Promoting student engagement and continual improvement: Integrating professional quality management practice into engineering curricula

Final report 2015

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Engineering academics: This project would not have been possible without engineering academics agreeing to participate in the trial.

Engineering students: The main findings of this project have been concluded by reviewing and evaluating the perceptions of engineering students who participated in the trial.

List of acronyms used

AAEE	Australasian Association of Engineering Education
ACED	Australian Council of Engineering Deans
ADLT	Associate Dean Learning and Teaching
CEME	Civil, Environmental and Mining Engineering
EA	Engineers Australia
IMPEL	Impact Management Planning and Evaluation Ladder
KBR	Kellogg Brown and Root Pty Ltd
MaSEE	Management System for Engineering Education
MEA	Mining Education Australia
OLT	Australian Government Office for Learning and Teaching
UoA	The University of Adelaide

Executive summary

Project context

Traditional teaching assesses the competency of the individual, while industry requires and promotes collaborative effort. To improve the alignment between the professional work and the higher education learning environments, this project has incorporated a quality management process and design verification into undergraduate engineering curricula. The learning and teaching tools developed in this project encourage a move towards a culture of peer-generated feedback and review for continual improvement.

Aim of project

The main purpose of this seed project was to develop a design verification online teaching resource for trial. Its implementation would allow the project team to understand how the teaching strategy could be transferred to other disciplines and institutions as part of a wider dissemination process. In addition, the trial would serve to introduce the concept of using adapted industry management system processes in the curriculum, and set the scene for change and further development.

Project outcomes and deliverables

Completion of the project resulted in three main deliverables: (i) exemplar teaching package; (ii) research publications; and (iii) management framework. For the quality management process of design verification, the preparation of an exemplar teaching resource package included an adapted industry template for student use; a student online learning module; and a teacher implementation guide. The work was published as part of three conference papers, including two papers at the 2013 and 2014 Australasian Association for Engineering Education (AAEE) conference. In addition the design verification process, as a learning and teaching tool, was embedded as part of a newly developed framework, the Management System for Engineering Education (MaSEE), to incorporate industry processes in the undergraduate engineering curriculum.

Project impact

To assess and set the scene for change and to encourage the uptake of this teaching strategy by potential adopters, dissemination included activities ranging from conference presentations to networking opportunities. In addition, the project featured in both the 2013 and 2014 University of Adelaide Festivals of Learning and Teaching.

The project demonstrated a direct impact on participating students, whereby they improved their understanding of the verification process; improved their understanding of technical concepts presented in their courses; and were given the opportunity to improve their work. On a broader scale opportunities exist for students to further develop required competencies, particularly if further processes are developed within the MaSEE framework.

Recommendations

Given the positive impacts demonstrated by this project the following recommendations are made:

- continue dissemination of the project, to identify and support further adopters
- actively monitor the progress of identified projects investigating industry engagement in the engineering curriculum to leverage and build upon their outcomes
- further develop the MaSEE concept and identified industry processes for adaption
- identify other disciplines to which the concept can be extended.

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1. Introduction

1.1. Background and context

The need for greater connectivity between industry and the engineering curricula has been recognised for a number of years. A significant report prepared for the Australian Council of Engineering Deans (ACED) highlighted the need in 2008 (King, 2008). Its importance is emphasised by ongoing work to identify how industry engagement within the curriculum is undertaken, and how it can be improved (Male & King, 2014).

One of the challenges for engineering educators, when addressing this need, is to identify how authentic industry practice can be incorporated into the curriculum, as the professional work and the learning environments differ. For example, the work environment has an innate culture of collaboration and peer review through the use of corporate management system processes. Conversely, the learning environment has discrete learning and assessment tasks that are designed to demonstrate the competence of the individual. This project exploits an opportunity that has been identified to blend these two environments by adapting industry processes for use in the curriculum as learning and teaching tools.

In 2010 Kellogg Brown and Root Pty Ltd (KBR), a multidisciplinary engineering company, approached the School of Civil, Environmental and Mining Engineering (CEME) at The University of Adelaide (UoA) with an offer to assist with the development of curricula to address an emerging area of concern for them. This concern related to professional engineers having varying levels of knowledge relating to quality management practice. In turn, there were inconsistencies between how the practice was valued and implemented within their organisation and those organisations with which they worked.

The approach by KBR was timely as a review of the Management Stream within degree programs offered by the School of CEME identified quality management as an area for further development. To avoid adding content at the expense of removing (or reducing the emphasis on) existing core material, the project team devised a teaching strategy to embed the content within the curriculum, to complement the existing content and also to add authenticity. This strategy was deemed achievable due to similarities between quality management and learning, with continual improvement a core focus of both practices.

1.2. Design verification for learning and continual improvement

In industry, continual improvement is prominent in an overarching management system. In higher education, students need to be given opportunities to develop and continually improve.

A fundamental management system process, design verification, was used in the first instance to assess the adequacy of the proposed teaching strategy. Verification is applicable to all engineering disciplines. It requires work to be reviewed, and corrected if necessary, prior to the work being delivered or used. More than simply examining the mathematical correctness of a design, verification assesses whether design outputs have met their input requirements (Standards Australia, 2006).

The verification process can be considered as a form of cyclical feedback (Figure 1-1). Cyclical feedback provided by teaching staff has been demonstrated to improve student learning through increased engagement with, and reflection on, feedback prior to the next step (Hounsell, McCune, Hounsell, & Litjens, 2008; Quinton & Smallbone, 2010).

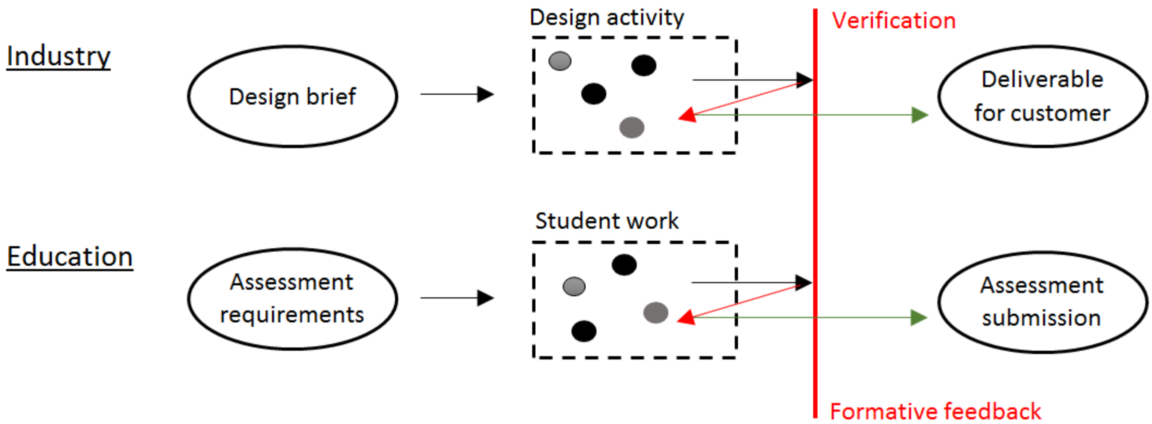

Figure 1-1: Design verification as cyclical formative feedback

A distinguishing feature of the teaching strategy was that the verification feedback was peer-generated. This added another layer of engagement and represented an additional similarity to industry. Peer review has been demonstrated to improve student learning due to increased reflection and engagement (O'Moore & Baldock, 2007; Li, Liu, & Steckelberg, 2010). Li et al. (2010) surmised that the process of reviewing and giving feedback was more beneficial to student learning than just receiving feedback. This supports findings by O'Moore and Baldock (2007) indicating that students used the process to see other possible solutions and sources of error. In industry, it is essential that engineers are comfortable receiving, and also are able to give, critical feedback.

1.3. Project aims

This seed project had three specific aims:

1. to develop a design verification online teaching resource for trial to understand how the implemented teaching strategy can be transferred to other disciplines and institutions (addressed in Section 2)
2. to assess and set the scene for change in the sector to enable the teaching strategy to be up-scaled with additional quality management practices (addressed in Sections 3 and 4)
3. to build the capacity of the project team, including an early career academic who had transitioned from industry to higher education (addressed in Section 5).

2. Exemplar design verification trial

2.1. Teaching resource

A design verification exemplar teaching resource package was developed and trialled to assess whether the positive outcomes achieved during a local pilot trial by the project team (Willis, Foley & Wilson, 2012) could be replicated within different learning environments.

The package was developed progressively throughout the project and participating educators chose the components that suited their teaching practice. The materials developed included an adapted industry design verification template (Appendix A), an online student learning module (Appendix B) and an implementation guide (Appendix C).

Adapted industry design verification template

The template was adapted directly from the KBR Management System and required only minor modifications for use by students. The modifications predominately related to terminology, to reflect that students would be completing an assignment in a course rather than in an industry project. The template included a summary of the design verification process on the reverse side to act as a guide. This is representative of industry where such templates are associated with a documented process, and this was again an adapted version of the KBR process. The template is provided in Appendix A.

Online student learning module

The online student learning module was created as a 30-minute interactive introduction to design verification. The module included a case study to highlight the importance of design verification, an explanation of the process and examples of use. It was created in Articulate Storyline® and included a combination of open-ended interactions and multiple choice questions. The module was designed as a stand-alone package, providing guidance for students together with the template for use. Representative extracts from the module are included in Appendix B.

Teacher implementation guide

The implementation guide was prepared using information from the previous work of the project team and through dissemination activities. It is consistent with learnings on the design of peer assessment tasks from the literature (Ballantyne, Hughes & Mylonas, 2002; van Hattum-Janssen & Lourenço, 2006; Søndergaard & Mulder, 2012). The guide provides an overview of the process and seeks to answer some common questions about the process and its impact. Participants in the trial did not use the guide, rather the project team discussed the main components with each participant when determining how the trial would be conducted. The guide at Appendix C is provided for use by others.

2.2. Trial participants

Interest in the trial was generated at initial dissemination activities (refer Section 4) with the objective of undertaking the trial in Semester 1, 2014. However, differences in human ethics approval requirements among institutions delayed progress with a resulting approval to extend the project timeline. This enabled the trial to be undertaken in Semesters 1 and 2 of 2014.

The trial was conducted in six classes throughout 2014. An overview of the participating classes is provided in Table 2-1. Participants were from four disciplines in two locations. Interest was received from a further three locations, but the academics involved ultimately chose not to participate. Feedback received indicates that this was primarily due to the academics being comfortable with their existing assessment tasks, and hesitation about trying something new.

Table 2-1: Participant summary

Class	Engineering discipline	Location	Class size	Year Level	Trial timing (2014)	Resources used
A	Architectural	Location 1	132	1	Semester 1	Module (Rev 0) Template
B	Mechanical	Location 2	208	3	Semester 1	Template
C*	Mechanical	Location 1	132	3	Semester 1	Template
D	Mining	Location 1	76	3 and Masters	Semester 2	Template
E*	Civil/Structural/ Environmental	Location 1	166	1	Semester 2	Module (Rev 1) Template
F	Mechanical	Location 2	160	3	Semester 2	Template

* These courses were included in the initial trial, and also included in this trial to enable ongoing comparisons.

The assessment tasks selected for use (Table 2-2) ranged from ‘design and construct’ tasks to written reports. In each case, the inclusion of design verification introduced only a minor change to how the task was implemented. The required technical content and outcome(s) did not change.

Table 2-2: Summary of assessment tasks

Class	Task	Task undertaken as group?	Verification undertaken in class?	Student perception survey?	Learning outcome measured?
A	Design, construct and test straw and wire bridge	Yes	Yes	Yes (Paper)	No
B	Design, build and test a gear box	Yes	No	No	Yes
C	Design, construct and test straw and wire bridge	Yes	Yes	Yes (Paper)	No
D	Prepare mine operation plan	Yes	No	Yes (Online)	No
E	Design, construct and test straw and wire bridge	Yes	Yes	Yes (Online)	No
F	Systems design (two design options)	Yes	No	Yes (Online)	No

2.3. Results

Preliminary results of the trial are reported in this section, including measured learning outcomes and a student perception survey. These results are then compared to the initial local project outcomes. The project team will be further analysing these results for a journal publication.

Learning outcomes

A comparison with previous learning outcomes was undertaken in one class within the trial, Class B (Table 2-2). Comparison was either not practical in the other classes, or an earlier version of the trial had been implemented and, therefore, a direct comparison could not be made.

The task for Class B was to design, build and test a gear box. The assessment task had been used in the class for a number of years and the only difference in 2014 was the inclusion of the design verification step. Students were required to switch designs, verify the documented design of a peer, receive feedback on their design, improve their design where appropriate, and then test the gear boxes. Student results were directly related to the performance of the gear box and, therefore, the 2013 and 2014 data could be compared.

Figure 2-1 provides the distribution of results for the 2013 and 2014 cohorts. This shows a redistribution of results, with the number of students receiving high distinctions more than doubling. As this is not a longitudinal study, the results may be perceived as being due to a variation in cohort abilities. However, the same academic has been responsible for the course for several years and reported that the 2013 and 2014 cohorts were comparable. The academic intends to continue using design verification in the course due to its success.

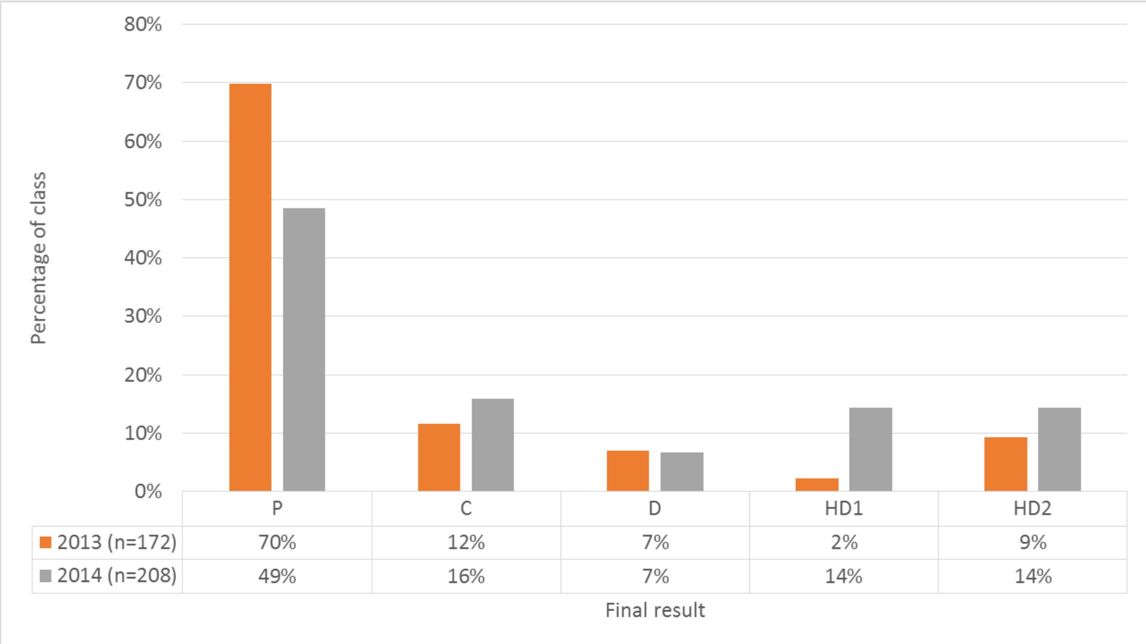

Figure 2-1: Class B result comparison (P - pass, C - credit, D - distinction, HD1 - high distinction 1, HD2 - high distinction 2)

Student perceptions

Upon completion of the assessment tasks, students were surveyed to evaluate their perceptions of the task and the impacts on their understanding. The survey included six questions using a 7-point Likert scale and two open-ended questions. A sample survey is contained in Appendix D. Questions 3 to 5 were modified for each class to refer to the specific assessment task undertaken. In addition to the 7-point Likert Scale a 'Not Applicable' (N/A) option was available for each question of the surveys administered online. Class E (Table 2-2) were asked two additional questions about the online module. The primary questions were:

Q1. The applied verification process improved my understanding of how designs are verified in industry (7-point Likert)

Q2. The applied verification process improved my understanding of the technical concepts in the course (7-point Likert)

Q3. The applied verification process (giving and receiving feedback) allowed improvement of the designed system compared to its original design (7-point Likert)

Q4. The feedback that I provided would have allowed the design originator to make improvements to their design (7-point Likert)

Q5. Having the opportunity to improve the design prior to constructing and testing improved my understanding of the importance of verifying designs (7-point Likert)

Q6. More guidance on the verification process would have been beneficial (7-point Likert)

Q7. How did you use the verification feedback to improve your design? (open)

Q8. What was the most/least valuable aspect of the applied process? (open).

The additional questions asked of Class E were:

Q9. The provided online module, *MaSEE - Guide to design verification*, assisted my understanding of the verification process (select N/A if you did not view the online module) (7-point Likert)

Q10. The provided online module, *MaSEE - Guide to design verification*, increased my awareness of the need for designs to be safe (select N/A if you did not view the online module) (7-point Likert).

Table 2-3 provides the results of the student perception survey. The table reports broad agreement (%) and represents the responses corresponding to 5, 6 and 7 on the 7-point Likert scale. Students in Class B were not surveyed.

Table 2-3: Student perception survey response data

Question	**Broad agreement (%) per class***						
	A (21,66)	B (NA)	C (124,94)	D (24,32)	E (60,36)	F (13,8)	Mean (242,36)
1 – understand verification process	57	-	87	92	95	62	86
2 – understand technical content	86	-	83	96	87	69	85
3 – improvements made	43	-	74	92	70	77	72
4 – others would have improved	67	-	89	92	85	69	85
5 – opportunity to improve beneficial	76	-	87	100	85	69	86
6 – more guidance required	52	-	68	96	68	54	69
9 – online module assisted verification	-	-	-	-	83**	-	-
10 – online module highlighted safety	-	-	-	-	80**	-	-

*For each class, the number of responses (n) and the response rate (%) is shown as (n,%)

**3 respondents in Class E selected N/A to indicate that they had not viewed the online module. N/A was not selected for any other question.

Response rates varied from 8 per cent to 94 per cent. As expected, the classes where the survey was administered in class achieved the two highest response rates. Class F had a low response rate and their results have been included for transparency. It is not clear why the response rate was low, as a number of reminders were sent to the class.

The results of the survey of student perception indicate that:

- the application of design verification within the learning environment can improve student's understanding of verification
- undertaking design verification can lead to a greater understanding of the technical content being studied within the course
- the extent to which students improved their work based on the process varies, but students perceive that the feedback provided by them to their peers would have enabled their peers to improve
- although not all students improved their work, they reported that the opportunity to improve their work prior to the final submission was beneficial
- the level of guidance required by students warrants further investigation
- introducing design verification provides an opportunity to raise awareness of other engineering design requirements, such as safety.

Further analysis of the survey results will be undertaken to provide greater detail (refer Section 3.2), and to enable the incorporation of these results into subsequent revisions of the implementation guide (Appendix C). For example, the results of Class A show an anomaly between the perceived guidance required and the level of understanding of the process achieved.

The open-ended questions will also inform revisions of the teacher implementation guide, with a focus on the concerns raised by students. Although the results in Table 2-3 are positive, some concerns raised by students need to be articulated for teaching staff. Similarly, the benefits that students report need to be highlighted for both teaching staff and future students. Below is a sample of the student responses.

> *We improved the cross bracing of our truss to prevent an early collapse.*
>
> *Didn't end up using it, and our design failed. Should have looked into it more.*
>
> *See from others' point of view and change mistakes.*
>
> *The comments from verification allowed for an in-depth group discussion on several factors of the model leading to changes in the overall design and process of construction.*
>
> *We never got the verification back, so we could not improve it.*
>
> *By using an objective opinion we were able to rectify any small errors we have missed before construction of the truss.*
>
> *I personally think by introducing this you gave the students a chance to copy your ideas, if two countries cant share their technology for free why should the students then? I believe in the knowledge I possess, never did and never will use someone else ideas to improve my design. Feedback is welcomed but exchanging designs with students didn't make any sense.*

Was able to make changes to the final report which would not have been made unless feedback was used.

The feedback our group received was not very useful in improving our design. However, I understand how the process would be very helpful in reducing mistakes.

Comparison with 2010–2012 results

A primary objective of the trial was to assess whether positive results obtained in a pilot trial, which first introduced design verification into an assessment task could be replicated more broadly. Table 2-4 provides the results of the local trial conducted between 2010 and 2012 (Willis et al., 2012) at The University of Adelaide and compares the results with those of the 2014 trial. The local trial included four 7-point Likert scale questions, similar to questions 1, 2, 3 and 5 of the 2014 trial. The local trial included previous cohorts of the 2014 Classes C and E.

Table 2-4: Comparison of 2012 and 2014 student perceptions of design verification

2010–2012 Survey statement*	2012 Broad agreement (mean)	2014 Broad agreement (mean)**
1. Verification improved my understanding of the importance of checking designs	93%	86%
2. Verification improved my understanding of the technical concepts in the course	88%	85%
3. Verification feedback allowed improvement of the final constructed truss model compared to its original design	81%	72%
2014 additional question: The feedback that I provided would have allowed the design originator to make improvements to their design	–	85%
4. Constructing and testing the truss model improved my understanding of the importance of checking designs	92%	86%

*The statements were modified in 2014 to accommodate different tasks and to replace the word 'checking'
**As shown in Table 2-3 for the similar 2014 question

The comparison in Table 2-4 demonstrates a general alignment of the outcomes for the two trials. The third question shows lower agreement in 2014. However, the 2014 survey included an additional question relating to the feedback provided and this indicated a perception that others should have been able to improve. The comparison overall suggests that the positive results of the initial local trial have been replicated in the 2014 trial.

Another feature of the local trial was that it was possible to measure differences in learning outcomes between cohorts that had, and had not, used the process. The local trial indicated a 44 per cent increase in the key performance measure for the task, the strength-to-weight ratio. While a similar performance measure was not available for the 2014 trial, the redistribution of results for Class B (Figure 2-1) also indicated improved learning outcomes.

3. Project deliverables and outcomes

3.1. Summary of project deliverables and outcomes

The initial project proposal anticipated one conference paper and the exemplar teaching resource package. Extending the project duration into Semester 2, 2014 enabled the following deliverables and outcomes to be achieved:

- preparation of an exemplar teaching resource package for design verification, including an adapted industry template for student use, a student online learning module and a teacher implementation guide (refer to Section 2)
- three conference papers (refer to Section 3.2)
- development of a framework, the Management System for Engineering Education (MaSEE), to embed industry processes within the engineering curriculum (refer to Sections 3.2 and 3.3).

3.2. Publications

As part of project's dissemination strategy the project team used conference presentations to introduce and communicate the work being undertaken. The conference papers published were:

Foley, B. & Willis, C. (2013). A framework for the development of a Management System for Engineering Education (MaSEE). *Proceedings of 24th Annual Conference of the Australasian Association for Engineering Education (AAEE2013),* 8-11 December. Gold Coast, Australia.

Foley, B.A. (2014a). Reforming engineering training by introducing quality fundamentals into the undergraduate curriculum: The case study of The University of Adelaide. Invited conference presentation at Qualcon 2014, 19-23 October. Adelaide, Australia.

Foley, B.A. & Willis, C. (2014). Transforming engineering students into student engineers through multi-course project based learning. *Proceedings of 25th Annual Conference of the Australasian Association for Engineering Education (AAEE2014),* 8-10 December. Wellington, New Zealand.

The first paper, presented at the 2013 Australasian Association of Engineering Education (AAEE), introduced the concept of using adapted industry processes within the curriculum as learning and teaching tools. It also presented the Management System for Engineering Education (MaSEE) framework for the first time. The paper expanded the teaching strategy from ‘quality’ management practice to management system processes more broadly. This will enable the framework to be more adaptable and be more representative of industry where integrated systems can include quality, safety, environmental, financial and human resource processes.

The second publication was an invited conference presentation at the industry conference, Qualcon 2014. The presentation extended the reach of the work by crossing the engineering education boundary. It presented the work to quality management professionals and demonstrated its potential relevance to other disciplines.

The third publication indirectly related to the project. It documented a project planning task undertaken by students which is consistent with the MaSEE concept and has the potential to be incorporated as one of the MaSEE processes. Within the project planning task, students were required to prepare a project plan (based on an industry practice) and apply it to one of their own concurrent university projects in a different course. As for design verification, students applied the industry practice to their own studies.

The publications were prepared prior to the exemplar trial being completed and a journal publication is being prepared to present the trial results in detail.

3.3. Management System for Engineering Education (MaSEE)

The Management System for Engineering Education (MaSEE) provides the framework and structure to allow industry adapted management system processes to be used by students throughout their studies (Foley & Willis, 2013). MaSEE would be a resource for students and be accessible for use in all appropriate coursework. It has been designed in a modular form for scaffolded introduction and to allow for incorporation of additional institutional processes. Such additional processes may relate to institutional health and safety processes.

Figure 3–1 outlines the MaSEE structure and demonstrates the progressive introduction of processes throughout a degree program. Once introduced, each process would become a requirement for appropriate tasks in later years, reinforcing the process as standard practice. For example, this project required the exchange of work for ‘design verification’ as a form of peer-generated cyclical formative feedback. At The University of Adelaide it is introduced in Level 1 and then used in later years.

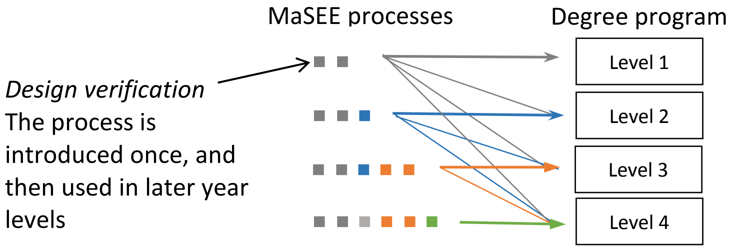

Figure 3-1: Use of MaSEE throughout a degree program

Six processes have been identified for adaptation including: design verification (Level 1), project meeting minutes (Level 1), design review (Level 2), project planning (Level 3), risk assessment (Level 3) and document management (Level 4). All processes, except document management, have been used at The University of Adelaide within the School of Civil, Environmental and Mining Engineering and have shown potential for further refinement. If this seed project were to be up-scaled to the national stage, agreement would need to be reached as to whether other processes should be added.

Consistent with an industry management system, each process included within the MaSEE framework would outline the requirements of, and responsibilities for, the process and be accompanied by an appropriate template(s) similar to those described in Section 2 for design verification. For the learning environment, and to provide guidance on use for academics, each process would include an implementation guide and learning module as shown in Figure 3-2.

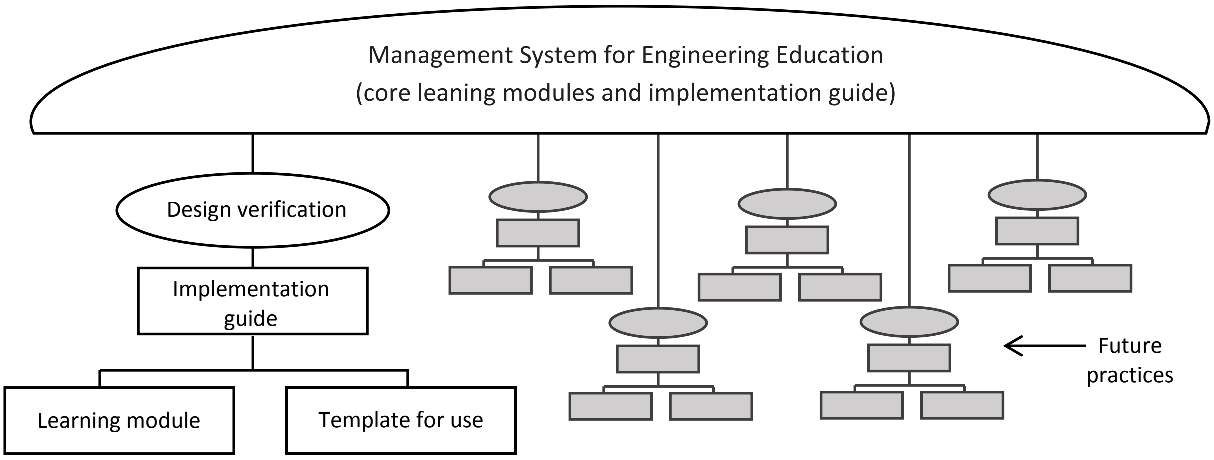

Figure 3-2: Overview of MaSEE learning resources

4. Project dissemination and impact

4.1. Project dissemination

The project team planned dissemination activities to address the second project aim of assessing and setting the scene for change. The project team had the opportunity to disseminate the project at nine activities (Appendix E). The main activities were conference presentations and networking opportunities. However, as the project was an OLT-affiliated project, there were a number of additional opportunities to disseminate the project to a wider audience. For example, the project featured in both the 2013 and 2014 University of Adelaide Festivals of Learning and Teaching.

In 2013 the project was presented at the Festival as a poster for discussion. However, in 2014 the project team were invited to present the project at the Festival as a case study (Foley, 2014b). While the purpose of the presentation was to showcase the Articulate Storyline® learning module, it provided the opportunity to disseminate the project more broadly.

The dissemination activities have been associated with activities that Hinton et al. (2011) would describe as assessing the climate and engaging with potential adopters. These dissemination activities can now move into the next phase as the project team can discuss results and the refined exemplar teaching resource for adoption by others.

Contact has been maintained with all stakeholders initially identified for involvement in the project. The stakeholders will be briefed again in the coming months to identify their support for the project to progress.

4.2. Project impact

This *seed* project commenced in July 2013, prior to the development of the OLT Impact Management Planning and Evaluation Ladder (IMPEL) model (Hinton, 2014). However, Table 4-1 uses the IMPEL model to provide an indication of the impact to date as well as the expected impact should the project be up-scaled and additional processes included.

The potential impact is related to the Engineers Australia Stage 1 Competency Standard for the Professional Engineer (Engineers Australia, 2011) upon which Australian engineering degrees are accredited. The competency standard identifies suggested indicators of attainment for the 16 elements of competency. The use of design verification by students allows for the development of a number of competencies, e.g. element 2.2 (j) which relates to understanding the role of quality management systems. However, MaSEE as a whole would allow the systematic development of a broad range of competencies that have the potential to be applied directly to student learning.

Table 4-1: Project impact potential

IMPEL Rung	Impact of the seed project (design verification exemplar)	Potential impact of an up-scaled project to develop MaSEE
1. Team members	- Opportunity to develop curricula, to develop team capacity and to contribute to the engineering education community.	- Increased networking and opportunities to contribute to the advancement of knowledge.
2. Immediate students	- Improved understanding of technical concepts presented. - Increased awareness of industry processes. - Gain experience with giving/receiving feedback.	- Seed project impacts enhanced by adding additional processes.
3. Spreading the word	- Dissemination through conferences and networking activities.	- Greater networking within the engineering education community. - Greater engagement with industry.
4. Narrow opportunistic adoption	- Academics who participated in the trial have indicated that they intend to continue using the verification template. - Project resources have been created under creative commons and can be used directly by others.	- Opportunistic adoption of additional processes.
5. Narrow systemic adoption		- Contribution to student learning demonstrated through evidence-based resources to aid uptake. - Stand-alone management system that can be used across courses and disciplines. - Students experience benefit and therefore willing to use processes on their own.
6. Broad opportunistic adoption		- Key stakeholder support (ACED, ADLT network, Engineers Australia etc.) to drive adoption.
7. Broad systemic adoption		- Potential to influence future revisions of the EA Competency Standard to reduce differences between the professional and learning environments. - Potential to identify industry processes in other disciplines that can be used in the learning environment (e.g. law).

5. Project learnings and links

The final project aim related to building the capacity of the project team. Undertaking the project as an OLT seed project enabled the project team to gain exposure to the OLT and related projects.

The project provided the project team with the following:

- an understanding of OLT project management requirements
- an appreciation for human ethics approval processes in different institutions
- access to a network of like-minded researchers, invested in improving higher education outcomes
- time to develop skills in e-learning design and e-learning software (e.g. Articulate Storyline®).

The key learnings for the project team to be taken into future projects include:

- the importance of creating a dedicated project team to ensure project impact and take ownership of the project
- the necessity of having a human ethics approval plan at the beginning of the project
- the constraints associated with trialling course content within the academic year, as there may only be one 'window' for trialling per year.

Enhancing engineering education is a challenging and ongoing endeavour, with much of the recent activity relating to improving the authenticity of the undergraduate experience. The following projects have been identified as relevant as this project moves to its next phase:

- 2012 OLT Innovation and Development project: Improving assessment: Understanding educational decision-making in practice
- 2012 OLT Innovation and Development project: Assessing final year engineering projects (FYEPs): Ensuring learning and teaching standards and AQF8 outcomes
- 2013 OLT Commissioned project: Developing graduate employability through partnerships with industry and professional associations
- 2013 ACED sponsored project: Enhancing industry engagement in Engineering Degrees Project
- 2013 SafeWork SA Innovative Practice Grant: Embedding Safety in Design (SiD) into the engineering curriculum.

6. Discussion and conclusion

This report has detailed the *seed* phase of a project to embed adapted industry management system processes into the engineering curriculum for use by student engineers. The purpose of the project was to assess the scene for further work and to demonstrate how an integral aspect of the work environment, a management system, can be used within the learning environment for improved student outcomes.

The project introduced the concept of a Management System for Engineering Education (MaSEE) by using an adapted industry design verification exemplar process as a peer-generated cyclical formative feedback tool in the learning environment. A trial of the exemplar process indicated alignment with previous local data, suggesting that use of the process can improve understanding of an industry process *and* improve the student's understanding of the technical concepts presented.

Industry engagement and authentic industry experiences in the learning environment are topical within the engineering education community. This emphasis will continue as requirements, such as the Engineers Australia competency standard, include a broad range of competencies which relate to understanding the working environment. Management systems provide a framework within which professional engineers operate. The development of a Management System for Engineering Education introduces similarities between the two environments for students – learning and working – and also provides an avenue to raise awareness of other requirements such as safe design.

While this *seed* project has focused on the development of a teaching strategy within the discipline of engineering, it is important to note that the replication of successful student outcomes in other educational settings is anticipated. The design verification process has a basis in quality management practice but is also a form of cyclical peer-generated formative feedback, which has been shown to have positive impact on student performance in a variety of disciplines. As a result, further dissemination could include incorporation into degree programs other than engineering.

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Appendix A – Adapted industry template

This adapted industry design verification template is also provided as a separate document (in PDF and Word formats) to this final report on the OLT website. The PDF version can be printed and completed by students manually. The Word document is saved as a form for electronic completion. The Word form is password-protected for ease of use. Should teaching staff need to modify the template to use terminology appropriate to their institution, the password to unprotect the template is *masee*.

DESIGN DOCUMENTATION VERIFICATION (CHECKING) RECORD

Management System for Engineering Education
MaSEE

Course ____________ Assignment title ______________________________ Document/Calculation Originator ____________________

Document (calculation) title ________________________________ Verifier's (Checker's) Name ____________________ Date __________

Items checked*	Corrections required*	Description of corrective action taken**	Corrective action taken by (signature)**

All design documentation checked and requested corrections satisfactorily incorporated ______________________________ Date __________

(Signature of Verifier/Checker)

** Completed by the verifier. The form should not be signed off / closed out by the verifier until the verifier is satisfied that the appropriate corrections have been made.*

*** Completed by the document originator upon receipt of comments from the verifier.*

Verification form Rev. 1 (01/2015) *Page 1 of 2* *Management System for Engieering Education*

VERIFYING DESIGN DOCUMENTATION AND/OR CALCULATIONS

The design documentation and/or calculations shall be independently checked by the Verifier to ensure that:

- Reasonable design assumptions, inputs and acceptance criteria have been used.
- The design documentation and/or calculations meet the identified design requirements, including relevant standards as appropriate.
- The design decisions are reflected accurately in the associated documents (drawings, reports etc) and that the final output (deliverable) is technically adequate.

The extent of the verification shall be determined by the Verifier, who must be satisfied that the verification process has been sufficiently rigorous to confirm completeness and accuracy of the design. The Verifier may:

- Compare the calculations with empirical or previously proven designs.
- Carry out a detailed check of some or all of the calculations prepared.
- Prepare independent design documentation and/or calculations.

The Verifier shall record the details and extent of the verification activities carried out, documenting details of any corrections required. Any corrections required shall be made by the Designer and re-verified, including a re-check of the associated deliverable(s). The final completed design documentation, calculations, verification record and deliverables shall be signed off by the Verifier.

KEY RESPONSIBILITIES FOR EACH ROLE

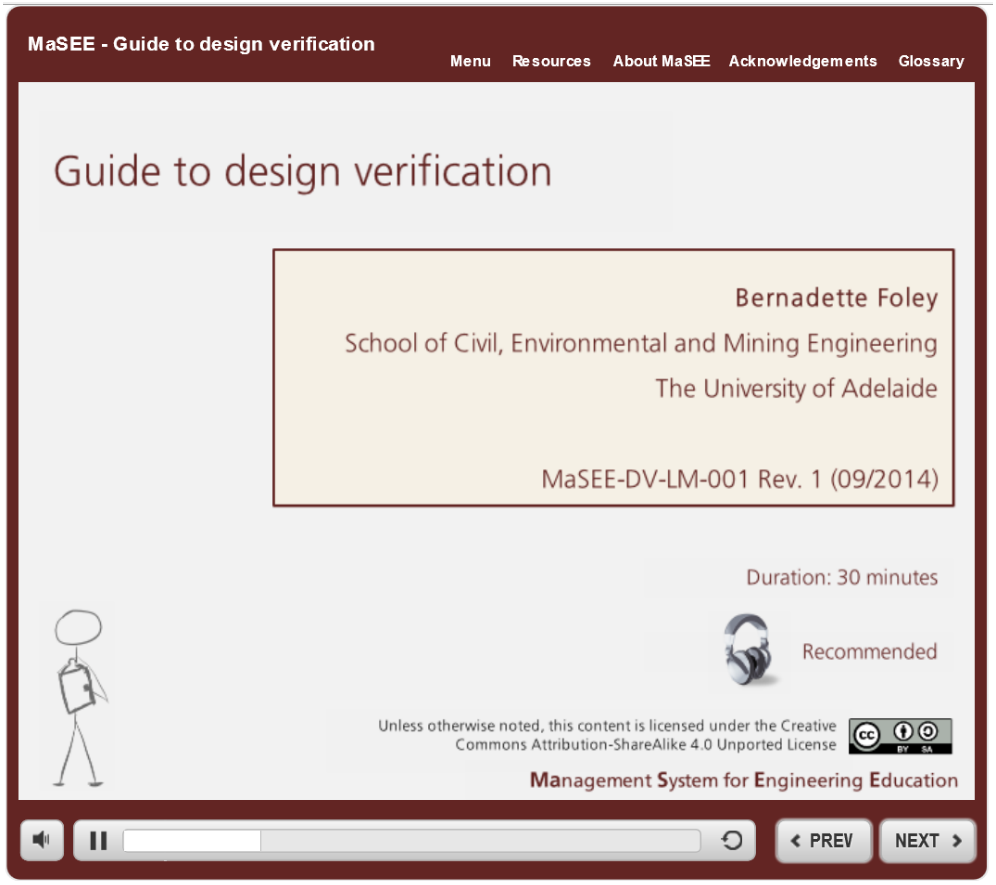
Designer	Responsible for the preparation of the design documentation and calculations. Responsible for self checking their design documentation and calculations and for ensuring that the contractual and design requirements are met.
Verifier	Responsible for the independent verification of the calculations and verifying the conclusions in the design documentation. Responsible for verifying that the design intent is reflected in the deliverables associated with the design documentation and calculations and ensuring that the final outputs are technically adequate.
Project Manager	Responsible for ensuring that the appropriate preparation, self checking, verification and Project Review processes are implemented and that the calculations and design documentation reflect the current brief and project status.

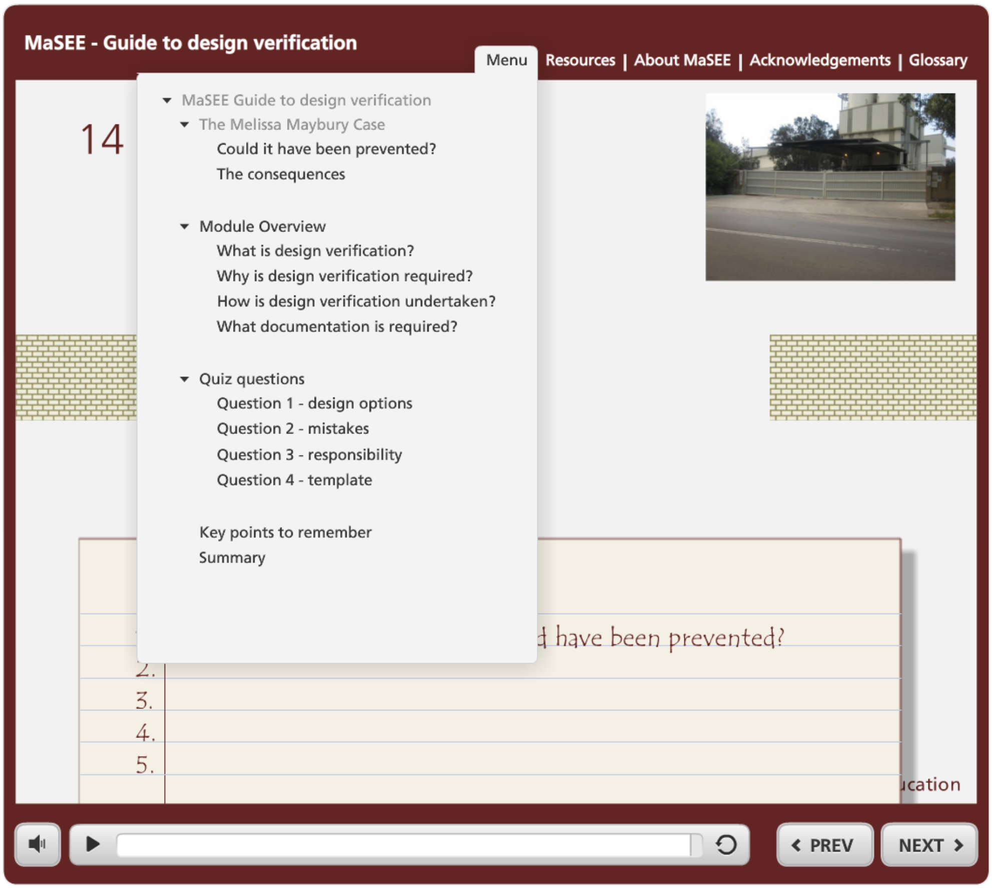
Acknowledgement: This document has been developed by the School of Civil, Environmental and Mining Engineering at the University of Adelaide with support from the Australian Government Office for Learning and Teaching. The views expressed in this document do not necessarily reflect the views of the Australian Government Office for Learning and Teaching.

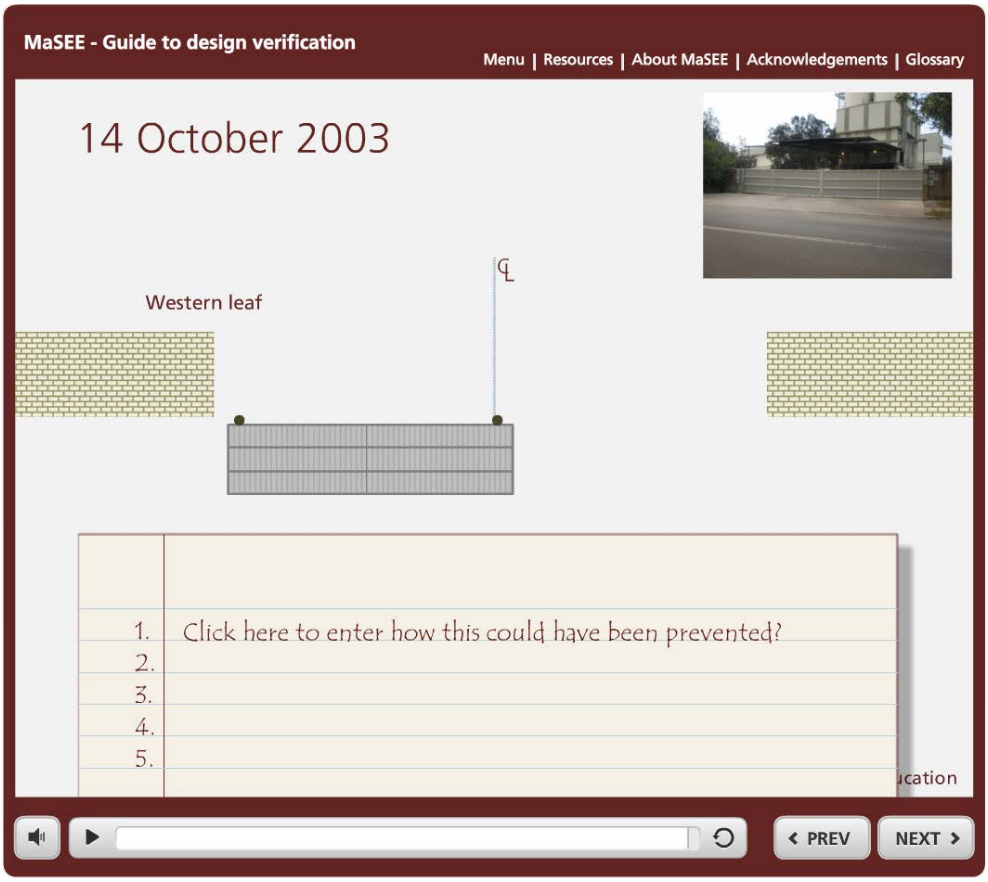
Appendix B – Extracts from online learning module

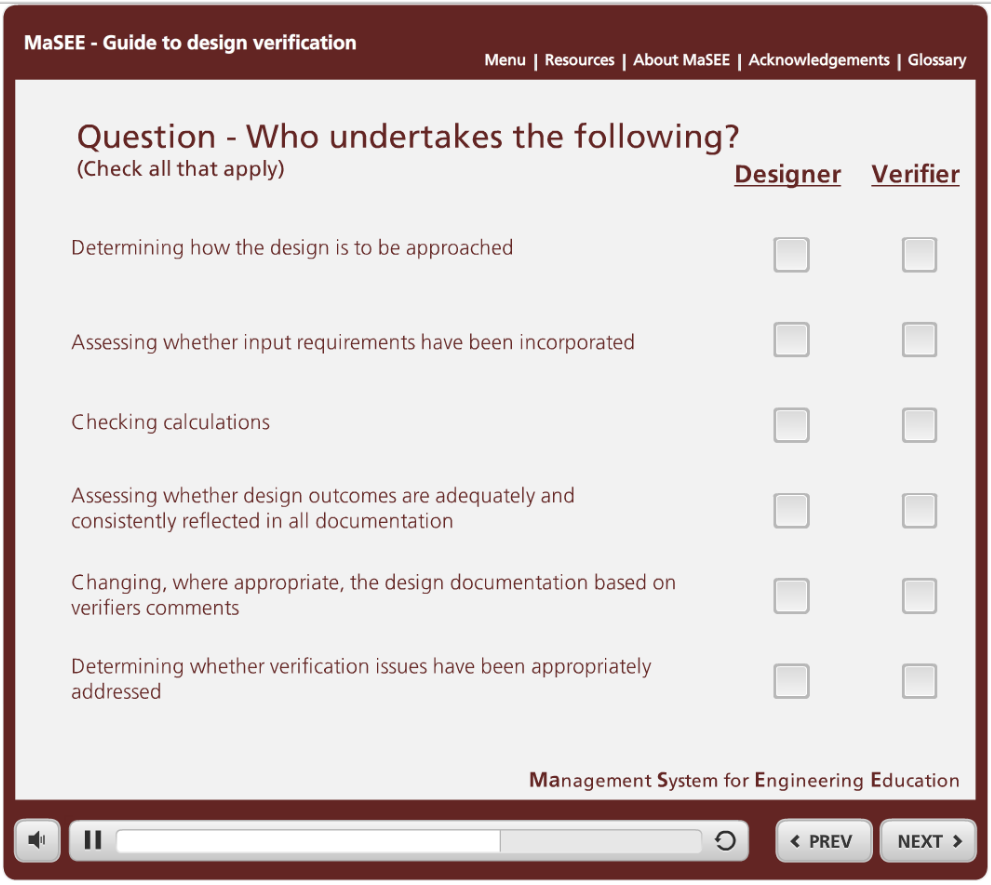
The online student learning module was created in Articulate Storyline®. The module can be obtained from the Project Leader at bernadette.foley@adelaide.edu.au. The module has not been provided on the OLT website as there are a number of publication options; these are dependent upon the Learning Management System within which it will be used.

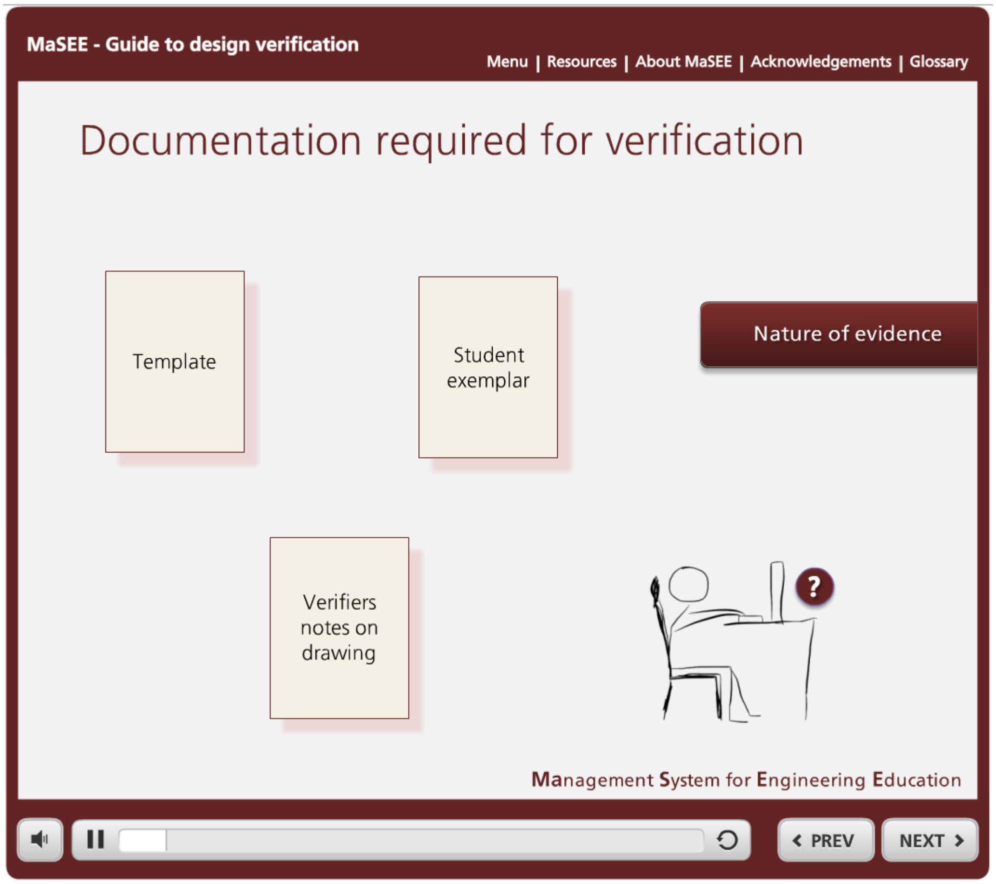
The module features the case of Melissa Maybury, who was fatally injured whilst assisting a friend to close a sliding gate. She was simply picking him up after work. A detailed case study is embedded in the module as an additional resource, as is the adapted industry design verification template for student use. The case study was developed, in part, with the support of a SafeWork SA Innovative Practice Grant and highlights the need for engineers to consider Safety in Design principles. It is a very simple example of how basic design requirements can be overlooked.




MaSEE - Guide to design verification
Menu
Resources | About MaSEE | Acknowledgements | Glossary
14
MaSEE Guide to design verification
The Melissa Maybury Case
Could it have been prevented?
The consequences
Module Overview
What is design verification?
Why is design verification required?
How is design verification undertaken?
What documentation is required?
Quiz questions
Question 1 - design options
Question 2 - mistakes
Question 3 - responsibility
Question 4 - template
Key points to remember
Summary
PREV
NEXT


MaSEE - Guide to design verification
Menu | Resources | About MaSEE | Acknowledgements | Glossary
14 October 2003
Western leaf
1. Click here to enter how this could have been prevented?
2.
3.
4.
5.
PREV
NEXT


MaSEE - Guide to design verification
Menu | Resources | About MaSEE | Acknowledgements | Glossary
Question - Who undertakes the following?
(Check all that apply)
Designer
Verifier
Determining how the design is to be approached
Assessing whether input requirements have been incorporated
Checking calculations
Assessing whether design outcomes are adequately and consistently reflected in all documentation
Changing, where appropriate, the design documentation based on verifiers comments
Determining whether verification issues have been appropriately addressed
Management System for Engineering Education
PREV
NEXT


MaSEE - Guide to design verification
Menu | Resources | About MaSEE | Acknowledgements | Glossary
Documentation required for verification
Template
Student exemplar
Nature of evidence
Verifiers notes on drawing
?
Management System for Engineering Education
PREV
NEXT

Appendix C – Teacher implementation guide

This implementation guide has been prepared to provide guidance to teaching staff on introducing an adapted industry design verification process into assessment tasks, as a peer-generated cyclical formative feedback tool.

C-1 What is the design verification process?

Design verification is a professional quality management process (Standards Australia, 2006). In essence, it examines whether the proposed design outputs have met the input requirements; it is different from simply checking mathematical correctness of calculations. Typically, there are two parties involved, the *designer* and the *verifier*, with the following responsibilities:

Designer

- preparing the design documentation and calculations
- self-checking of design documentation
- ensuring the contractual and design requirements are met.

Verifier

- independently verifying design outputs
- verifying the conclusions in the design documentation
- verifying the design intent is reflected in the deliverables associated with the design documentation and calculations
- ensuring the final outputs are technically adequate
- recording the details and extent of the verification activities carried out
- documenting details of any corrections required.

Adapted from industry, the design verification process can be used in the undergraduate learning environment to deliver student-generated peer feedback. Depending on the nature of the design task (for industry) or assessment task (for learning), the designer and verifier roles may be undertaken by individuals or teams.

FAQ 1: What are the main objectives of the process?

> *The primary consideration when verifying a design should be 'will this design work and is it fit-for-purpose?' As a bonus it could consider whether any improvements can be made to the design to improve efficiency. It is important that students recognise that this is not an opportunity to change designs. This process is assessing the design that was chosen for documentation. Assessing different design options is undertaken earlier in the design and forms part of a design review.*

C-2 What are the pedagogical advantages?

Two of the main features of the design verification process are:

- use of peer assessments for the giving and receiving of feedback
- application of that feedback to revise the design in an iterative process.

As a result, design verification shares attributes with the teaching strategies of *peer review* and *cyclical feedback*, which have been shown in the literature to demonstrate several pedagogical advantages for various disciplines:

- Peer assessments have improved student learning through increased reflection and engagement and placed emphasis on both giving and receiving feedback (O'Moore and Baldock, 2007; Li et al., 2010).
- Students used peer assessment processes to see other possible solutions and sources of error (O'Moore and Baldock, 2007).
- Cyclical feedback strategies increased student engagement with, and reflection on, feedback prior to application in the next step (Hounsell et al., 2008; Quinton and Smallbone, 2010).

In addition to preparing students for industry expectations, use of the design verification process at The University of Adelaide had the following advantages:

- improved student perceptions (refer to Table C-1 for responses from over 300 students for three representative course offerings)
- increase in a key student outcome; as discussed in Willis et al. (2012), the strength-to-weight ratio increased by 44 per cent between two course offerings, one without and one with the design verification process.

Table C-1: Student perceptions of design verification process (from Willis et al., 2012)

Survey statement	Broad agreement (mean)
1. Verification improved my understanding of the importance of checking designs.	92.7 %
2. Verification improved my understanding of the technical concepts in the course.	87.7 %
3. Verification feedback allowed improvement of the final constructed truss model compared to its original design.	80.7 %
4. Constructing and testing the truss model improved my understanding of the importance of checking designs.	91.7 %

C-3 What type of assessment task is suitable?

As the design verification process uses peer feedback to allow an iterative process, the most suitable assessment tasks are those with several stages such as open-ended design projects. Therefore, any recommendations for improvement can be reflected on prior to the final submission. As a guide, this section discusses an example of an assessment task given in a cornerstone design course at The University of Adelaide.

Students are required to design, construct and test a model truss structure. Figure C-1 indicates the problem specification where the span and applied loading are given but the internal geometry of the truss is not. The truss design involves conceptual, preliminary and final design procedures, along with validation through testing. The aim is to minimise the strength-to-weight ratio of the structure to maximise efficiency. The design documentation to be provided by students includes a report (discussing the critical assessment of different design options), along with supporting engineering calculations and a design drawing.

For the design verification, the drawings are swapped between student groups for peer feedback prior to final construction and testing.

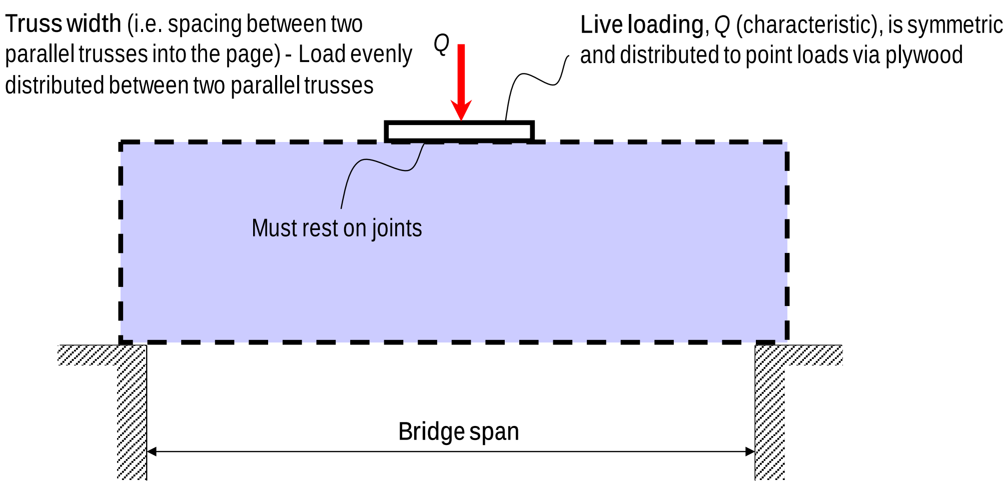


Figure C-1: Problem specification

FAQ 2: What type of assessment task works best?

The main consideration is that a truly open-ended design task can potentially have an infinite number of solutions – but this is not essential for this process. There really only needs to be 'at least one' possible solution for students to narrow down (with a solution space restricted by a logical argument such as optimising the strength-to-weight ratio or similar) but, of course, the more potential solutions the better. A simple design calculation, with one correct solution, is not an appropriate task.

C-4 How is the process implemented?

Design verification should be used at a point prior to the final stage in an assessment task so that feedback can be reflected on and used. For example, for the assessment task discussed in Section C-3, the feedback loop occurs once the design drawing is complete (Figure C-2). This allows feedback to be reflected on and the design drawing potentially revised prior to construction and testing (which can be considered as validation of the design). Depending on the task, feedback from teaching staff is not essential prior to the final submission/design. As a guide, the following is the process used for the example discussed in Section C-3. The timing of the feedback from teaching staff changed from year to year, and was dependent on the time allocated between submission of the design and the testing day.

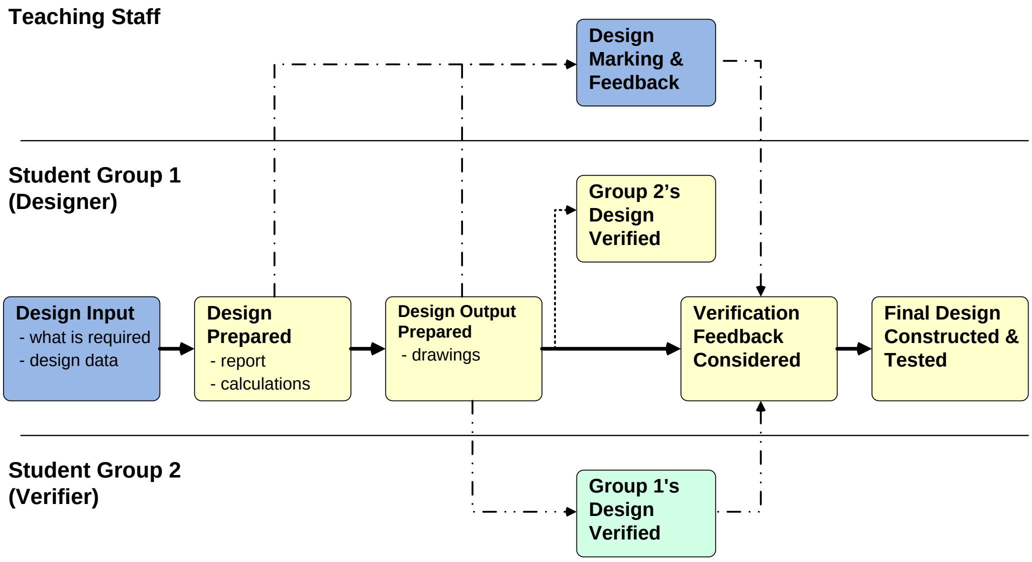


Figure C-2: Design project workflow including verification process (from Willis et al., 2012)

Sample instructions

To complete the verification process, swap your design drawing (do not include any calculations) with another student group. The final documentation must include the following:

- *(i) submission cover page (signed by all group members)*
- *(ii) verification form (only first two columns of the table completed, refer Appendix A)*
- *(iii) design drawing (designed by another group)*
- *(iv) supporting calculations (optional and only if deemed necessary).*

Note: Items (ii) and (iii) should be marked up and checked amongst team members as appropriate. Also, the second two columns of item (ii) are not required for this assignment – they are transferred directly from the process used in industry.

Submit two copies of the completed documentation:

- *return the original to the other group (i.e. the design engineers)*
- *submit a copy for assessment.*

A vital feature of the design verification process is that it does not merely check mathematical correctness but assesses whether a design output is practical and efficient. The most important two questions to consider are:

- *Can it be constructed as drawn?*
- *Is it efficient based on the applied loading?*

Importantly, students are not redesigning the drawing, but providing *recommendations* for improvement (where possible). The objective is for the design engineers to then use this peer feedback to potentially improve their design prior to constructing their final model.

FAQ 3: When should it be conducted in the assessment cycle?

As a guide, the verification process should be late enough in the assessment cycle to ensure that any opportunity for plagiarism is minimised (students must focus on improvement to their own design rather than attempting to completely copy another design), but with enough time to allow modification to the design if necessary through reflection on the peer feedback.

FAQ 4: Is 'closing the loop' essential to this process?

No, this is optional. 'Closing the loop' involves the designer documenting to the verifier the change(s) made to the design (i.e. corrective actions taken) in response to the peer feedback. For education purposes, evidence of these 'corrective actions' have been demonstrated by student outcomes and perceptions (discussed in Section C-2). It is important that students are aware that in industry the loop is always closed.

FAQ 5: How should students (groups or individuals) swap their work?

It is recommended that swapping be randomised to ensure that students do not simply choose to exchange with their friend(s). For example, students can either directly switch their work or the switch can occur within a triad (Figure C-3). Triads also provide an additional perspective, as groups give and receive feedback from different groups. However, triads are more complex for the teacher to administer.

Figure C-3: Verification switch

C-5 What is the impact on teacher and student workload?

Feedback is peer-generated by students; therefore, the only significant additional teacher workload is from marking. However, to minimise workload, the teacher could simply use a 0 or 1 participation mark if the activity is completed or not, with the student incentive being the pedagogical advantages referenced in Section C-2. As a result, the weighting of the assessment task should be relatively small to reflect the amount of time and effort expected by students for completion.

The objective is that students see other design options to generate potential for reflection. Plagiarism can be a concern and therefore the consideration needs to be given to minimise the concern. The objective should be that only minor changes are required as a result of the verification. The process can be completed in a one-hour teaching session, as the objective is to provide recommendations for improvement rather than a redesign. Spot check calculations may be undertaken if deemed necessary, but are not essential.

FAQ 6: Is one hour long enough for students to complete the process?

> *Although a short turnaround time for submission is consistent with industry requirements, the actual submission deadline may be significantly greater than one hour (e.g. 24 hours) so that students can feel more comfortable with the reflection process and type their submission (rather than completing by hand) if desired.*

FAQ 7: How much guidance should be given to students upfront?

> *The design verification documentation provides an explanation of the requirements so the level of guidance is generally at the discretion of the teacher. Depending on the assessment task, it may be appropriate to simply introduce the process verbally; for more complex tasks, it may be more suitable to provide an exemplar of the types of feedback possible. For most teaching environments used to date, the 'less is more' approach has been very successful in encouraging student curiosity, innovation and independent study.*

C-6 References

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Li, L., Liu, X. & Steckelberg, A. (2010). Assessor or assessee: How student learning improves by giving and receiving peer feedback. *British Journal of Educational Technology*, 41(3), 525–536.

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Quinton S. & Smallbone, T. (2010). Feeding forward: Using feedback to promote student reflection and learning – a teaching model. *Innovations in Education and Teaching International*, 47(1), 125–135.

Standards Australia, (2006). AS/NZ ISO9000:2006 Quality management systems-Fundamentals and vocabulary. Sydney: Standards Australia.

Willis, C., Foley, B. & D. Wilson, (2012). Improved student engagement in civil and mechanical engineering using a professional peer feedback process. *Proceedings of the 7th Australasian Congress on Applied Mechanics (ACAM7)*. Adelaide.

Appendix D – Student perception survey

Each survey was amended to refer to the task that students were completing within the course. Two surveys were administered in class while the others were administered through www.surveymonkey.com

THE UNIVERSITY of ADELAIDE

Management System for Engineering Education (MaSEE) Design Verification Trial

STUDENT PERCEPTION SURVEY
COURSE DETAILS

Dear Student,

This semester you were required to use a design verification template prior to completing your design project assessment task. As part of a research project investigating the integration of industry adapted management system processes into the engineering curriculum we are interested in your perceptions of, and experience with, using the design verification process and template.

It would be appreciated if you could spend 5 minutes completing this survey. The survey is structured in a similar manner to other evaluations of teaching that you may have completed. Your responses will be anonymous and will not have any impact your results in this course or any other. The results of the survey will be compared to results from other courses and/or institutions that are also using the template and may be reported in publications associated with the research. The results of the survey from students within your course will also be made available to your course coordinator, to allow improvements to the course design. Again, this information will be provided on an anonymous basis.

By participating in the survey you have the opportunity to inform how industry adapted processes are integrated within the curriculum in future years. The project is being conducted by Ms Bernadette Foley and Dr Craig Willis from the School of Civil, Environmental and Mining Engineering at the University of Adelaide. Should you have any questions or concerns about this project please email bernadette.foley@adelaide.edu.au or phone Ms Foley on (08) 8313 0689. This survey has been reviewed and approved by the University of Adelaide Human Research Ethics Committee. Should you have concerns about the conduct of the research and wish to discuss your concerns with an independent party please email hrec@adelaide.edu.au or phone the Secretariat on (08) 8313 6028 and refer to approval number H-2014-024.

Participation in this survey in voluntary. By starting the survey you are giving your consent for your data to be used by the project team. You are free to withdraw from the survey at any time by simply leaving your responses blank. Once you have submitted the survey you will not be able to withdraw your consent for your data to be used, as your data cannot be identified.

Thank you for your participation.

Bernadette Foley
Principal Investigator

Support for this project has been provided by the Australian Government Office for Learning and Teaching. The views in this survey do not necessarily reflect the views of the Australian Government Office for Learning and Teaching.

Management System for Engineering Education (MaSEE) Design Verification Trial

Course details xxxxxxx

For each of the questions below please indicate how strongly you agree with the statement.

	Strongly Agree			Neutral			Strongly Disagree
Q1. The applied verification process improved my understanding of how designs are verified in industry	☐	☐	☐	☐	☐	☐	☐
Q2. The applied verification process improved my understanding of the technical concepts in the course	☐	☐	☐	☐	☐	☐	☐
Q3. The applied verification process (giving and receiving feedback) allowed improvement of the designed system compared to its original design	☐	☐	☐	☐	☐	☐	☐
Q4. The feedback that I provided would have allowed the design originator to make improvements to their design	☐	☐	☐	☐	☐	☐	☐
Q5. Having the opportunity to improve the design prior to constructing and testing improved my understanding of the importance of verifying designs	☐	☐	☐	☐	☐	☐	☐
Q6. More guidance on the verification process would have been beneficial	☐	☐	☐	☐	☐	☐	☐

Q7. How did you use the verification feedback to improve your design?

Q8. What was the most/least valuable aspect of the applied process?

Appendix E – Dissemination activities

Table E-1: Summary of project dissemination activities

Event Date	Event title, Location (city only)	Brief description of the purpose of the event	No. of participants	No. of higher education institutions represented	No. of other institutions represented
25 Jun 2013	Faculty L&T committee meeting (Adelaide)	To provide an overview of the project to other schools within the Faculty of Engineering, Computer and Mathematical Sciences (ECMS).	11	1 The University of Adelaide	0
31 Jul 2013	School Industry Advisory Board Meeting (Adelaide)	To provide an overview of the project and to obtain industry feedback in relation to key industry processes for inclusion in the project.	Approx. 10	1 The University of Adelaide	6 All were industry representatives.
21-22 Oct 2013	OLT Project Management Workshop (Sydney)	To gain insight into the project management requirements for an OLT project and, in part, to disseminate information about the project and network with other project teams.	Approx. 25	>10	2 OLT plus the Learning Partnership.
04 Nov 2013	Festival of Learning and Teaching, The University of Adelaide - Interactive Poster Session (Adelaide)	To showcase Learning & Teaching research and achievements of The University of Adelaide staff. (http://www.adelaide.edu.au/festival-lt/)	187 registered participants for day one; 18 Posters presented; 40-50 participants attended Poster session.	5 The University of Adelaide plus 1 external keynote speaker and 3 workshop facilitators	1 OLT General Manager as an invited guest
27 Nov 2013	Mining Education Australia (MEA) Staff Workshop (Perth)	To provide an overview of the project and seek interest in participating in the design verification exemplar trial.	38	4 The University of Adelaide, Curtin University, The University of NSW and The University of Queensland.	0

Event Date	Event title, Location (city only)	Brief description of the purpose of the event	No. of participants	No. of higher education institutions represented	No. of other institutions represented
08-11 Dec 2013	2013 AAEE Conference (Gold Coast)	The annual AAEE conference is the primary forum for Australian (and NZ) engineering educators to network and discuss research relating to Learning & Teaching. The project team presented a paper and facilitated a workshop.	>200 participants; 137 papers; 11 workshops	>15 Most Higher Education Institutions within Australia and New Zealand with Engineering programs.	>5 Conference sponsors and accreditation bodies
19-23 Oct 2013	Qualcon 2014 Conference (Adelaide)	Invited paper on the work of the project team, including this project.	>100 participants	>4 Mix of professionals and Higher Education institutions	>20
11-12 Nov 2014	Festival of Learning and Teaching The University of Adelaide. (Adelaide)	Workshop presentation using the online learning module developed for this project as a case study for use of Articulate Storyline	Primary internal opportunity for the celebration of work being undertaken in the L&T space.	4 The University of Adelaide plus guest speakers	0
08-11 Dec 2014	2014 AAEE Conference (Wellington, NZ)	The annual AAEE conference is the primary forum for Australian (and NZ) engineering educators to network and discuss research relating to Learning & Teaching. The project team presented a paper to potential future opportunities associated with this project.	>200 participants	>15 Most higher education institutions within Australia and New Zealand with Engineering programs	>5 Conference sponsors and accreditation bodies

Appendix F – Certification

Certification by Deputy Vice-Chancellor (or equivalent)

I certify that all parts of the final report for this OLT grant provide an accurate representation of the implementation, impact and findings of the project, and that the report is of publishable quality.

Name: Professor Philippa LEVY (PVC Student Learning) Date: 29-04-2015