The Virtual Workshop: An on-line adaptive resource for engineering and architecture

Final report 2015

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https://adaptivemechanics.edu.au

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List of acronyms used

AeLP	Adaptive eLearning Platform
AI	Artificial Intelligence
ATs	Adaptive Tutorials
CoP	Community of Practice
ITS	Intelligent Tutoring System
LMS	Learning Management System
OLT	Office for Learning and Teaching
TC	Threshold Concept
UNSW	The University of New South Wales
UoSA	University of South Australia
UoW	University of Wollongong
UTAS	University of Tasmania
UTS	University of Technology, Sydney
WSU	Western Sydney University

Executive summary

This project attempted to investigate the development and implementation of Adaptive Tutorials (ATs) using the Smart Sparrow adaptive eLearning platform in engineering design and architecture to develop a Community of Practice in engineering departments or schools at various Australian universities. The project team consisted of a team of academics from mainland and regional Australian universities including, UNSW Australia (the lead university), University of Wollongong, University of Tasmania, University of South Australia, Griffith University, and Western Sydney University. The focus of this project was to develop and implement a number of Adaptive Toolboxes, made up of Adaptive Tutorials to teach in design-related engineering and architecture courses. The data gathered from academics and students and both the partner universities and the lead university was then used to understand the suitability of using ATs in teaching engineering design and architecture.

Design is fundamental to the process of engineering a product and applying scientific concepts to obtain a functional output. However, design is a very difficult concept to teach. There are no right or wrong answers in design, and one problem can have a variety of different solutions depending on the availability of materials, costs and other factors. This is largely in contrast to science-based subjects taught at university, where students are marked based on exam style questions with right and wrong answers. Students find it difficult to accept the broad spectrum of answers that are possible in design and require a lot of feedback and support to help guide their learning. With the increasing class sizes providing such individual feedback becomes a labour intensive task for the academic undertaking the course, and the physical and financial constraints of design spaces and tools necessary add a further element of difficulty. Using an eLearning Platform to create Adaptive Toolboxes, made up of Adaptive Tutorials can help to combat these problems by providing students with a self-paced learning model capable of providing them instant adaptive feedback based on their input into the system.

The primary outcomes of this project include the following:

1) *Development of Adaptive Toolboxes/Workshop:* Workshops were developed as described in the initial grant application to support the Adaptive Toolboxes, composed of adaptive tutorials, simulation and other resources within the adaptive tutorials, and the reiteration of the design loop at every stage of the design tutorial process.

2) *Development of ATs*: tutorials were developed as described in the initial grant request in the disciplines of Mechanical Engineering (three tutorials), Civil Engineering (one tutorial), Aerospace Engineering (one tutorial), Naval Architecture and Ocean Engineering (one tutorial), and Architecture (two tutorials).

3) *Incorporation of ATs into the course curriculum*: All seven ATs have been incorporated and implemented throughout courses at various universities with the following numbers: Semester 1, 2013 (304 students); Semester 1, 2014 (241 students); Semester 2, 2014 (470 students); Semester 1, 2015 (392 students); Semester 2, 2015 (576 students).

4) *Expansion of existing community of practice*: a web-based community portal where all Adaptive Tutorials are featured, accessible to all universities within Australia for their use, along with published pedagogical research on using them has been established and is available for access at Adaptive Mechanics Network (AMN): https://adaptivemechanics.edu.au

5) *Professional development of staff in the use of adaptive design software*: Two training sessions have been held to assist academics in familiarising themselves with the design software and detailing what can be achieved.

6) *Availability of online support materials*: A set of support materials including screencasts, previews of all tutorials, how-to guides for all the tutorials created and further tutorial and information presentations have all been collated and are available online (this information can also be accessed through the AMN website in the FAQ section): http://adaptive-virtual-workshop.eng.unsw.edu.au

The ATs were trialled with 2076 students thus far, studying various disciplines of engineering over a period of two years, 2014-2015, spread out as follows:

- Mechanical Engineering (Weld, Flywheel and Beam Design Tutorials – 1533 students);
- Civil Engineering (Column Design – 183 students);
- Naval and Ocean Engineering (Barge Design – 26 students);
- Aerospace Engineering (Stiffened Panel Design – 233 students);
- Architecture (Functionality Design – 101 students).

The students were surveyed each time they used the tutorials. Students' self-reported ratings indicate a very positive response to the usability and suitability of the ATs to their learning needs. The majority of students found the ATs to be relevant (67 per cent of students), would prefer the ATs to also be used in their other subjects (68 per cent of students surveyed) and 73 per cent of the students surveyed found that the ATs helped them to better understand the design loop used in engineering design.

The project makes the following recommendations for future work and directions of this research:

1) Retain the focus on guiding the student's learning process and understanding of threshold concepts in engineering design;

2) Create further Adaptive Tutorials for engineering design topics through collaboration with other academics;

3) Use the results of this study to help plan for and implement further versions of Adaptive Tutorials in class;

4) Continue to promote the Community of Practice through the use of the create website portal: http://www.adaptivemechanics.edu.au; and

5) Investigate how group-work could be used in the context of the Adaptive Virtual Workshop in design-based exercises in engineering and architecture.

Table of contents

Tables and figures

1.1 Tables

1.2 Figures

1 Introduction

1.1 Project Background and Rationale

Engineering design is the creative application of scientific or technical knowledge in problem solving. Design is at the core of every engineering problem. It is a skill that requires both technical expertise and also an element of creativity. Good design is essential to create objects that fulfil their objective intuitively. It is well established that "…engineering programs should graduate engineers who can design effective solutions to meet social needs…" (Dym, Agogino, Eris, Frey & Leifer, 2005). This corresponds to the stance taken by Engineers Australia, who deem design to be a vital ingredient in an engineering curriculum and state that "… Research and analysis is science. Both Engineering and Science are important; but knowledge alone is of no consequence to the future of life if it does not manifest itself into material significance through DESIGN…" (Engineers Australia, Accessed 3 March 2015).

Predominantly, engineering students graduate with a solid scientific understanding of engineering principles, which allow them to solve particular problems in particular ways. The skills and knowledge build hierarchically based on prior knowledge. To solve an engineering problem, prior knowledge of scientific theory is essential. However, this can misleadingly imply that there is an ideal approach to the problem and an ideal solution. This is not indicative of real-world problems that are seen in the engineering discipline. When developing a design, engineers are dependent on the situation at hand, so goals, problems and constraints are often ill defined and may change as the problem continues to unfold (Lemons, Carberry, Swan, Jarvin & Rogers, 2010). There is no single ideal solution in this situation. Assumptions and estimations are required before each analysis step, and the results need to be evaluated against the desired functional output. Often, many analysis iterations are required before a suitable solution is found. Although engineers often have general guidelines for the design process, there is no consensus regarding one correct procedure to follow in order to reach a solution (Lemons et al., 2010).

Whilst design is fundamental to engineering, design principles are hard to teach with every problem having a multitude of solutions leading to no concrete right or wrong answers. This is in contrast to scientific concepts, that can be easily assessed with the help of exam style questions that test for knowledge and understanding (Goldsmith, Reidsema, Beck & Campbell, 2010). Such questions always have a right and wrong answer. This is in contrast to teaching design, where there are no right or wrong answers. Students are often uncomfortable with the notion that there is no correct answer leading to poor student engagement with engineering design subjects.

Many initiatives have been taken to identify the reasons for poor student engagement and to find ways to address the problem, both by individual teachers and, increasingly, by the community of engineering academics. The problem may lie in graduate students' capability to find solutions to previously unseen problems. A theoretical position on this capability and threshold concepts has been proposed in the body of research (Baillie,

Bowden & Meyer, 2013). Numerous efforts have also been made to better integrate design into engineering curricula (Carroll, 1997; Kartam, 1998; Kurfess, 2003) and prepare graduate engineers for the industry (Todd, Magleby, Sorenson, Swan & Anthony, 1995). Ultimately, engineering design seeks to find a technical solution that best satisfies a particular set of requirements. This design process takes into account a range of factors, including economics, buildability, sustainability, technical performance and safety, but it is largely driven by the requirements of the problem space and the availability of certain resources.

Despite incorporating long-practised teaching and learning approaches for engineering design courses, current methodologies still suffer from a number of issues. First and foremost is the costs and space associated with the types of resources and materials required in an engineering design problem. Additionally, resources to teach are becoming more limited despite increasing student enrolments, making authentic design experiences difficult to achieve (Dougherty & Parfitt, 2009). This is further exacerbated by the inability to provide feedback to such a large number of students in a timely and efficient manner. Traditional design teaching (workshops, studios, laboratories, and so on) does not translate well spatially or temporally. The interactivity of design teaching requires students to be located in the same time and place as the teacher. This limits opportunities for distance education (MOOCs) and limits a student's capability to learn at an individual pace. Furthermore, it can be difficult to evaluate student performance in complex design assignments due to the variability of student responses. This problem is exacerbated when students work in teams, as accurate evaluation based on individual effort is difficult to implement (Dutson, Todd & Magleby, 1997).

There thus exists a need for complementary tools to augment existing design education in the online space. These tools need to replicate, as closely as possible, authentic design experiences and surround students in the design ethos. The learning tools should aim to minimize the student's cognitive load, in line with cognitive load theory principles (Sweller, 1988). Cognitive load is described as the mental effort required of the working memory to complete a task or solve a problem. The design of instructional material can lead to three types of cognitive load being imposed on the learner; intrinsic load, extraneous load and germane load. Intrinsic load is determined by the complexity of the task being undertaken, extraneous load refers to the load that is experienced by learners when there are instructions present that are not beneficial to student learning, and finally germane load refers to the beneficial instructional features that contribute to learning taking place. The goal of the tool is to reduce extraneous load, so as to insure that valuable cognitive resources are instead used in the intrinsic load, that is, learning the technical material.

One of the proposed solutions is using adaptive workshops, made up of adaptive toolboxes in design education (Ben-Naim, Marcus & Bain, 2008). Adaptive toolboxes are made up of the mathematical tools necessary to solve engineering problems and design solutions, and result in Adaptive Tutorials. ATs cater to students by adapting the interactive elements to an individual student's level of understanding. Learning adaptively within the tutorials can be used to overcome the constraints of limited resources while providing students with improved and personalised support when and where they want it. Adaptive tutorials provide a complete feedback loop to the students. They are designed so that a student is able to interact with a simulation whilst being guided, and given unique feedback

based on student input into the system (Marcus, Ben-Naim & Bain, 2011; Prusty, Russell, Ford, Ben-Naim, Ho, Vrcelj, Marcus, McCarthy, Goldfinch, Ojeda, Gardner, Molyneaux & Hadgraft, 2011b; Prusty, 2010 & 2011; Prusty & Russell, 2011; Prusty, Ben-Naim, Ho & Ho, 2011a; Ben-Naim & Prusty 2010).

Online ATs are already well established in engineering science courses. Positive results have been shown in domains such Mechanics (Khawaja, Prusty, Ford, Marcus & Russell, 2013; Prusty, Russell, et al., 2011b), Electronics (Scott, Balsom, Round, Peter & Harlow, 2013), and Medicine (Polly, Marcus, Maguire, Belinson & Velan, 2014; Morgulis, Kumar, Lindeman & Velan, 2012; Velan, Ben-Naim, Kumar, Bain, Kan & Marcus, 2009), and even in construction management (Kamardeen, 2014). Furthermore, this project analysed the developed adaptive tutorials in terms of student cognitive load, by using a survey instrument developed by Leppink, Paas, Van der Vleuten, Van Gog, and Van Merrienboer (2013). Overall, adaptive tutorials could form a promising solution that could bring many benefits to the global field of engineering design education.

1.2 Project Aims and Outcomes

1.2.1 Aims

The aims of the project were as following:

i) Provide on-demand access to authentic design experiences with guided support and immediate, tailored feedback for the students.

ii) Provide students with a Learner environment to work on an adaptive design activity. Teachers should be able to access an Analyser tool to learn about student mistakes and possibly further adapt the content to learning needs.

iii) Reduce the ongoing costs associated with running design courses by reducing the need for physical design workshops and laboratories.

iv) Allow for individual assessment of student performance in design tasks in a timely and efficient manner.

v) Reduce the load on teachers, engaged in teaching design courses in engineering. Providing an authentic online preparatory tool for design class allows more time to focus on higher order concepts and class discussion and to address any individual learning needs.

vi) To develop the software using an eLearning platform that will allow the collaboration and sharing of knowledge within the engineering design faculty across Australia.

1.2.2 Outcomes

The primary outcomes of this project include the following:

1) *Development of Adaptive Virtual Workshop composed of Adaptive Tutorials*: tutorials were developed as described in the initial grant request in the disciplines of Mechanical Engineering (three tutorials), Civil Engineering (one tutorial), Aerospace

Engineering (one tutorial), Naval Engineering and Architecture (one tutorial), Architecture (two tutorials).

2) *Incorporation of ATs into the course curriculum*: All seven ATs have been incorporated and implemented throughout courses at various universities with the following numbers: Semester 1, 2013 (304 students); Semester 1, 2014 (241 students); Semester 2, 2014 (470 students); Semester 1, 2015 (392 students); Semester 2, 2015 (576 students).

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4) *Professional development of staff in the use of adaptive design software*: Two training sessions have been held to assist academics in familiarising themselves with the design software and detailing what can be achieved.

5) *Availability of online support materials*: A set of support materials including screencasts, previews of all tutorials, how-to guides for all the tutorials created and further tutorial and information presentations have all been collated and are available online (this information can also be accessed through the AMN website in the FAQ section): http://adaptive-virtual-workshop.eng.unsw.edu.au

These resources and their associated information form some of the major achievements of this project. The adaptive tutorials have immediate and practical effects when implemented in higher education to improve overall assessment, engagement and understanding of threshold concepts. The presence of the web portal allows the project to have longevity and encourages the use, discussion and editing of the tutorials for years to come.

The final report describes the achievements of this multi-institutional approach to engineering design education, the dissemination strategies, the final adaptive tutorials and the results of implementation. It summarises the positive implications for individual learners and for the teaching staff in the area of engineering education with the use of ATs.

2 Development of Adaptive Toolboxes

Adaptive Toolboxes assemble and integrate the mathematical tools and concepts required to perform a relatively simple but authentic design task, such as designing a beam. The toolboxes provide the student with a guided design and analysis procedure known as the design loop as well as links to any relevant resources that can be explore further by the students (Figure 1). Altogether seven Adaptive Toolboxes were developed in five engineering disciplines: Mechanical Engineering (Flywheel, Beam and Welding designs); Civil Engineering (Column design); Aeronautical Engineering (Stiffened panel design); Naval Engineering and Architecture (Barge design), and one AT developed for use in Architecture (Lighting design). Screenshots of all the adaptive tutorials can be found in Appendix C.

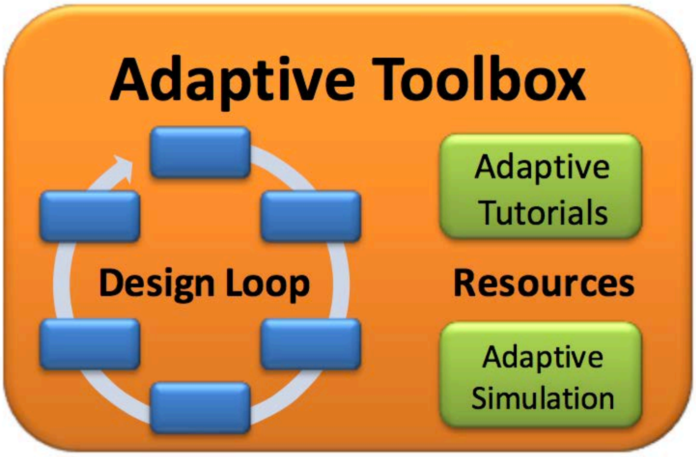

Figure 1: Schematic for an Adaptive Toolbox

2.1 Mechanical Engineering

2.1.1 Flywheel design

The flywheel tutorial (for screenshots, please refer to Appendix C: Adaptive Tutorial Screen Shots) teaches students how to design the axle of a stationary bike and an accompanying flywheel. There are many ways in which students can alter their designs and allowing the opportunities for creativity and experimentation. The final slides contain summary videos discussing practical design issues and summary sheets detailing design costs based on student selections. The summary sheet also contains estimated values of other designs, which forces students to reflect on their design choices.

2.1.2 Beam design

In the beam design tutorial (for screenshots, please refer to Appendix C: Adaptive Tutorial Screen Shots), students are provided with the assumed loads acting on a column holding up a garage and asked what type of cross section would be appropriate from a choice of three, based on standards and previous knowledge. Unlike other tutorials, this tutorial was designed to be linear. The purpose was to teach students how to follow the AS4100 in a range of different cases. To make the tutorial more dynamic, students that chose a cross section that was inadequate were asked to redesign their cross section. This

encouraged students to think more critically about the properties of the cross section instead of choosing one at random.

2.1.3 Design of welds

The welding tutorial required students to calculate the ideal weld thickness required to weld pieces of metal together (for screenshots, please refer to Appendix C: Adaptive Tutorial Screen Shots). Students are asked to perform three separate weld calculations and choose appropriate cross sections. Different arms of the metal welded requires calculations varying in complexity and students are encouraged to think critically at each stage of the tutorial through personalised feedback given to them at each step based on their inputs.

2.2 Civil Engineering

2.2.1 Column Design

The column tutorial allows students to design a beam that will be suitable for holding up part of a garage (for screenshots, please refer to Appendix C: Adaptive Tutorial Screen Shots). The process involved is in accordance with the AS4100; a document that contains legal restrictions on the dimensions and type of beam used. Students are allowed to choose what type of beam to use and are given step-by-step feedback to help them follow the AS4100.

2.3 Naval and Ocean Engineering

2.3.1 Barge Design

The Barge Tutorial teaches students how to design the cross section of a barge such that it can withstand a distributed load (for screenshots, please refer to Appendix C: Adaptive Tutorial Screen Shots). The design of the AT is unique for each student because it utilizes randomized loads and allows students to design the cross-section based on their preferences. At the end of the tutorial, students are also show different design decisions and how they can affect the structure design.

2.4 Aerospace Engineering

2.4.1 Design of a Stiffened Panel

This tutorial investigates the design of a stiffened panel in an airplane wing (for screenshots, please refer to Appendix C: Adaptive Tutorial Screen Shots). The tutorial aims to provide the students with a more dynamic way to explore the variety of factors required in wing design, using a highly interactive simulation. Students are able to modify skin thickness and stiffener pitch components of their design whilst being informed of the repercussions of their choices in terms of price and material quality.

2.5 Engineering and Architecture

2.5.1 Introduction

Throughout the progress of this project, there were some issues with a development of an Architecture design tutorial (as described in more detail in the six-monthly and annual

reports). Thus, there was a need to design a tutorial that could cater to the architectural side of design. After meetings with a number of different academics in the field of Architecture, a tutorial was developed in conjunction with Engineering Principles - to be implemented in a first year Architectural Engineering subjects.

2.5.2 Design for Functionality

In this tutorial students are taught how to use an adjacency matrix (for screenshots, please refer to Appendix C: Adaptive Tutorial Screen Shots). Students are shown a video about the UNSW Tyree building and are asked to think about the proximity of different areas around the building. No answers are incorrect, but automatic feedback is triggered to advise students of conventional design practices.

2.5.3 Planning and Design of a Cantilevered Staircase

The aim of this tutorial was to teach students to design and plan a staircase build using their knowledge of engineering and architecture principles, including the Australian Engineering Standards and architectural design knowledge. The design is performed in groups, and students are asked to write a report to advocate the design of their particular staircase, with other teams grading the aesthetics and practicality through subjective criteria. This tutorial encourages teamwork, engineering and architectural thinking, whilstmaximising student engagement throughout the design and 'build' process.

3 Implementation

3.1 Adaptive Toolboxes

A cross-institutional approach to implementation was adopted with a number of ATs being implemented in different institutions. Table 1 details the implementation statistics, including the number of students involved in the implementation. Tutorials were implemented with ethics approval (Appendix B) in engineering subjects over the course of Semester 1 and Semester 2, 2014, as part of course curriculum. All students undertaking the tutorials were undergraduate students at varying levels of their engineering degrees. For instance, the ATs implemented as part of the mechanical engineering design curriculum were given to 2nd year engineering students, often providing students with their first experience of engineering design. Civil Engineering Design tutorial was also implemented in a 2nd year engineering course, whereas the Naval Architecture and Aerospace Engineering Design tutorials were undertaken by 3rd year students, who have been exposed to previous design problems in earlier years of their degree.

Table 1: Implementation of ATs

Discipline	AT Implemented	Semester Implemented	Class Size (students)	% Completion
Mechanical Engineering Design (UNSW	Welding Design	Session 2, 2014	193	81%
		Session 2, 2015	188	Pending

Australia)	Flywheel Design	Session 1, 2014	138	30%
		Session 2, 2014	191	93%
		Session 2, 2015	188	97%
	Beam Design	Session 1, 2013	304	91%
		Session 1, 2015	331	94%
Civil Engineering (WSU, Sydney)	Column Design	Session 1, 2015	61	2%
		Session 2, 2015	122	89%
		Session 2, 2015 (Griffith University)	Currently in progress	Currently in progress
Naval and Ocean Engineering (UTas, Tasmania)	Barge Design	Session 2, 2014	26	50%
Aerospace Engineering (UNSW Australia)	Stiffened Panel Design	Session 1, 2014	13	100%
		Session 2, 2014	11	100%
		Session 2, 2015	26	100%
Architecture (UNSW Australia)	Design for functionality	Session 2, 2014	49	2%
		Session 2, 2015	52	56%
Architecture (UNSW Australia)	Cantilevered staircase	Session 2, 2015	Currently in progress	Currently in progress

3.2 Cognitive Load Tutorial Survey

A eleven-point cognitive load survey was developed to understand the cognitive impact of the adaptive tutorials (where 0 means that the statement does not apply to the student at all and 10 means that the statement absolutely applies to the student). The survey examined two types of cognitive load and how these impacted student learning. Firstly, questions 1, 2 and 3 of the survey examined the intrinsic load, determined by the student's prior knowledge and the complexity of the task. Questions 4, 5, and 6 of the survey examined the amount of extraneous load placed on the user, determined by the structure of the presented material and not beneficial to learning. The survey was developed based on an instrument developed by Leppink et al (2013). The current survey did not have a high enough sample size to do confirmatory factor analysis, however, an exploratory factor analysis will be conducted once exam data becomes available, to understand whether exam performance correlated with the factors that represent the intrinsic and extraneous cognitive load. A copy of the survey can be found in Appendix D.

Table 2: Cognitive Load Survey (Column Tutorial – Semester 2, 2015)

		N	Mean	Standard Deviation
INTRINSIC LOAD	Q1: The topic covered in this tutorial was very complex	N=104	5.90	2.88
	Q2: The tutorial covered formulas that I perceived as very complex	N=107	5.74	2.97
	Q3: The tutorial covered concepts and definitions that I perceived as very complex	N=106	6.03	3.02
EXTRANEOUS LOAD	Q4: The instructions in the tutorial were very unclear	N=107	4.53	3.68
	Q5: The instructions in the tutorial were ineffective to my learning	N=107	4.57	3.71
	Q6: The instructions in the tutorial were full of unclear language	N=105	4.00	3.76

3.3 Adaptive Mechanics Network (AMN)

Over the last five years, UNSW Australia and other partner universities have invested significant amounts of time and resources into creating and enhancing adaptive mechanics resources in the form of adaptive tutorials. There have been two projects, supported by the Australian Government funding through ALTC (ID CG10-1586) and OLT (ID13-2837) that have helped to create content in the fields of Engineering Mechanics, Mechanics of Solids and Design in Engineering and Architecture fields. Each of these has been a separate project, despite all the tutorials being relevant to one another and potentially building one on another. The resources have been created with the intention of being used in their respective schools to help train undergraduate and postgraduate students in a more efficient and more engaging manner.

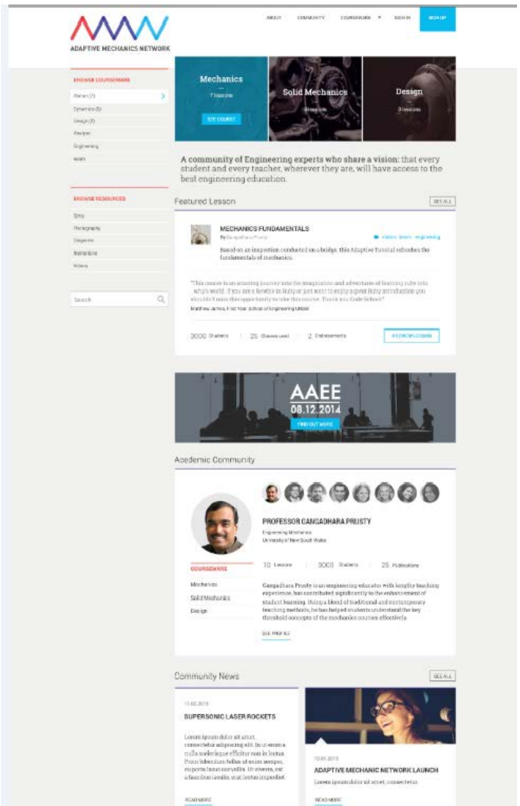

Figure 2: AMN screenshot

Effective collaboration and the sharing of educational knowledge and resources are required to improve engineering education both in Australia and globally. With this mind, the Adaptive Mechanics Network (AMN) was launched. The network aimed to create an expert community portal, and an online access point, which can help to ensure sustainability of the last two projects, undertaken with the support of OLT. Furthermore, the AMN provides a central repository for the collaborative work and contribution of Australian academic community to an engineering image collection, and an adaptive tutorial collection covering the foundational mechanics concepts, covered in most engineering disciplines. It is envisaged

that this will help to expand the community of practice to date and additionally ensure project longevity and sustainability (Figure 2).

The goal of the AMN is to facilitate such a network of Australian academics working collaboratively and sharing knowledge, ensuring the sustainability of developed resources.

4 Key Findings

Detailed data analysis can be found in the following publications that are included as Appendices:

Conference Papers:

Vassar A; Prusty BG; Marcus N; Ford R, (2014), 'The virtual design workshop: An online adaptive resource for teaching design in engineering', in *CSEDU 2014 - Proceedings of the 6th International Conference on Computer Supported Education*, SciTePress, pp. 452 - 458, Barcelona, Spain, 1-3rd April 2014

Vassar, A., Prusty, G., Burton, L., Do, J. H., Ford, R., James, M., ... & White, T. (2014). The Adaptive Virtual Workshop: Maintaining student engagement through an on-line adaptive resource for engineering design education. In *25th Annual Conference of the Australasian Association for Engineering Education* (pp. 1-12), Wellington, New Zealand, 8-10 December 2014.

Vassar A; Prusty BG; Marcus N, (2015), 'The Adaptive Virtual Workshop: improving engineering education with the use of online adaptive tutorials', In *Proceedings of the 6th Research in Engineering Education Symposium,* Dublin, Ireland, 13-15th July 2015

Poster presentations:

Vassar, A., Prusty, B.G. & James, M., (2014). The Adaptive Virtual Design Workshop: how adaptive tutorials can improve learning by providing personal customised feedback to students. *UNSW Learning Teaching Forum: Personalised Learning. What is it? How do we do it*? (8th October)

Vassar, A., Prusty, B.G. & James, M., (2014). The Virtual Design Workshop: the role of adaptive tutorials in providing immediate tailored feedback to students. *UNSW Learning and Teaching Forum: Moving Feedback Forward: Innovation and Opportunity*. (9th May)

Vassar, A. et al., (2013). Virtual Design Workshop for Engineering and Architecture. *UNSW Learning and Teaching Forum: Engaging Students in the Blended Learning Landscape*. (1st November)

Overall, preliminary data supports the use of the Adaptive eLearning Platform in developing learning experiences that are rich in their interactive elements, are able to target threshold concepts and are engaging enough to maintain student attention. Students found the tutorials to be an engaging method of interaction, and beneficial to their learning outcomes. Across all the students surveyed, in all disciplines, 68 per cent of students

indicated that they would like to use adaptive tutorials in other subjects in the curriculum (Figure 3). Additionally, 67 per cent of students felt that the adaptive tutorial completed benefitted them for their more advanced design exercises and further design subjects (Figure 4). The vast majority of surveyed students, 73 per cent, also indicated that they found the adaptive tutorial a useful tool in learning about and understanding the design loop concept in engineering (Figure 5).

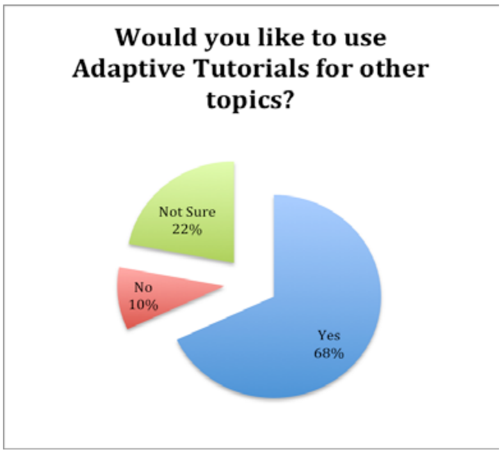

Figure 3: Survey results to question: Would you like to use Adaptive Tutorials for other topics?

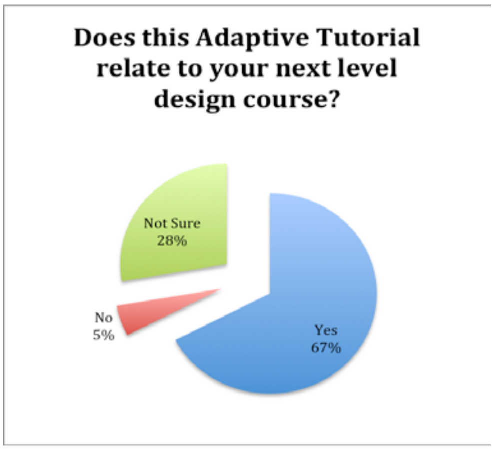

Figure 4: Survey results to question: Does this AT relate to your next level design course?

The increased flexibility, ability to practice concepts at the pace of the individual student and improved feedback mechanisms have contributed to the popularity of the adaptive tutorials in engineering design courses, as part of this study. Some of the student feedback received in the surveys indicates that the feedback received by the students was valuable in guiding their learning with some direct quotes:

"The comments are quite useful and directed towards what you are actually wanting to know. This is quite useful…"

"This teaches us straight if we are wrong or not and this allow us to concentrate to understand much better as we are given feedback straight away…"

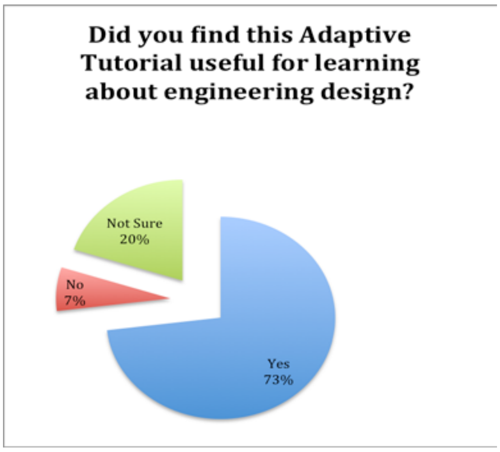

Figure 5: Survey results to question: Did you find this AT useful for learning about Engineering Design?

Students found the tutorials easy to navigate, with only 12 per cent of students strongly disagreeing or disagreeing that the interactive elements were easy to work with and learn (Figure 6). A large portion of students also preferred using the Adaptive Tutorials in comparison to traditional written assignments, with only 11% disagreeing or strongly disagreeing to this preference (Figure 7).

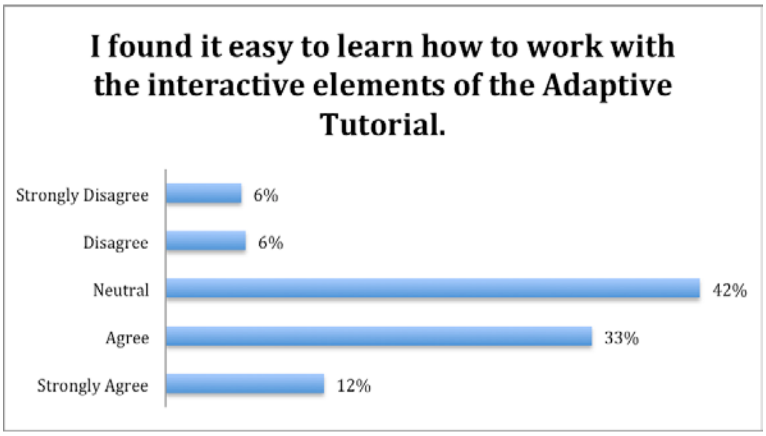

Figure 6: Survey results to question: I found it easy to learn how to work with the interactive elements of the Adaptive Tutorial

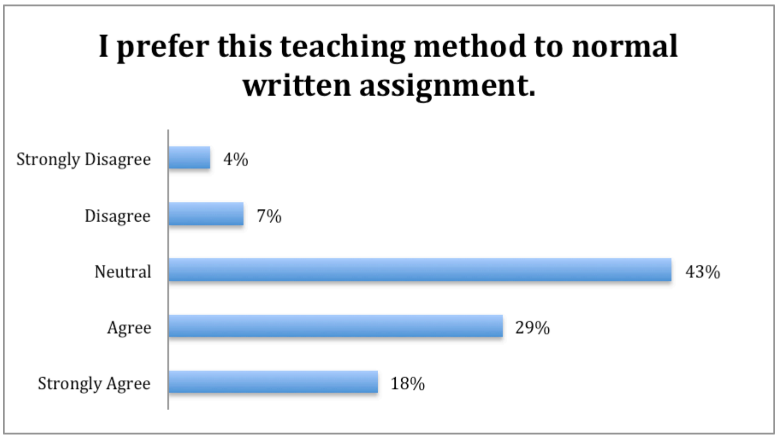

Figure 7: Survey results to the question: I prefer this teaching method to normal written assignments.

There were a few technical difficulties with some good student feedback received and implemented to improve further iterations of adaptive tutorials. In particular the following comments stood out:

“I really like these tutorials. They are an excellent ways to learn. However, in this particular tutorial some instructions were unclear/misleading, which is very frustrating. Also, the software makes marking mistakes. But apart from that, it's pretty good...”

“Was a good learning experience, however this tutorial had many glitches, could not go back to check previous shear forces needed for the current questions and other dimensions etc. most of marks were lost here…”

A new survey for tutorials implemented in Semester 2, 2015 examined student response to the adaptive tutorial feedback and their overall satisfaction with adaptive tutorials. A ten-point scale was used, with ‘0’ meaning does not apply to the student at all and ‘10’ meaning that it completely applies to the student. This survey was used to follow up a column design tutorial, implemented at Western Sydney University, in a second-year Civil Engineering course in Semester 2, 2015, showed the following results:

Table 3: Student satisfaction survey results (Column Tutorial, Semester 2, 2015)

	Number of students	*Mean*	*SD*
Q1: The feedback provided to me in the tutorial was sufficient	102	7.54	2.254
Q2: The feedback provided to me in the tutorial really helped me to understand the topic	100	7.81	2.168
Q3: The tutorial really enhanced my understanding of Engineering Design	101	7.68	2.177
Q4: The tutorial really enhanced my understanding of the formulas covered	101	7.75	1.920
Q5: I prefer this method of learning to traditional written assignments	101	7.46	2.598
Q6: I would like AT’s used in my other subjects	103	7.39	2.583

The survey showed that the students overall were satisfied with the feedback that they were provided with in the tutorials and that the feedback helped them to understand the subject matter. Furthermore, students were positive in their engagement with the adaptive tutorial preferring this method of learning to traditional written assignments and would like to see ATs used in other subjects.

5 Dissemination

During the project the project team undertook the following dissemination activities:

1) Poster of project was accepted and presented at the 2013 Learning and Teaching Forum held at UNSW in November 2013. UNSW learning and teaching forums are designed to bring together the university community to explore a key priority in learning and teaching, with the participation rate of at least 100 academics and administration staff from differing disciplines. Poster titled: “Virtual Design Workshop for Engineering and Architecture”.

2) Paper accepted and presented at the 2013 Australasian Association for Engineering Education (AAEE) Annual Conference, held at Griffith University on the Gold Coast, 8-11 December, titled: "Adaptive Tutorials for Design in Engineering".
   The annual AAEE conference gathers large numbers of engineering educators in Australasia to discuss engineering education research and best practice.
3) Brochure prepared and distributed at the 2013 Australasian Association for Engineering Education (AAEE) Annual Conference, held at Griffith University on the Gold Coast, 8-11 December
4) Short paper accepted and presented at CSEDU 2014, 1-3 April 2014 in Barcelona, Spain – The International Conference on Computer Supported Education, titled: "The Virtual Design Workshop: An on-line adaptive resource for engineering".
   The conference aims at becoming a yearly meeting place for presenting and discussing new educational environments, best practices and case studies on innovative technology-based learning strategies, institutional policies on computer supported education including open and distance education, using computers.
5) Professor Prusty was invited by The University of Sydney and The University of Adelaide to talk about the OLT project and the use of adaptive tutorials in April 2014.
6) Presentation by Professor Prusty in India at KIIT India, regarding the OLT project and the use of adaptive tutorials in January 2014.
7) Poster of project was accepted and presented at the 2014 Learning and Teaching Forum held at UNSW on the 9th May 2014, with the subject of: "Moving Feedback Forward: Innovation and Opportunity."
8) Poster of project was accepted and presented at the 2014 Learning and Teaching Forum held at UNSW on the 8th October 2014, with the subject of: "Personalised Learning. What is it? How do we do it?"
9) Professor Prusty was invited to give a presentation in the 2014 International Association for Continuing Engineering Education (IACEE) 14th World Conference, hosted by the Stanford Center for Professional Development at Stanford University on the 24-27th June 2014. The highlight of the presentation was; Smart Partners: Business & Academia Creating Adaptive Technology to Improve Student Outcomes in Engineering.
10) Paper (detailing the preliminary results of the implementation of the Mechanical Engineering adaptive tutorials) was accepted and presented at the 2014 Australasian Association for Engineering Education (AAEE) Annual Conference (December 2014, Wellington, New Zealand). Paper title: "The Adaptive Virtual Workshop: Maintaining student engagement through an on-line adaptive resource for engineering design education".
11) Workshop was presented in conjunction with Smart Sparrow at the AAEE Conference in December 2014 discussing the results of using adaptive tutorials in Engineering, in Wellington, New Zealand.
12) Paper presented at the Research in Engineering Education Symposium (REES 2015) in Dublin, Ireland, 13-15 July 2015. Paper titled, "The Adaptive Virtual Workshop: improving engineering education with the use of online adaptive tutorials".
13) Professor Prusty presented and led a successful seminar on 13th February, 2015 at the Queensland University of Technology on the subject of "Adaptive eLearning: Pathway for feedback and feed forward".

6 Lessons Learnt

The following is a list of the key lessons learnt from this project that can be applied to further research and work in the area:

1) Development of ATs – the development of ATs can be improved by the use of simulations, however, this may require specialist designer/coder skills. The project would have benefitted if a skilled simulation developer was hired in the beginning as well. All tutorials now have been updated with simulations and are ready for the next implementation. However, the presence of rich simulations to allow students to interact with their design could greatly improve the current tutorial design.

2) Use of ATs in context – student and instructor feedback has indicated that to achieve the best outcomes when using adaptive tutorials, it is important that the tutorials are used in context with the content being covered in class. This makes it vital, that tutorials are developed in consultation with the lecturers in charge to coordinate timing of particular concepts and to ensure that the correct concepts are covered in a timely manner coinciding with lecture and tutorial design.

3) Group Work – a lot of engineering design work involves working in groups. This is a complex task to implement as an assignment or project, largely due to the inability to measure individual student contributions. It is recommended that an examination of the current design workshops be undertaken to determine the platform's suitability for group work, and for the suitability of adaptive tutorials in group work course components overall. One of the recommendations, is to work on implementing a group based adaptive tutorial task, to examine whether adaptive tutorials can be used in a group setting. Such a task would require the design of the tutorial in such a way as to encourage collaborative work within the team, whether it be by assigning a specific role to each student within a group or by allowing the students to do this within their own discussion forum so as to mirror the way it is done in the industry. In either case, it would be important to allow collaborative student discussions within a group forum, a collaborative simulation that students can modify within their group and work on together without having to be face-to-face with each member of their group, i.e. allowing remote interaction at a time suitable to that group. Another important component that would be required is the ability of each group to receive individualised feedback based on their group design and performance. This would require a flexible design paradigm to be developed in conjunction with the releavant academic staff, so as to address common threshold concepts encountered by students within the relevant engineering discipline.

4) Analysis – this project has yielded a rich source of data that can be further analysed to examine the effective use of adaptive tutorials in engineering design. One recommendation here is to implement a less quasi-experimental experimental approach. This would mean that within the same class intake, some students would randomly have access to the adaptive tutorials to aid in their learning whilst others would not. Such a design would allow a more specific understanding of what impact adaptive tutorials might have on overall student performance and engagement with the engineering design subject. One issue with performing such an experimental

setup would be whether some students (those with no access to adaptive tutorials) feel that they have been unfairly provided with not all possible instructional material – this also impacts ethics approval for such a design, as a cohort of students within the class would be disadvantaged. One potential way to overcome this issue is to allow the adaptive tutorials to be optional – to be completed at the students own discretion. However, this could be problematic if no one decided to use the tutorials or if everyone uses these. Certainly, the possibility of a more rigorous experimental design can be considered and how this fits within the realistic classroom environment.

7 Conclusion and Final Remarks

The construction of authentic learning experiences in Engineering Design courses is a complex undertaking, and is often influenced by physical and financial constraints. This project has sought to combat these issues by investigating the effectiveness of using ATs in engineering design education. The proposed framework of ATs implemented as part of the engineering design curriculum has been shown to be successful in increasing student engagement, understanding of subject matter and enhancing learning outcomes.

The evaluation of this project's aims has involved a cross-institutional approach, with the participation of six universities and six individual engineering disciplines. The next few years will provide a rich resource of data and comparisons as to the final performance of students who have been given ATs and those that have not participated in ATs.

The project resources will continue to be updated and enhanced in the future and can be accessed at: https://adaptivemechanics.edu.au Anyone who would like to participate in the research and use the resources, please contact the Project Lead, Professor Gangadhara Prusty at: g.prusty@unsw.edu.au.

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Appendix A

Certification by Deputy Vice-Chancellor (or equivalent)

I certify that all parts of the final report for this OLT grant/fellowship (remove as appropriate) provide an accurate representation of the implementation, impact and findings of the project, and that the report is of publishable quality.

Name: ....Date: 23-10-15

Appendix B: Ethics Approval

THE UNIVERSITY OF
NEW SOUTH WALES

HUMAN RESEARCH ETHICS ADVISORY
PANEL 'H'
SCIENCE & ENGINEERING

11 December 2013

Dr Gangadhara Prusty
School of Mechanical & Manufacturing Engineering

Re: **The evaluation of an on-line adaptive eLearning resource for engineering and architecture**

Reference Number: 08/2013/85

Dear Dr Prusty

At its meeting of 10th December 2013 the Human Research Ethics Advisory Panel 'H' was satisfied that this project is of minimal ethical impact and meets the requirements as set out in the National Statement on Ethical Conduct in Human Research*. Having taken into account the advice of the Panel, the Deputy Vice-Chancellor (Research) has approved the project to proceed.

Your Head of School/Unit/Centre will be informed of this decision. This approval is valid for 12 months from the date of the meeting.

Yours sincerely

Professor Mike Regan
Panel Convenor
Human Research Ethics Advisory Panel 'H'

Cc: Head of School
Prof Anne Simmons
School of Mechanical & Manufacturing Engineering

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THE UNIVERSITY OF
NEW SOUTH WALES

HUMAN RESEARCH ETHICS ADVISORY
PANEL 'H'
SCIENCE & ENGINEERING

12 September 2014

Dr Gangadhara Prusty
School of Mechanical & Manufacturing Engineering

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Reference Number: 08/2013/85

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Your request for a modification to your application has been approved for a further 12 month period ending September 2015. You may proceed continue with your research.

Yours sincerely

Professor Mike Regan
Panel Convenor
Human Research Ethics Advisory Panel 'H'

Cc: Head of School
Prof Anne Simmons
School of Mechanical & Manufacturing Engineering

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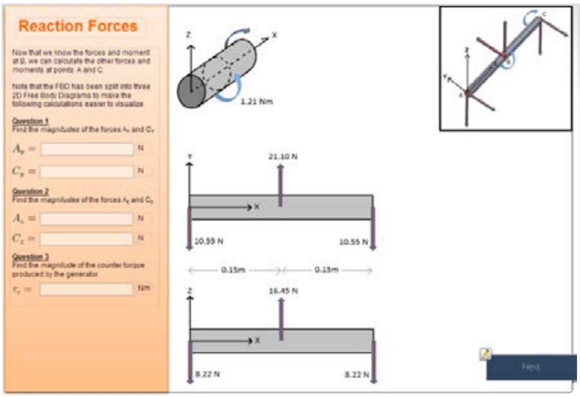
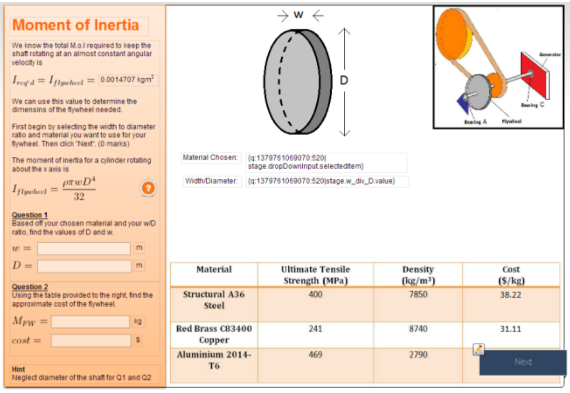
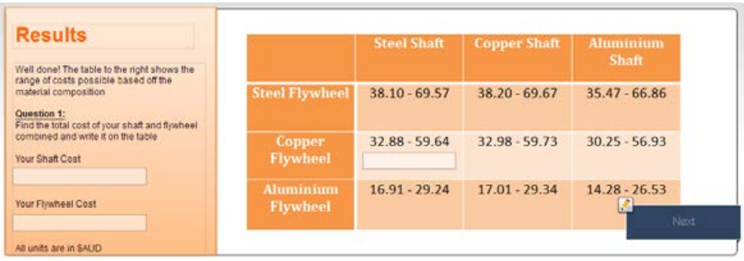
Appendix C: Adaptive Tutorial Screen Shots

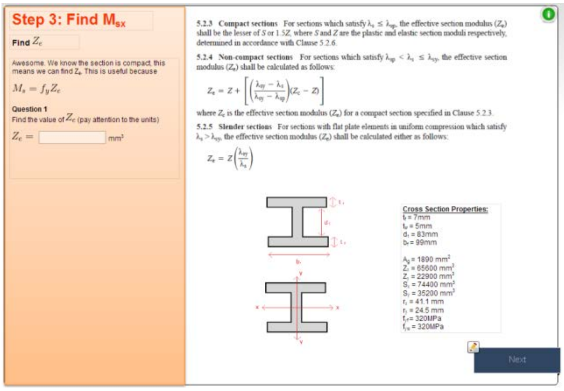
Flywheel Design Tutorial

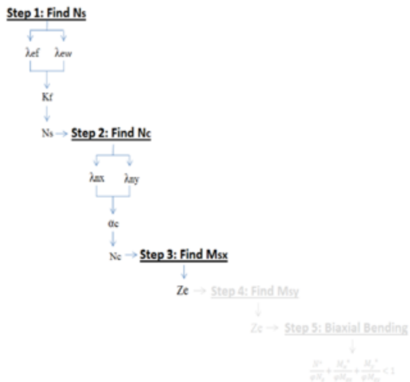




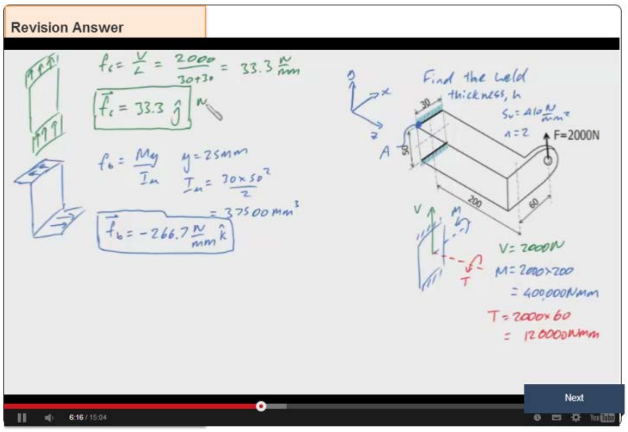


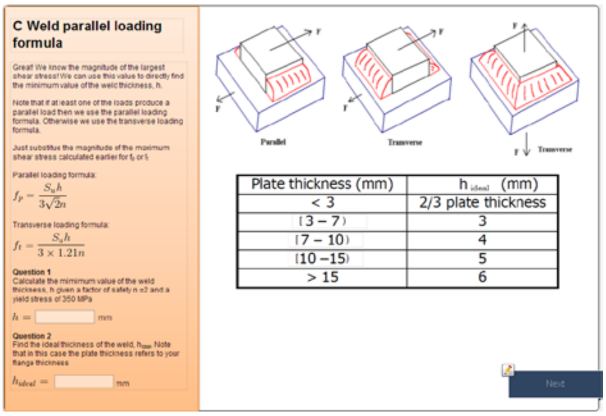
Beam Design Tutorial

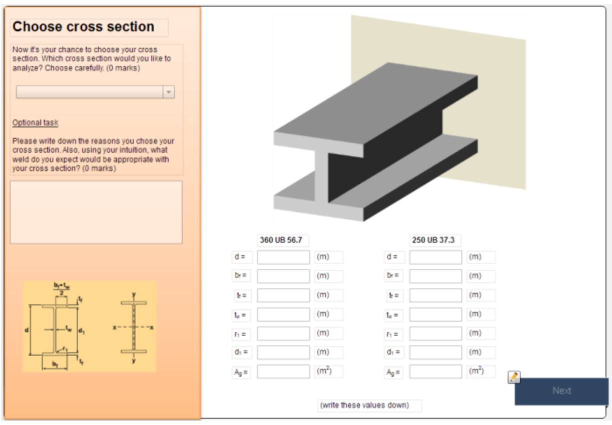




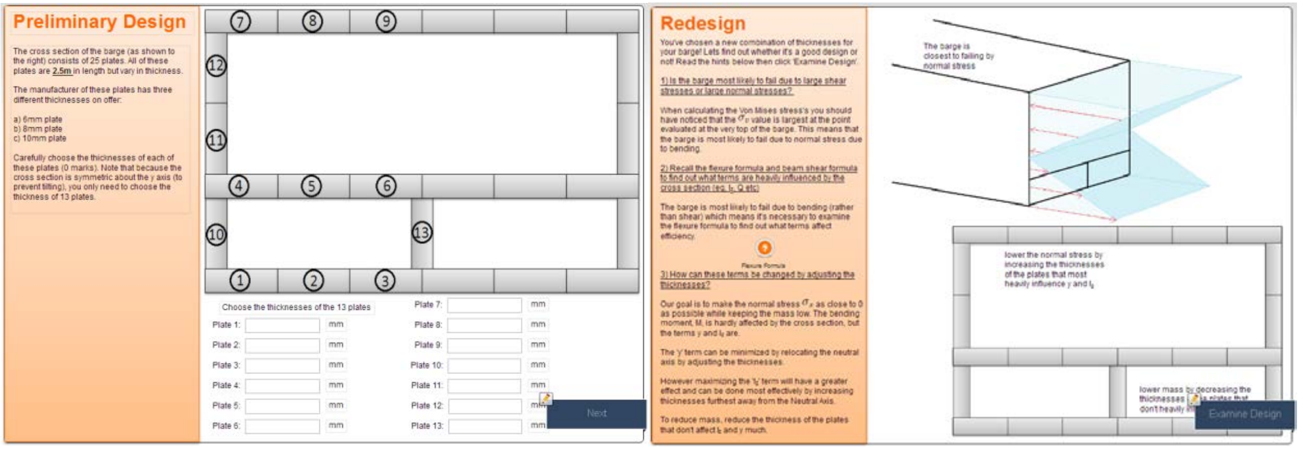
Design of Welds Tutorial

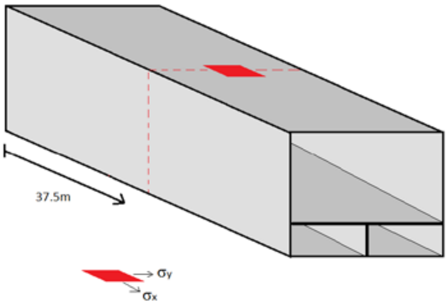






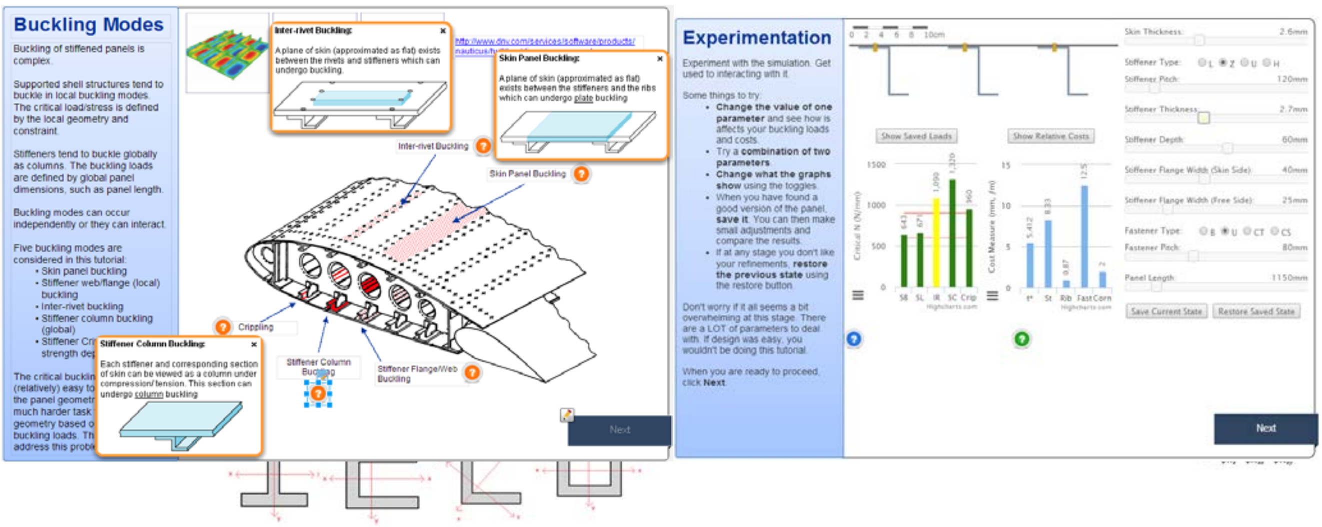
Column Design Tutorial



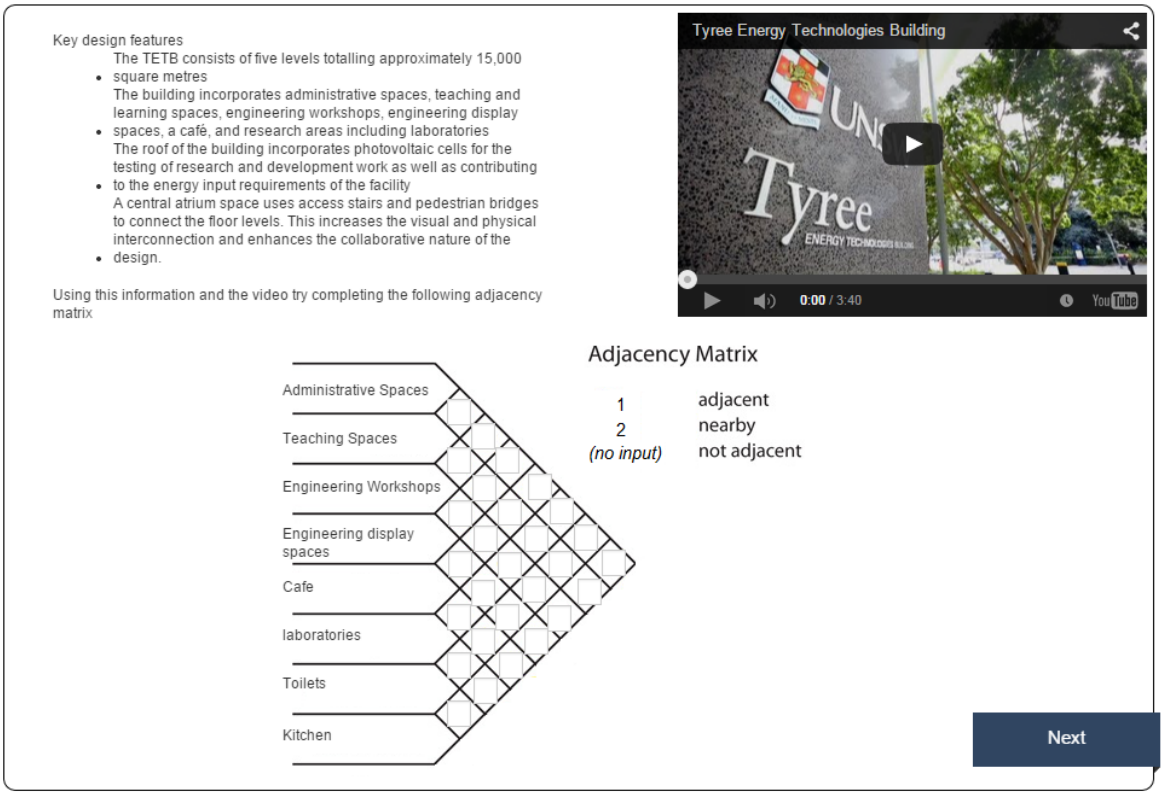


Barge Design Tutorial

Stiffened Panel Design Tutorial



Design for Functionality Tutorial



Appendix D: Cognitive Load Survey

Feedback - 0 Marks

The topic covered in this tutorial was very complex

0 does not apply at all — 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9 — 10 applies to me completely

The tutorial covered formulas that I perceived as very complex

0 does not apply at all — 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9 — 10 applies to me completely

The tutorial covered concepts and definitions that I perceived as very complex

0 does not apply at all — 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9 — 10 applies to me completely

The instructions in the tutorial were very unclear

0 does not apply at all — 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9 — 10 applies to me completely

The instructions in the tutorial were ineffective to my learning

0 does not apply at all — 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9 — 10 applies to me completely

The instructions in the tutorial were ineffective to my learning

0 does not apply at all — 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9 — 10 applies to me completely

The instructions in the tutorial were full of unclear language

0 does not apply at all — 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9 — 10 applies to me completely

The feedback provided to me in the tutorial was sufficient

0 does not apply at all — 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9 — 10 applies to me completely

The feedback provided to me in the tutorial really helped me to understand the topic

0 does not apply at all — 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9 — 10 applies to me completely

The tutorial really enhanced my understanding of Engineering Design

0 does not apply at all — 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9 — 10 applies to me completely

The tutorial really enhanced my understanding of the formulas covered

0 does not apply at all — 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9 — 10 applies to me completely

I prefer this method of learning to traditional written assignments

0 does not apply at all — 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9 — 10 applies to me completely

I would like AT's used in my other subjects

0 does not apply at all — 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9 — 10 applies to me completely

Any other comments