year 2011.

The low performing students appeared to gain from the 8 ATs at an individual practice level and so performed better in the BTs. The extra practice for each module seemed to help them when they were assessed straight afterwards. However, when it came to the final exam, and its assessment of the whole semester’s work, there was just so much extra information to consider that these low performing students became cognitively overloaded.

Student Survey Data
The feedback from students in survey questions and comments about the ATs indicates that students enjoy doing them and feel they are helpful for learning – whether or not they did well in the final exam or not. The fact that scores for the AT activities were fairly high, as a percentage, and that students in general found them easy to follow may mean that they are not sufficiently challenging for some of the students.

The greater number and detail of comments from students who did better in the final exam perhaps reflects better metacognition of learning processes. In general, these students indicated that they used the ATs to practice and refresh material that they were already familiar with. The students who performed poorly in the final exam offered fewer comments and often indicated that they had forgotten the concepts. So for them, the cognitive load of the additional ATs would be higher, and may led to poorer retention in long term memory.

In 2011 semester 1 the solution trace graph tool was not fully implemented in a form that the teachers were able to use. However in 2012, it will be possible to analyse in more detail the solution trace graphs from the FBD and other ATs, in relation to the student scores and the student feedback. The results will guide further adaptation of the feedback given within the tutorials, in particular for 1st year students, who may be struggling with threshold concepts that we have not fully identified.

This exercise has shown the value of taking a CoP approach to piloting and evaluating the ATs over different learning contexts. It enabled us to identify patterns that inform us how and when the tutorials can be used and how to adapt the feedback given to students at different levels.

Teacher Experience
Data on the teacher experience of using the tutorials came from semi-structured interviews with the four teachers who deployed the ATs in their courses, and from project team discussions on use of the ATs.
Before the start of 2011, the teachers agreed to deploy the same versions of the tutorials, but used differently in different contexts. Although they were able to adapt the tutorials the team agreed to leave them unchanged and deal with student responses through other teaching. This enabled a comparative analysis across four different student groups using the same AT.

Four interviews with project team members found that:

- Teachers believed the ATs had helped their student learn, even when the scores were poor.
- None of the teachers had been able effectively to use the solution trace graph tool to track student responses in semester 1 of 2011. The tool was not fully ready for use at that point. Also some said they needed more support in finding out how to use the analyser tool and had not had enough time to explore its potential.

**Improving effectiveness**

Students have approved of the general scheme for using ATs, but have requested more and better feedback. We will improve the ATs to respond to these requests.

We have identified the potential for adding too many ATs to produce cognitive overload in students. One possible response is to keep the number of ATs to a moderate number, say four as in year 2010, so all students would have the capacity to improve their understanding of basic mechanics concepts and hence their overall score performances. Another possible response is to adjust the overall conceptual and design complexity of the ATs. Simpler ATs may increase students’ understanding and result in better performance.

The varying capabilities of students means we must carefully consider the way in which we use the ATs, ie. when and how and how often. For more able students, it is less critical how much new information we include than it is for students who are struggling and so can be easily cognitively overloaded. We want to provide strugglers with extra support, practice and examples, without overloading them with too much superfluous non-essential or redundant information for each sub-topic. In this context, 4 ATs seemed to be the right amount to keep both cohorts of students performing well. A potential solution could be to give the higher performing students extra ATs but only give the lower performing students 4 ATs that focus on the topics they traditionally perform worst in. This instructional strategy that is guided by the expertise reversal effect, needs to be applied with caution as it has the potential to widen the gap between the low and high performing students if not applied appropriately.

We also need to provide more flexibility to adjust to specific learning needs. Less knowledgeable students may need more activities of a routine nature and exposure to many worked out problem solutions in order to gain understanding, but a more knowledgeble student who has understood a concept from its presentation, and is already capable of applying the concept to complex problems should not be forced to complete extensive routine example problems in order to gain marks. ATs provide the possibility of resolving these conflicting student needs, but it will take time and skill to realise this.

Nevertheless, it may be possible to adopt a flexible approach in which all students work through just a few ATs of a routine nature in order to ensure basic understanding. Then students who have already understood a concept can be offered more challenging ATs; where they practice applying the concept to complex problems, rather than being forced to do additional routine examples in order to gain marks that they find easy to achieve, as indicated by Figure 16. It may not be a simple question of helping students across a single conceptual threshold and stopping there. ATs have the potential to give students practice with using a concept for increasingly challenging applications that take them well beyond the threshold, to a point where the concept is integrated into their view of the world around them.
2.1.10 Developing Web-Based Community Portal featuring ATs

One of the important project outcomes was to develop and provide a web-based community portal where all the developed ATs were to be featured, accessible to all the universities within Australia for their use, along with published pedagogical research on creating and using them. In that regard, a web-based Community of Practice for Mechanics in Engineering portal, “Adaptive Mechanics”, has been developed, which was officially launched during the final project workshop on 13th February 2012. The portal can be accessed via its web address: http://adaptive-mechanics.eng.unsw.edu.au.

The main objective of developing the portal was to provide access to all the ATs to the academics who are engaged in teaching mechanics courses in engineering. Figure 25 is a screenshot of the home page of the portal showing various ATs organised into different categories.

The design and development process of the web portal took a lot of thinking in terms of organising the content in a way that is easily accessible and usable for the users. Special attention was given to the development of the ATs and their integration into the portal. The feature-rich portal has been developed using the Joomla, which is an open source content management system (CMS) that helped streamline and simplify the development process. The community web portal has been hosted on UNSW’s data centre and servers.

To access an AT, the user will visit the home page of the portal and select an AT listed under different categories, e.g. Statics, Dynamics, or Solid Mechanics. On selecting an AT, the user will be taken to that AT’s home page, where the user can either run the demo for the selected AT, or alter and/or adapt the AT. Appendix E shows some screenshots from the portal showing an example AT (Free Body Diagram) and its demo pages illustrating the feedback windows.

The CoP web portal also features many other supporting materials to help the academics understand various components of the portal and how to use them. About page of the portal provides a brief introduction of the project, names of the seven universities involved in the project, the project team members and their brief bios. It also includes the research publications that formed the part of this project. This project report can also be accessed through this page of the portal. The Wiki page is the area where academics can get information on how to use the portal content. A user manual on how to access the authoring area and how to author new ATs is also accessible through this page. Appendix E shows some more screenshots of some of these components to illustrate how they look.

2.2 Achievement of Projected Outcomes

Overall, the project has met all the outcomes as described in Table 1. Given the scale and complexity of the factors that may potentially affect the learning of TCs in engineering mechanics, establishing a definitive solution to the overall problem, especially with large class sizes, is an unending challenge. The outcome of this project presents one effective option for moving forward with the help of e-learning tools such as ATs. Continuing work in developing effective e-learning methods and designing more ATs can be shared amongst the Community of Practice (CoP). This includes the ongoing use, enhancement, evaluation, and promotion of the CoP web-portal (http://adaptive-mechanics.eng.unsw.edu.au) in coming year.

As outlined above, the project also included pedagogical evaluation of the ATs, through quantitative analysis of student performance in assessments, along with quantitative and qualitative analysis of student feedback via surveys.
In the following, the project outcomes and methods used to address them are discussed.

2.2.1 Developing a set of ATs covering identified core TCs

In order to help students grasp TCs effectively, especially in large classes sizes with the realities of student-teacher ratios, 12 ATs were proposed to be developed and integrated into the community portal. In consultation with engineering academics, 12 different TCs were identified in engineering mechanics (see Table 4) and 12 ATs successfully developed, each covering an identified TC. The 12 ATs were developed with the objective to provide visually engaging graphics, user-friendliness, high interactivity, and the ability to produce adaptive feedback in response to a learner’s actions and responses. The complex development process of the ATs consisted of storyboarding, learning object development,
authoring, deployment, and teaching. The ATs also underwent several design and development revisions for quality improvement throughout the project time.

All the developed ATs were then integrated into the community web-portal (http://adaptive-mechanics.eng.unsw.edu.au), making them accessible to all the members of the Australian universities. The ATs were used by the engineering mechanics academics through the community portal at several institutions. The data generated during their use by students and teachers over a period of 3 years was collected and analysed for evaluating the impact of these ATs on students’ overall performance and course satisfaction. The results and findings from these analyses have provided a better understanding of the impact and effective implementation of the ATs to improve students’ understanding of the TCs.

2.2.2 Incorporating ATs into curricula

One of the objectives of establishing a Community of Practice (CoP) for mechanics in engineering is to enable widespread use of this new eLearning technology based on ATs and support the engineering academics at various higher education institutions in helping their students learn the TCs. To achieve this we developed a range of ATs covering Statics, Dynamics and Solid Mechanics topics of mechanics courses in engineering and integrated them into the community web-portal to help both the students and teachers for use and reuse. Several of these ATs were incorporated at the lead-university (UNSW) into the curricula of Engineering Mechanics 1 and Mechanics of Solids 1 of 1st and 2nd year courses in Mechanical Engineering over last five years and the results have been very encouraging, showing students overall improved performance.

Additionally, as a pilot implementation of these ATs at partner universities, we demonstrated the use of one AT and incorporated the Free Body Diagram (FBD) AT in four different contexts at partner universities. The FBD concept was identified by the project team as one of the more problematic TCs in engineering mechanics. Hundreds of students in 1st and 2nd year of engineering mechanics courses completed the FBD tutorial at these universities. After completing the tutorial, all students provided feedback on their experience via a survey questionnaire with multiple choice and open-ended questions (See Appendix C). The results of the analyses of students’ comments, and their course performance showed improved results, higher course satisfaction and increased interest in such ATs for other concepts.

In the future, we expect more engineering mechanics academics to be using the community web-portal and incorporating other available ATs into their course syllabi. In addition to modifying and enhancing the content and responses plus feedback to students within the existing ATs, the academics will also be able to author new ATs on any other potential TCs and share their feedback through the common portal platform with other community members.

2.2.3 Staff training workshops

Six formal workshops and three seminars in total were organised by the project team as compared to two workshops originally proposed. Table 5 in Section 2.1.5 listed the workshops conducted throughout the project period.

The workshops and seminars have proved to be the most effect training methods to academics of all Australian engineering faculties as they have provided live training, demonstrations, and hands-on experience to the academics on the creation, use, and implementation of ATs through the community portal into their courses. Several dozens of the engineering academics from various higher education institutions attended these training workshops and provided their feedback as well on how to improve the ATs and the community portal.

As an ongoing training process, the project team’s technical members from the lead-
university (UNSW) will always be available to provide any required training or online support to the academics from various member universities, if there are any issues related to the use and/or implementation of the ATs into their respective courses. Besides, as a Community of Practice (CoP), the experiences shared by the academics though the community portal will also serve as additional reflection on the effective implementation of the ATs for other member academics.

2.2.4 Developing a web-based community portal

One of the major project outcomes was to develop a web-based community portal where all the ATs developed are featured and accessible to the academic community (and to any other engineering educator for other related courses) for their use along with the essential information on how to use them. This was achieved through the development of the Community of Practice for Mechanics in Engineering Portal (http://adaptive-mechanics.eng.unsw.edu.au). This web-based portal is now available to the community and incorporates all the ATs proposed and developed throughout the project and provides all the necessary information on using them.

2.2.5 Support material for teachers

In order to support the engineering academics in their effective use and implementation of the community portal and the ATs into their respective courses, a comprehensive support material in the form of a user manual was developed. This manual is accessible by the community members through the Community of Practice for Mechanics in Engineering Portal (http://adaptive-mechanics.eng.unsw.edu.au).

2.2.6 Pedagogical evaluation

The pedagogical evaluation of the AT use as described above in Section 2.1.7 generated analyses that are suitable for publication as conference and journal papers, and that will also be available via the project’s Community of Practice web portal.
Chapter 3: Dissemination

3.1 Activities and Outcomes

This project was dissemination-oriented by its very nature as we sought to establish a Community of Practice revolving around this pedagogical e-learning technology through the development of ATs and the community of practice web-portal (http://adaptive-mechanics.eng.unsw.edu.au) that hosts the ATs. The project team has conducted six formal workshops and three seminars in total, compared to two workshops originally proposed.

The first project workshop was held at The University of New South Wales, Sydney, in June 2010 and was attended by 16 mechanics engineering academics and project team members. The objective of the workshop was to introduce the project, the e-learning technology i.e. the ATs using the AeLP, and the proposal to target TCs, and to get the participants to generate ideas regarding the targeted TCs in foundation mechanics courses in engineering. The objective was also to brainstorm about what it means to have a Community of Practice for Engineering Mechanics in Australia and beyond. During the workshop session, the participant academics were presented with a list of proposed engineering mechanics TCs (see Table 3) and identified several key TCs, which were assigned to selected academics to be responsible for the development of ATs on each TC. The development methodology of the ATs and instructional strategies to be incorporated in them were also derived and decisions were taken as to which ATs will be used in what semesters and what universities.

A public workshop was held at The University of New South Wales, Sydney in December 2010 with the objective to introduce the project and describe the ATs to academics and general public. About 25 participants attended the workshop and watched a hands-on training demonstration on the use of ATs. This public workshop helped attract a lot of interested academics who liked the idea and wanted to use the technology in their teachings.

The workshop run at the 2010 Australasian Association for Engineering Education Conference at the University of Technology Sydney in December 2010 focussed on providing an orientation of the project and the ATs to the academics and conference participants. The participants came from 7 different higher education institutions in Australia. They watched a live demonstration on the use of ATs and had a hands-on experience of creating and using a sample AT. They were also introduced about the community of practice (CoP) approach concerning the use of ATs in engineering mechanics. This workshop generated a lot new ideas and attracted participants and interested academics.

Another project workshop was held at RMIT University, Melbourne in February 2011 with the objective to inform the community about the project and the novel e-learning technology and to invite new academics to have a hands-on experience on developing the ATs using the Adaptive eLearning Platform (AeLP). The participants were encouraged to develop, deploy, and adapt the tutorials by applying the adaptive elearning approach. The workshop was attended by 26 academics coming from 8 various higher education institutions. The participants were provided project information sheets, handouts, and other introductory material about the project. As all the project team members were also present in the workshop, an update on the project progress was also provided and details of new ATs and the community web-portal were discussed. Evaluation and implementation strategies to use ATs in different institutes and courses and to integrate the ATs in various Learning Management Systems (LMS) were also discussed.

The workshop held in July 2011 at The University of New South Wales, Sydney was attended by about 11 academics and was focussed on the providing and sharing the information amongst the community about their use of the ATs and the AeLP during the first semester of...
2011. The project team members shared their experiences with the community about the difficulties and successes they experienced during the first implementation of the tutorials at partner universities. Most of the academics told that with the use of ATs in their teachings, students’ overall failure rates have reduced and the distinction and high distinction rates improved compared to previous years. They also shared that ATs have helped save time in detailed teaching of the complex TCs. The academics suggested though to introduce a demo/trial example in the ATs to guide students about what is expected and start using the ATs as early in the course as possible. Overall, the information shared by the community members and discussions held during the workshop generated many good ideas that helped improved several design and implementation issues of the ATs.

The final project workshop was held in February 2012 at The University of New South Wales, Sydney with the objective to provide training to the academics and members of the CoP on using and reusing the final set of ATs for their courses and the final version of the Community of Practice for Mechanics in Engineering Portal (http://adaptive-mechanics.eng.unsw.edu.au). The portal, which was one of the deliverables of the OLT project, was also officially launched during the workshop in the presence of all the team members. About 15 engineering mechanics academics and project team members attended the workshop. Support material including a set of frequently asked questions (FAQs), a user manual, and a wiki page were also provided to the participants. Figure 26 shows a couple of photos taken at the final workshop.

In addition to the structured workshops, some invited interactive seminars were also held at various international higher education institutions. These were held at Szczecin University of Technology (Poland), University of Liege (Belgium), and KIIT University (India) in November 2010, December 2010, and January 2011, respectively. The objective was to disseminate information and introduce the higher education institutions beyond Australia to the adaptive elearning technology and ATs and how they can help in improving students’ learning in mechanics courses. Another invited seminar was held at Learning and Teaching at UNSW (Sydney) in May 2011.

The project team has also made six conference presentations at five different conferences. Conferences have been found to be the most effective means of reaching a wide audience within the engineering education community. The presentations and research publications made during the project period at these conferences served as important dissemination activities where all the research findings and information stemming from this work were discussed. Besides these conference publications, a book chapter has also been published related to the research. Appendix A provides details of all the publications made related to the project. At several of the conference presentations, the project information was distributed in the form of posters, project information sheets, and brochures (see Appendix B for a sample of the distribution material).
In addition to the formal workshops, seminars and conference presentations, the project also made use of a website for dissemination of project information, updates, and obtaining feedback on the project and on the use of ATs. The website was available for access to project members and other stakeholders throughout the project duration at [www.adaptiveelearning.com/educational-portals/mecheng](http://www.adaptiveelearning.com/educational-portals/mecheng). All information on this website was later integrated into the project’s dedicated online Community of Practice Mechanical Engineering portal [http://adaptive-mechanics.eng.unsw.edu.au](http://adaptive-mechanics.eng.unsw.edu.au). This portal remains the first point for publishing findings, information, content researched and developed during this project and beyond. Besides, informal measures of dissemination, for example, lunchroom debates and discussions during conference breaks have also proved to be very useful.

### 3.2 Usable Project Outcomes

Right from the beginning, the project intended to develop approaches and learning tools that can be used by others as they are, or adapted to other disciplines and applications. The most immediately useable project outcome is the online Community of Practice for Mechanics in Engineering Portal ([http://adaptive-mechanics.eng.unsw.edu.au](http://adaptive-mechanics.eng.unsw.edu.au)). The portal incorporates 12 ATs covering TCs in engineering mechanics. All academics and students in engineering mechanics in any Australian university are invited to use the portal and the ATs to effectively enhance students’ learning of the TCs. As mentioned earlier, we have initially delivered 12 ATs with this web-based portal, but the development of new ATs and enhancement of the existing ones and the community portal itself will be an ongoing process. Any enhancements made, new results achieved, and feedback received from the students and the teachers will continue to be disseminated through engineering education, for bodies such as the Australasian Association for Engineering Education (AAEE).

All the ATs and other tools like the AT-analyser developed through the project and available via the community portal can also be used by other interested academics in the engineering areas other than mechanics, for example in fluid mechanics. The existing ATs and the AT-analyser are fully customisable and can be adapted as per the requirements of other courses.

The demonstration tutorials and training videos created for the current OLT project can also be used by any interested academics in engineering mechanics. The content of the videos was directed by the project team and created under a creative commons license. They can be accessed through the Community of Practice for Mechanics in Engineering Portal ([http://adaptive-mechanics.eng.unsw.edu.au](http://adaptive-mechanics.eng.unsw.edu.au)). The videos can also be accessed through the engineering mechanics YouTube channel. More of such demonstrations and videos can be created and posted in the future on a range of topics related to engineering mechanics. Any academics who wish to access an offline copy of these videos are invited to contact the report’s authors.

One of the most valuable project outcome generated through the current research is the data on students’ ATs usage, its analyses (both qualitative and quantitative), and the research findings. These analyses and results can be used by any engineering academics to fully understand the impact of an elearning technology such as the ATs and how to effectively use them in order to improve students’ overall learning performance and satisfaction. Because a significant amount of data generated through the project is still available, more analyses can be performed on various other dimensions, e.g. comparing the students’ performance when they use ATs for different courses. We aim to perform such analyses in the future and share the results with the community. Any other interested researchers in engineering education who would like to access the data for any study and analyses, are invited to contact the report’s authors.

All the data analyses and research findings generated throughout the project have been
published in various local and international conferences and workshops. All publications are listed and described in Appendix A of this report. These published papers are publicly accessible and can be downloaded from their respective publishers or can be requested from the authors of this report. Besides these publications, this report also provides an overview of the research and development conducted through this OLT funded project. The project team will continue to publish more detailed information on the work carried out as part of the project, and the work carried out after the conclusion of the project.
Chapter 4: Linkages

Over the course of the project, several internal and external linkages have been established with other people and OLT projects. These links have provided mutual benefits and have helped enhance the understanding and implementation of this project and its impact.

This project, by its very nature, was meant to establish linkages with several Australian universities by establishing a Community of Practice (CoP) of the academics teaching mechanics courses in engineering. Other than the leading university (UNSW), six other universities including the University of Wollongong, University of Tasmania, University of Technology, Sydney, RMIT University, The University of Melbourne, and University of Western Sydney were involved in this project. Several academics from these universities, some of them the project team members too, actually contributed towards the design and development of the ATs. Therefore, through this project, the objective of establishing links with several engineering academics has been achieved effectively. Table 2 listed some of the names of the academics from various universities who contributed to the project.

Some other important links established with other Australian academics and institutions who showed their interest in the project and aimed to use the adaptive elearning technology in their research and teachings include academics from School of Civil Engineering at the University of Western Sydney and the University of Tasmania including Dr. Walid Amin, who is a Lecturer in Statics at Australian Maritime College at University of Tasmania. Dr. Amin has already moved towards using the ATs in his courses in 2012 and has already been added as a user to the community web portal. Other potential people who have also been involved in developing engineering thresholds through another OLT (ALTC) project “Engineering thresholds: an approach to curriculum renewal”, have also shown their interest in the adaptive elearning technology include Professor Caroline Baillie and Assistant Professor Sally Male from University of Western Australia.

Within The University of New South Wales, several linkages have been established with academics with the School of Mechanical Engineering and at the Faculty of Engineering level. Within the school, many academics have already adopted the technology and have started using the ATs for the 2nd year Fluid Mechanics and 3rd year Aerospace Structures courses. At faculty level, Dr. Zora Vrcelj from School of Civil Engineering has already implemented ATs in her courses during 2011 and will be using in future as well. Academics from School of Electrical Engineering and School of Chemical Engineering have also shown their interest and plan to use the ATs in their courses in 2012.

Besides these national linkages, some international links have also emerged during the course of this project. During some invited seminars, various academics from some international higher education institutions, including Szczecin University of Technology (Poland), University of Liege (Belgium), and KIIT University (India), showed their interest in adopting the ATs in their courses. We intend to follow-up with these academics in future to explore the opportunities to implement the ATs in their institutions and learn from the international multi-cultural experience to further improve the technology.

Also, Dr. Prušty was invited to the annual meet of Australian Council of Engineering Deans (ACED) on 4th Dec 2011 at Frementle, WA where selective OLT projects of interest to Engineering were presented for information and possible future collaboration or input.
Chapter 5: Project Evaluation

5.1 Evaluation Process

Evaluation process of this project spaned to three facets: technical, pedagogical, and project management. The technical and pedagogical evaluations also involved user data collection from the students and academics on various learning and usability aspects. The project management evaluation was the responsibility of an external assessor. These are discussed as below:

5.1.1 Technical Evaluation

Technical evaluation consisted of the evaluation of software solutions developed during the project for their usability and interoperability with institutions’ backend software. Other important technical aspect evaluated were:

- Ease of use and easy to setup for academics and students
- Authentication and integration with learning management systems of institutions
- Software interface usability
- Availability of ATs to academics for easy use and adaptation
- Availability of easy to use web-based analysis tool for academics
- Access to technical information and publications online
- Support for sharing of experience by the users of the software.

Some aspects of the technical evaluation, particularly the ease of use and any problems arising with deployment in different university contexts, could affect the students’ learning experience. Hence, to make sure such problems are overcome, data was collected from users on their experience with the online software so that the system could be continuously improved and any potential usability issues could be overcome.

5.1.2 Pedagogical Evaluation

Pedagogical evaluation was an inherent component of the adaptive elearning process, in that ATs respond to learners’ misconceptions and provide feedback to them. Therefore, they can be considered as an embodiment of the teachers’ understanding of their students’ misconceptions, mistakes, and difficulties. For the evaluation purpose, the same range of ATs was used across different university contexts and the disciplines covered were mechanical and civil engineering. The objective of the pedagogical evaluation was to get answers to following questions:

- Do students use ATs and do they like them?
- Do they learn from them? (Specifically, do the ATs help students who have been struggling to acquire TCs such as free body diagrams or sign conventions?)
- How does this technology help teachers?
- How often should the teachers adapt the tutorials and/or their teaching?
- Overall, how does the use of ATs compare with the traditional face-to-face interaction between students and teachers, in terms of
  - Development time and effort (academic and support staff)
  - Teaching time and effort to achieve equivalent learning outcomes
  - Student time and effort to achieve equivalent learning outcomes
To effectively evaluate all these aspects, various types of data were collected including student responses through survey questionnaires, students use of the tutorials and their course score performance, teachers responses through open-ended interviews, and the data from the ATs logs themselves.

Teachers using ATs used an evaluation methodology that employed the AT-Analyser, questionnaires, and cross-over pedagogical experiments to evaluate the impact of ATs targeting the identified TCs.

5.1.3 Project Management Evaluation

Project management evaluation was the responsibility of an independent external evaluator, Professor Roger Hadgraft, the Director of Engineering Learning Unit at The University of Melbourne, whose primary aim was to understand and evaluate the technical development of the project and its appropriateness in achieving the project aims and outcomes. Dr. Hadgraft has been involved with the project right from the beginning and has been continuously monitoring the progress of the project. He has also attended most of the project workshops and attended project meetings. He prepared a detailed evaluation report of the project in September 2011. Refer to Appendix D for the Evaluation Report by Dr. Hadgraft.

Many other formative evaluation processes were used. Evaluation of the project was also conducted through the feedback forms that were distributed at the workshops amongst the participants with the objective of improving our research, development, and implementation processes.

Besides, the use of the online engineering mechanics community portal that hosts the ATs, has also served as an effective evaluation method. The students have been able to provide their evaluation feedback of the portal as well as the ATs through the questionnaires that were integrated as part of the online tutorials. Appendix D provides some technical and pedagogical comments that helped evaluate the effectiveness of the ATs and improve their usability. Additionally, interviews with academics also served as useful evaluation technique proving insight into the ATs’ effectiveness and adaptation issues.

Peer reviewed conference publications have also formed an important evaluation process for the project. Much of the work presented in this report has been published in, and presented at, engineering education conferences. Formal feedback through the peer review process, and informal feedback through conference presentations, has been taken on board throughout the project. Project information sheets, posters, and brochures (see Appendix B) have been circulated at some of these events, as well as feedback forms.

The various types of data to be collected from students and teachers for the study needed ethics approval from each partner institution. Especially, The University of New South Wales’ Human Research Ethics Advisory Panel ‘H’ proved to be the most valuable evaluation and quality assurance mechanism. Each component of the research for the project involving student participants was reviewed by the Panel to determine whether it was a well designed approach, and provide useful outcomes. In total, three separate approvals were granted for this project.

5.2 Evidence of Project Impact

One of the most significant indication of the project impact is the citation of a number of papers published by the project in papers being published in engineering education conferences, especially the Australasian Association for Engineering Education conference held in December 2011. So far over six research papers related to the project have been accepted by engineering education conferences, which shows the engineering community’s
interest in the value of the current project and related research.

In terms of the people who participated in six project workshops and four seminars, their number is over 100 and represented around 25 different higher education institutions. This represents a significant number of academic staff involved directly and indirectly with the 1st and 2nd year engineering mechanics education. The breakdown of workshop attendance was presented earlier in Table 5.

Regarding the implementation of ATs, at UNSW alone, during and prior to the current project initiation, over 1000 engineering mechanics students have used ATs at School of Mechanical Engineering over a period of 4 years (Prusty & Russell, 2011). From the Engineering Mechanics Community of Practice (CoP) perspective, in Semester 1 of year 2011 alone, over 700 students attending different engineering mechanics courses and various academics who taught these courses at different institutions, have used ATs. Students also filled survey questionnaires and showed their acceptance of the tutorials in their learning as discussed earlier. Table 15 summarises the use of ATs by the mechanics academics at various institutions and the number of students who used the ATs.

Table 15. Summary of the use of ATs at various institutions during 2011

<table>
<thead>
<tr>
<th>Institution</th>
<th>Academic</th>
<th>Course</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNSW</td>
<td>A/Prof. B. Gangadhara Prusty</td>
<td>Mechanics of Solids 1</td>
<td>335</td>
</tr>
<tr>
<td>UNSW</td>
<td>Dr. Zora Vrcelj</td>
<td>Engineering Mechanics for Civil Engineers</td>
<td>115</td>
</tr>
<tr>
<td>UoW</td>
<td>Prof. Tim McCarthy</td>
<td>Engineering Mechanics</td>
<td>120</td>
</tr>
<tr>
<td>UTAS</td>
<td>Roberto Ojeda</td>
<td>Mechanics of Solids</td>
<td>68</td>
</tr>
<tr>
<td>UTS</td>
<td>Mrs. Anne Gardner</td>
<td>Engineering Mechanics</td>
<td>96</td>
</tr>
</tbody>
</table>

The numbers of active academics and student users of the currently available 12 ATs in engineering mechanics and others to be developed in near future through the community web-portal, are expected to grow significantly in upcoming months and years. The community web-portal itself, which has gone live only two weeks prior to the completion of this report, has also attracted a lot of public interest. Full impact of its usage on the teachers and students’ learning improvement will be visible only after some time. With the availability of more ATs, demos, videos, and other support material, along with the announcement and dissemination activities, the portal is expected to attract more users. We will constantly monitor the usage activity in the coming months and will publish this information in any upcoming official publications.

The Community of Practice for Engineering Mechanics will lead the way and have impact on other disciplines, e.g. in Civil engineering, Chemical engineering or even Software engineering, that are likely to benefit from a similar pedagogical learning approach. Furthermore, since the ATs are constructed using reusable software simulations called Virtual Apparatus, they can be reused and repurposed for similar learning activities in other engineering domains. For example, the concepts built on the fundamentals of mechanics courses in 1st and 2nd year engineering are often used in most courses in engineering during following years of study.
Chapter 6: Recommendations

Based on the research and its findings presented in this project report, following recommendations are provided.

6.1 Retain focus on developing students’ understanding of threshold concepts

The ultimate objective of this project and the related research was to build a technology, a tool, an effective method that will help students to develop their fundamental knowledge in engineering mechanics. With the growing need of more engineers in the industry and the ever increasing number of students at engineering schools of higher education institutions, teaching of engineering mechanics courses and learning of TCs therein are becoming ever more challenging. We need to put more focus on developing students’ understanding of the TCs and developing methods and tools that will help achieve this objective.

6.2 Create further Adaptive Tutorials for engineering mechanics

During the course of this research project, based on the consultations with several engineering mechanics academics, 12 different ATs were developed. These ATs covered several TCs suitable for mechanics courses in engineering such as Statics, Dynamics, and Solid Mechanics. There are several other complex knowledge components of the Mechanics of Solids and related courses that students may find difficult to grasp, and if support by the ATs, students’ overall course performance may improve even further. In future, more such ATs could be created to further target the TCs.

6.3 Reconsider the strategy for implementing Adaptive Tutorials

Results of the project have shown that one uniform strategy for implementing ATs in different situations with students having different learning abilities will not generate optimum results. In order to provide the most favourable results, the implementation of ATs will have to be strategised according to the specific engineering mechanics course at a specific institution. Consideration should also be given to the selection of ATs for use with low and high performing students separately for effective learning performance. From the results of this project we have already discussed and concluded that the use of ATs had different learning effect on low versus high performing students. Additionally, the adaptive learning supported by ATs works well in a blended teaching approach that consists of lectures, laboratory exercises, group discussions as well as ATs. Hence it is recommended to use the ATs in combination of other teaching methods, rather than using ATs as a standalone way to enhance students effective learning of TCs.

6.4 Promote the Community of Practice for Engineering Mechanics

One of the important objectives of this project was to build a Community of Practice for engineering mechanics professionals and academics who will create, author, and implement the ATs in their courses and help improve these tutorials by modifying them and sharing their experiences about how this technology has assisted them in improving their students learning. To that end, we contacted several engineering academics around Australian universities and established this community that helped shape this state-of-the-art technology. These academics have already played their role by using the Community Web-Portal (http://adaptive-mechanics.eng.unsw.edu.au), sharing their experiences and
difficulties they faced, and building a database of students’ course performance. In future, a large educational datalab could be established with an objective to mine into the data collected through the portal and investigate the problems and issues faced by both the teachers as well as the students in learning. More promotion of the portal is needed to attract and encourage even greater number of engineering academics to further enhance the impact of the technology.

6.5 Incorporate other e-learning resources for engineering mechanics

As discussed in the initial parts of the report that there are plenty of online e-learning resources available covering the basic concepts in engineering mechanics. Though mostly being static information and learning resources and lacking the ability to adapt according to learners’ requirements like the ATs, they can still be collected, filtered, organised, and presented as a repository of resources in a logical way that is easily accessible and searchable. Such repository of resources can be created and incorporated into the existing Community of Practice Portal to provide students and teachers with additional learning resource at their fingertips.

6.6 Create and implement AT technology for other engineering disciplines

Finally, it is recommended to create and implement the AT method of learning into other engineering disciplines like civil, chemical, electrical, even software engineering. Almost all of these disciplines has the same issue of large classes with hundreds of students where learning of TCs poses a great challenge. We have successfully demonstrated the use of ATs in Mechanical engineering. Several of the ATs developed during this project can even be directly used into some of the disciplines e.g. in civil engineering. Engineering academics in other disciplines can also create and use ATs in their courses. Even within the Mechanical engineering discipline academics from other courses such as Fluid Mechanics and Aerospace Structures could easily achieve this as demonstrated at School of Mechanical Engineering, UNSW. This will immensely enhance the overall impact of this technology.
References


Goldfinch, T., & Gardner, A. (2010). *The wheel has already been invented: facilitating students’ use of existing mechanics resources*. Paper presented at the The International Conference of Engineering Education (EE2010), Birmingham, UK.


Appendix A: Publications

A.1 AaeE 2009 Conference Publication

Adaptive Tutorials using eLearning Platform for Solid Mechanics Course in Engineering

**BG Prusty**  
School of Mechanical and Manufacturing Engineering  
The University of New South Wales, Sydney, Australia  
g.prusty@unsw.edu.au

**O Ho**  
Alumni of the School of Mechanical and Manufacturing Engineering  
The University of New South Wales, Sydney, Australia  
owen.hwh@gmail.com

**S Ho**  
Adaptive eLearning Research Group  
The University of New South Wales, Sydney, Australia  
shaowei.ho@unsw.edu.au

**Abstract:** The paper presents the concept, development and outcome following the development and implementation of a set of interactive teaching and learning tools for Mechanics courses in Engineering. The tools are designed, using Adobe Flex and Flash software and are hosted on the Adaptive eLearning platform (AeLP). The tool focuses on the strengths of conveying information by means of high interactivity, timely and adaptive feedback that tailors to the user’s needs and places the user in challenging but practical mechanics scenarios related to the real world. Three different eLearning tutorials were created and the interactive tutorials were scripted for teaching and assessment purposes in Solid Mechanics and Engineering Mechanics courses in Mechanical Engineering. The Adaptive Tutorials have proved to be a major teaching medium that has been accepted by the student community for better understanding of the fundamentals.

The article can be found at  
Towards a Community of Practice concerning the Use of Adaptive Tutorials in Engineering Mechanics

Dror Ben-Naim
School of Computer Science and Engineering
The University of New South Wales, Sydney, Australia
drorb@cse.unsw.edu.au

B. Gangadhara Prusty
School of Mechanical and Manufacturing Engineering
The University of New South Wales, Sydney, Australia
g.prusty@unsw.edu.au

Abstract: This paper outlines current work that seeks to address persistent challenges in Engineering Mechanics education through the development of Adaptive Tutorials that target threshold concepts in the field. Adaptive Tutorials are interactive online modules where an Intelligent Tutoring System adapts the instruction level to learners, based on their individual performance. Following a successful pilot study at UNSW, a new ALTC project was launched, in which a team of Engineering Mechanics educators from a range of Australian universities will explore the applicability of using Adaptive Tutorials in their teachings. This paper will concentrate on past experience in introducing Adaptive Tutorials in two mechanics courses at UNSW, focusing on a discussion on the shift of the role of teachers from conveyors of knowledge to that of educational action researchers. It will then proceed to discuss what it means to establish a community of practice revolving such educational technology.

The article can be found at
Teaching and assessment of mechanics courses in engineering, which encourage and motivate students to learn threshold concepts effectively

Dr. B. Gangadhara Prusty
Mechanical & Manufacturing Engineering,
The University of New South Wales, Australia

Mechanics fundamentals make the solid foundation for most engineering disciplines. Conventionally, at most engineering schools, the study of mechanics comprises up to 25% and 40% of 1st and 2nd Year levels respectively. Failure rates of up to 20% to 50% are common in introductory mechanics courses in engineering, which has been an issue of continuing concern.

The implementation of innovative teaching strategies into the UG courses such as 1st year Engineering Mechanics 1 (>275 students) and 2nd year Solid Mechanics 1 (>300 students) using blended online and face-to-face teaching has been carried out at UNSW. The development, use and evaluation ways of using an online intelligent tutoring system, i.e. Adaptive Tutorials (ATs), is targeted to help students develop their conceptual understanding of mechanics. In large and diverse groups of students, it is often difficult to identify and help the students who are struggling. The ATs provide a way of dealing with common sticking points, or threshold concepts that prevent students progressing in their study of mechanics. These can sometimes be addressed by skilled one-to-one coaching but are usually missed by traditional ‘book and board’ teaching in large classes. The ATs use artificial intelligence principles along with online interactive virtual laboratory activities (simulations), to: (a) track each student’s interaction with the simulation, and provide tailored feedback; (b) generate data that teachers can use to identify common conceptual sticking points in large classes; and (c) provide information for adjusting the simulation, feedback and other learning activities in a course to help students through threshold concepts.

The author’s work shows how ATs can help students to learn threshold concepts efficiently. The tutorials not only improve students’ performance in assessments, but also improve students’ satisfaction with the course. The student response has been very positive, and the technical and pedagogical approach adopted in developing the ATs has helped not only our learning and teaching activities in mechanics at UNSW but also provides the opportunity for further development and dissemination into cross-institutional, cross disciplinary, collaboration.

Student feedbacks such as “Fantastic program I was really struggling with the force analysis, however this program has instilled confidence for understanding real-life application of engineering and mechanics” and “I highly recommend this tutorial. It has a very appealing practical approach yet at the same time helps me in improving my conceptual understanding of the topic at hand especially regarding the shear force and bending moment. The free body diagram on the side is also very helpful. Two thumbs up!” bears testimony to the success of this approach.

The article can be found at http://www.thresholdconcepts2010.unsw.edu.au/Abstracts/PrustyG.pdf
ABSTRACT
In large and diverse groups of students, it is often difficult to identify and help the students who are struggling with the basic concepts they need to progress in the study of solid mechanics. Adaptive Tutorials (ATs) use an online ‘intelligent’ tutoring system that provides a way of dealing with common sticking points, or ‘threshold concepts’. These can sometimes be addressed by skilled one-to-one coaching but are usually missed by traditional ‘book and board’ teaching in large classes. The ATs use online interactive virtual laboratory activities (simulations), and (a) track each student’s interaction with the simulation to provide tailored feedback; (b) generate data that teachers can use to identify common conceptual sticking points in large classes; and (c) provide information for adjusting the simulation, feedback and other learning activities in a course to help students through threshold concepts. ATs developed in stages since 2005, used in blended online and face-to-face teaching in mechanics, have been evaluated and are shown to improve both engagement in learning mechanics concepts and performance in assessments, particularly among lower performing students.

The article can be found via http://www.mecsol2011.ufsc.br/
Engaging students in learning threshold concepts in engineering mechanics: adaptive eLearning tutorials

B. Gangadhara Prusty¹ & Carol Russell²
Faculty of Engineering, The University of New South Wales, Sydney
g.prusty@unsw.edu.au¹, carol.russell@unsw.edu.au.

Abstract
In learning mechanics fundamentals in engineering, many students struggle with basic concepts, and as a result fail to engage in the more rewarding higher level problem solving tasks where they learn in more depth. A good tutor can walk a student through sticking points and give customised feedback and encouragement. But such individual teacher-student conversations are rare in 1st and 2nd year undergraduate classes with several hundred students and limited numbers of tutors.
Online tutorials and simulations can help, but most do not track in detail where the students going wrong. Nor do they allow the teacher to customize the response as they would in a face-to-face conversation in a tutorial and lab class. The adaptive tutorials using the eLearning platform developed at UNSW are designed to allow the teacher to monitor overall responses in a large group of students and to adjust the teaching, and the feedback given by the online tutorials themselves, to respond to common sticking points. We have been using adaptive tutorials for four years, in 1st and 2nd year engineering mechanics classes within UNSW. We tracked student behaviour in using the tutorials and adjusted the teaching. By analysing student feedback and student performance in assessment tasks, we can show how the tutorials engage students in working through conceptual difficulties.

In 2011, a national project is using a wider range of adaptive tutorials for mechanics courses in engineering across several Australian universities, with different student cohorts and class sizes. Preliminary results show the tutorials compare with traditional teaching and how their use can be customised for students learning the threshold concepts of engineering mechanics in different curriculum contexts.

The article can be found at http://www.ineer.org/events/ICEE2011/papers/icee2011_submission_250.pdf
Adaptive Tutorials to target Threshold Concepts in Mechanics – a Community of Practice Approach

Gangadhara B. Prusty, Carol Russell, Robin Ford, Dror ben Naim, Shaowei Ho, Zora Vrcelj & Nadine Marcus
The University of New South Wales, Australia

Timothy McCarthy & Tom Goldfinch
University of Wollongong, Australia

Roberto Ojeda
Australian Maritime College @ University of Tasmania, Australia

Anne Gardner
University of Technology Sydney, Australia

Roger Hadgraft
The University of Melbourne, Australia

Abstract: We present our work on introducing Adaptive Tutorials in first and second year mechanics courses in Engineering. Adaptive Tutorials are interactive online modules where an Intelligent Tutoring System adapts the instruction level to learners, based on their individual performance. Through an ALTC-funded project, we formed a community of practice of Engineering Mechanics educators from a range of Australian universities. As a team, we began by identifying Threshold Concepts that if they are not grasped inhibit students’ learning before developing a set of Adaptive on-line Tutorials to target them. These Adaptive Tutorials were used by students throughout the first half of 2011, and were found to be both engaging and conducive to learning. In this paper, we present our approach and findings and discuss our strategy of giving educators pedagogical control over such advanced technologically-based instructional methods with the goal of increasing adoption and ultimately improving students’ learning.

The article can be found via the conference website
Online Adaptive Tutorials Targeting Fundamental Concepts of Mechanics Courses in Engineering

B. Gangadhara Prusty, Dror Ben-Naim, Shaowei Ho, and Owen Ho
The University of New South Wales, Sydney, Australia

ABSTRACT
This paper describes the development of a set of online, interactive learning modules for Mechanics courses in Engineering at The University of New South Wales. These modules are called Adaptive Tutorials and were developed using a unique software platform called the Adaptive eLearning Platform. The Adaptive Tutorials developed, utilise the strengths of conveying information by means of high interactivity, timely, and adaptive feedback; this feedback is tailored to the user’s needs and places the user in challenging but practical mechanics scenarios related to the real world. Three different Adaptive Tutorials were developed and the results of early pilot studies are presented. An important design decision was made that sought to separate the development process to pedagogical concerns, owned by the teacher, and technical concerns, owned by the software developer. This separation of concerns contributes to the teacher’s ability to exert pedagogical ownership over the Adaptive Tutorials. The Adaptive Tutorials have proved to be a successful teaching medium that has been accepted by the student community.

The article can be found in the following book:

Book Title: Engineering Education: an Australian Perspective
Editors: Dr. Steven Grainger and A/Professor Colin Kestell
Publisher: Multi-Science Publishing Co. Ltd., United Kingdom.
Publish Date: October 2011.
Book Website: http://www.multi-science.co.uk/engineering-education.htm
Appendix B: Samples of Distribution Material

B.1 Project Information Sheet

An Adaptive e-Learning Community of Practice for Mechanics Courses in Engineering

This project is set out to explore the use of online eLearning ATs in engineering courses and to develop a Community of Practice (CoP) for Mechanics courses in engineering departments or schools at various Australian universities. The project involved a team of engineering academics from several Australian universities including The University of New South Wales (the lead university), the University of Wollongong, the University of Tasmania, the University of Technology, Sydney, the RMIT University, and The University of Melbourne. The research is focused on the mechanics courses and will draw upon the data gathered from academics and students at the partner universities.

Projected Outcomes

Projected outcomes for this project are:

- Developing a web-based community portal where all ATs are featured, accessible to the universities within Australia for their use, along with published pedagogical research on using them.
- Developing 12 ATs covering identified core TCs, accessible to the universities within Australia through web-based portal.
- Incorporating ATs into the course syllabi at institutions where members of the OLT project team are teaching.
- Conducting 2 staff training workshops open to academics at all Australian engineering faculties.
- Developing comprehensive support material including a user-editable ‘how-to-use’ guide and a user manual that will support the teacher usage of the portal and the tutorials.

Project Team

Associate Professor Gangadhara B. Prusty, UNSW

Contact
Dr. B. Gangadhara Prusty
g.prusty@unsw.edu.au
+612 9385 5939

Timothy McCarthy (UoW), Anne Gardner (UTS), Roberto Ojeda (UTAS), Zora Vrcej, Carol Russell (UWS), Nadine Marcus (UNSW), Robin Ford (UNSW), Roger Hadgraft (UMelb), Tom Molyneaux (RMIT)

If you would like to know more about the project, visit the Community of Practice Engineering Mechanics Portal (http://adaptive-mechanics.eng.unsw.edu.au) or contact Dr. Gangadhara Prusty. We appreciate any feedback or suggestions, so please send us your thoughts via email, or through the website.
B.2 Project Information Posters and Brochures

Posters & Brochures produced to encourage the development of a community of practice
B.3 User Manual to provide training on using Adaptive Tutorials

First page of the User Manual. Full manual is accessible through the web portal website.
Appendix C: Survey Questionnaire

C.1 Student Survey Questionnaire

Questions offered after students complete their 1st AT

1) How easy or difficult was it for you to understand what was required of you within the online adaptive tutorials?
   Very easy, Easy, Neither easy nor difficult, Difficult, Very Difficult
2) I found it easy to learn how to work with the interactive elements of the adaptive tutorial.
   Strongly agree, Agree, Neither Agree nor Disagree, Disagree, Strongly disagree
3) I prefer this teaching method to normal written assignment
   Strongly agree, Agree, Neither Agree nor Disagree, Disagree, Strongly disagree
   Please elaborate why:
   TEXT ANSWER
4) Would you suggest this Adaptive Tutorial to a friend?
   yes, no, not sure ....
   Please elaborate why.
   TEXT ANSWER
5) Would you like to use adaptive tutorials for other topics?
   yes, no, not sure ....
   Please elaborate (e.g. which topics/courses or why not)
   TEXT ANSWER
6) Any specific issues you experienced?
   TEXT ANSWER

Questions offered after completion of each tutorial

1) There was enough help and support to complete the tutorial
   Strongly agree, Agree, Neither Agree nor Disagree, Disagree, Strongly disagree
2) How much exposure do you have to this topic, before starting this Adaptive Tutorial?
   No exposure, Very little exposure, Average exposure, Fair amount of exposure, Lots of exposure
3) I found the level of difficulty of the questions?
   Very difficult, Difficult, Neither difficult nor easy, Easy, Very easy
4) I feel I understand the topic better now?
   Strongly agree, Agree, Neither Agree nor Disagree, Disagree, Strongly disagree
5) How long did it take you to complete the tutorial? Select time from
   15 minutes or less, 16-30 mins, 31-45 minutes, 46-60 minutes, more than 60 minutes

Questions for final (end of semester feedback on the adaptive tutorials)

We would like you to give us your overall opinions about the online adaptive tutorials as used in your study of engineering mechanics this semester.

1) How easy or difficult was it for you to work out what was required of you within the adaptive tutorial system?
   Very easy, Easy, Neither easy nor difficult, Difficult, Very Difficult
2) I found it easy to learn how to work with the interactive elements of the adaptive tutorial.
   Strongly agree, Agree, Neither Agree nor Disagree, Disagree, Strongly disagree
3) I prefer this teaching method to normal written assignment
   Strongly agree, Agree, Neither Agree nor Disagree, Disagree, Strongly disagree
   Please elaborate why:
   TEXT ANSWER
4) Overall, did the Adaptive Tutorials help you to use key concepts and techniques in engineering mechanics?  
   yes, no, not sure ....  
   Please elaborate why.  
   TEXT ANSWER

5) Would you like to use more Adaptive Tutorials, on different topics?  
   yes, no, not sure ....  
   Please elaborate (e.g. which topics/courses or why not)  
   TEXT ANSWER

6) Would you recommend Adaptive Tutorials to a friend studying engineering mechanics?  
   yes, no, not sure ....  
   Please elaborate why.  
   TEXT ANSWER

7) Any other comments about the adaptive tutorials?  
   TEXT ANSWER

C.2 Teacher Survey Questionnaire:

A semi-structured interview questionnaire with teachers using Adaptive Tutorials:

Context

- Can you describe the teaching context in which you are using the adaptive tutorials (program, level of study, teaching support available, cohort size and typical characteristics)?  
- What were the main student learning challenges you were hoping the adaptive tutorials would help with?  
- How did the tutorial(s) fit in with other learning activities and assessment?

Development

- What was your role in developing the adaptive tutorials? (i.e. Were you involved in developing a completely new tutorial or did you use an existing one?)  
- How much of your time and effort was involved in developing or adapting the tutorials for your class?  
- Did you work with a developer and if so, what was the developer’s role in relation to yours?  
- How much work did the developers contribute?  
- To what extent did you feel in control of the process and the outcomes?  
- Any other comments on the adaptive tutorial development process?

Teaching experience

- Once you deployed the tutorials, how did you find using them with your students? What was easy and what was difficult or time-consuming?  
- Did you use the AT analyser tool to identify patterns in student use of the adaptive tutorials? If so, how useful was the information it provided?  
- At the start of the pilot the project participants agreed to leave each tutorial unchanged during the semester and review at the end of the semester. Did you stick to this or did you change anything, for example in the student feedback, within the tutorial?  
- Did you change any other teaching in the course as a result of information you gained from looking at the adaptive tutorial response patterns for the class?  
- Was it worth the effort in terms of student learning? Did you notice any tangible benefits?  
- What do you think are the pros and cons of the adaptive tutorials compared with other methods for teaching the same concepts?

Student response
• We have logs of the students’ use of the tutorials and we are also surveying students directly on their experience of using the tutorials. What are your impressions of how your students responded to the tutorials?
• What evidence are you mainly basing this on? (Could be based on informal observations and interactions with students or on formal assessment results.)
• Have you noticed any patterns in the student responses that may be worthy of further investigation? If so have you formed any hypotheses about these patterns?
Appendix D: Evaluation Report

D.1 Evaluation Report on the Adaptive e-Learning Project

Roger Hadgraft
Director, Engineering Learning Unit, The University of Melbourne
ALTC Discipline Scholar in Engineering and ICT
roger.hadgraft@unimelb.edu.au; 0412 809 597
7 Sept 2011

Overview
I have been involved in this project from the drafting of the application stage, so I have been able to follow its progress in some detail. The project is a successful spin-off of the adaptive e-learning work was under development at UNSW. Some prototype tutorials in Engineering Mechanics had already been developed, which meant that the refinement of these and the development of some new ones has been a predictable process, unlike some computer-assisted learning projects, which start with a good idea and uncertain implementation methods.

The project is also guided by a core group from the University of Wollongong (also a recipient of a previous ALTC grant in Engineering Mechanics), the University of Tasmania and UTS.

Dec 2010 Workshop at AAEE
At the 2010 AAEE conference at UTS, I attended the Workshop conducted by the project team. It was my first chance to try out the tutorials and see how they worked. I was impressed by the sophisticated interface that had been developed to enable content developers to create and modify the adaptive tutorials.

We were also shown how to modify a tutorial, which requires use of this programming interface. This was easy to use for those with some object-oriented programming experience. The ease of use of the programming interface is being continuously improved.

Feb 2011 Workshop at RMIT
In February 2011, I attended another workshop at RMIT for potential users. This was a similar presentation to the one at the AAEE conference, though without the chance to use the system. The workshop was well attended (more than 20), so there is quite a lot of interest in the application of this kind of technology to learning engineering.

June 2011 Review
On 7 June, I had the opportunity to spend the day with the team in Sydney to review progress. The full Powerpoint presentation of that day is available from the team. At that stage, the second batch of four tutorials had been completed, namely Free Body Diagrams, Trusses, Centre of Gravity and Friction, making eight tutorials in total developed by the project. The third batch of four tutorials is being developed through the second half of 2011.

The group is gradually expanding the Community of Practice through the workshops as described above and also through the AAEE-Scholar portal, which documents resources for many engineering subject areas, including quite an extensive page on Engineering Mechanics.

Some of the key developments that have occurred up until June have included:

- Concentrating on developing a robust platform to enable student-friendly tutorials, with particular attention paid to the Control Interface to the virtual apparatus. This enables the software platform to be used in the future for a wide range of new
applications. This work is already happening in other learning domains, such as medicine.

- Improved, easier to understand language in the tutorials
- Simpler more intuitive user interface, with less text and improved screen design
- Reviewed questions and their feedback
- Appropriate location of each tutorial in the semester narrative.
- Developing scaffolding for other users, eg YouTube videos.

One small example of improving the user interface is the consistent use of arrows, which are used for vectors such as forces and also for dimensions. It was agreed that each use should have distinctly different line styles so that students are not confused between forces and dimensions.

**Evaluation**

The analysis and evaluation of the tutorials is underway following final ethics clearance. We discussed a range of issues to be addressed:

- Who are the target students (the ones who get the most value from these kinds of tutorials)?
- What are their demographics? International, local, rural; gender; repeats?
- Connections to the PASS scheme already operating?

The Analyser tool was to be ready by the end of semester one.

We talked around some issues such as:

- Does making the use of the tutorials compulsory change the way in which students engage with them?
- Students now have quite a lot of experience with computer games, which they sometimes bring to their learning. They can be rewarded with badges and other strategies to increase engagement. Is this a useful thing to incorporate?
- Ultimately, however, we want students to engage because they want to, in the same way that people who use a gym get the most out of it when they are internally motivated to turn up.

Preliminary analysis of the data shows strong support from students for the use of the tutorials.

The Analyser tool produces some nice charts which aggregate the student data. This can be used to have purposeful discussions with the class around common errors.

**Future**

Future possibilities include:

- Connection to the Engineering Education Resources Exchange: https://sites.google.com/site/eereexchange/
- Using the system to present more complex design - oriented problems
- Getting students to use the authoring tools to build their own tutorials
- Other topics such as torsion and dynamics
- Integration with LMSs such as Moodle and Blackboard
- Use at UWA, Auckland, Curtin, UQ, Monash and Swinburne is anticipated

**Summary**

This project is progressing very well. It started from a solid platform of developed software and concepts. The team has been able to build the tutorials at the promised rate and the tutorials are now being tested in several universities. The formal evaluation of the software is being conducted this semester, with results expected by the end of this year or early next year. A LIEF grant application has also been submitted to obtain infrastructure funds to develop further tutorials in Mechanics and in other domains.
Appendix E: Community of Practice Web Portal

Free Body Diagram Adaptive Tutorial’s Home Page
Free Body Diagram Tutorial’s Demo Page 1 with Introduction

Free Body Diagram Tutorial’s Demo Page 2 with a Question.
Free Body Diagram Tutorial’s Demo – Feedback on the Question

Free Body Diagram Tutorial’s Demo – Showing Correct Solution for the Question
An adaptive e-learning community of practice for mechanics courses in engineering
An adaptive e-learning community of practice for mechanics courses in engineering