An Industry-Based Project in an Engineering Dynamics Course

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Structured Abstract

BACKGROUND
Students learn a range of fundamental theories and principles in the classroom. However it can be difficult for students to visualise or realise the promising applications of such complex knowledge. 'Inert' or abstract knowledge or knowledge without context is a form of troublesome knowledge that can be a barrier to learning and students can be overwhelmed by apparently irrelevant and abstract underlying mathematical equations and formulae that are often delivered without context (S. A. Male & Baillie, 2014, p 395). Students can hence lose interest and engagement in the unit and limit their expected learning outcomes. Giving students opportunities to use principles and engineering tools in applications that are relevant to engineering practice has been identified as important (Sheppard, Macatangay, Colby, & Sullivan, 2009).

PURPOSE
Resource industries, especially mining, are relevant for Australian engineering students, because they offer local engineering employment opportunities. Therefore, a project was developed, in which, students applied engineering principles and a modelling tool to applications associated with mineral processing. The primary objective was to enable students to develop a clear understanding of various engineering dynamics principles, by using real world scenarios in the classroom, and through comparing results derived using analytical approaches and hand calculation, with computer simulations. In this paper we describe the project design and implementation and ask whether the students perceived that the primary objective identified above was achieved.

METHOD
The first author worked with OneSteel and captured real world scenarios related to a rock crusher. He brought the scenarios into the classroom in a two-hour laboratory session in the engineering dynamics course in SP2 2014 at the University of South Australia. The students and laboratory demonstrator completed feedback questionnaires, and responses were analysed by the second author.

RESULTS
The industry-based practical described in this paper achieved its primary objectives. Students perceived improved learning of engineering concepts and tools through working on the task.

CONCLUSIONS
The project is now a ready-made and tested laboratory session for engineering educators. It was developed as part of a national project to enhance industry engagement in engineering degrees and the materials are available for other universities to use.

KEYWORDS
Industry-based laboratory session, engineering education, engineering dynamics, authentic curricula.

Introduction

Engineering curricula frequently include much engineering-science in the second and third years of study. Students learn a range of fundamental theories and principles in the classroom. However it can be difficult for students to visualise or realise the promising applications of such complex knowledge. 'Inert' or abstract knowledge or knowledge without context is a form of troublesome knowledge that can be a barrier to learning and students can be overwhelmed by apparently irrelevant and abstract underlying mathematical equations and formulae that are often delivered without context (S. A. Male & Baillie, 2014, p 395; Perkins, 1999, p 8).

Understanding the value of learning was identified as a threshold to students' learning by Parkinson (2011) for engineering students in a study to identify concepts that were thresholds to students' learning in a first-year engineering unit (S. A. Male, 2012). Giving students opportunities to use principles and engineering tools in applications that are relevant to engineering practice has been identified as important (Sheppard et al., 2009). These recommendations are consistent with the two strategies recommended by Perkins (1999, p 8) as responses to help students overcome inert knowledge: "Engage learner in active problem solving with knowledge that makes connection to their world" or "engage students in problem-based learning whether they acquire the target concept while addressing some medium-scale problem or project."

Resource industries, especially mining, are relevant for Australian engineering students, because they offer local engineering employment opportunities. Therefore, a project was developed in which students applied engineering principles and a software modelling tool to applications associated with mineral processing. The primary objective was to enable students to develop a clear understanding of various engineering dynamics principles by bringing real world scenarios into the classroom. Minesites use large tools that cannot be physically brought into the classroom. Instead a simulation of a real tool was developed and students compared results derived using analytical approaches using hand calculation, with those derived using computer simulation. For decades, computer simulation has been used to enable students to work on problems involving equipment that cannot be physically brought into the classroom (Smith & Pollard, 1986), and the simulation tools available now are much more powerful and convenient to use than when simulations were first used in engineering education. In this paper we describe the project design and implementation and ask whether the students perceived that the primary objective identified above was achieved.

Method

Development of the project

The first author worked with OneSteel on the development of the project based on a rock crusher at OneSteel in Whyalla. OneSteel is one of the largest mining companies in Australia, and has a strong relationship with the University of South Australia, which encourages and supports engineering education via industrial placements and cadetship programs. Leveraging this privilege, a jaw crusher was identified as the subject for a student project. The crusher is used to break big rocks into small pieces, as an important and foremost step of mineral processing at OneSteel. The jaw crusher consists of various mechanical components which have rotary and reciprocating motions, and is built on many key principles and concepts of engineering dynamics. Figure 1 shows an example illustration of a jaw crusher at OneSteel mine site.

The first author visited the mine site and the jaw crusher, and met with OneSteel engineers to discover the working principles, setup and specifications of the equipment. Knowing the underlying objectives of the project, delegated engineers were friendly and supportive in making site visits and explaining the facts as required. As per the company's confidentiality policy, a number of appropriate photographs and videos have been captured. As the equipment is very big, complex and covered with the safety shield around it, photographs taken possess limited information. However, overall a representative model of the equipment including kinematic and kinetics of motion was realised based on given information and discussion with engineers. It must be noted that again due to confidentiality issues, data and information associated with equipment used in the project are representative only and hence not necessarily actual details.

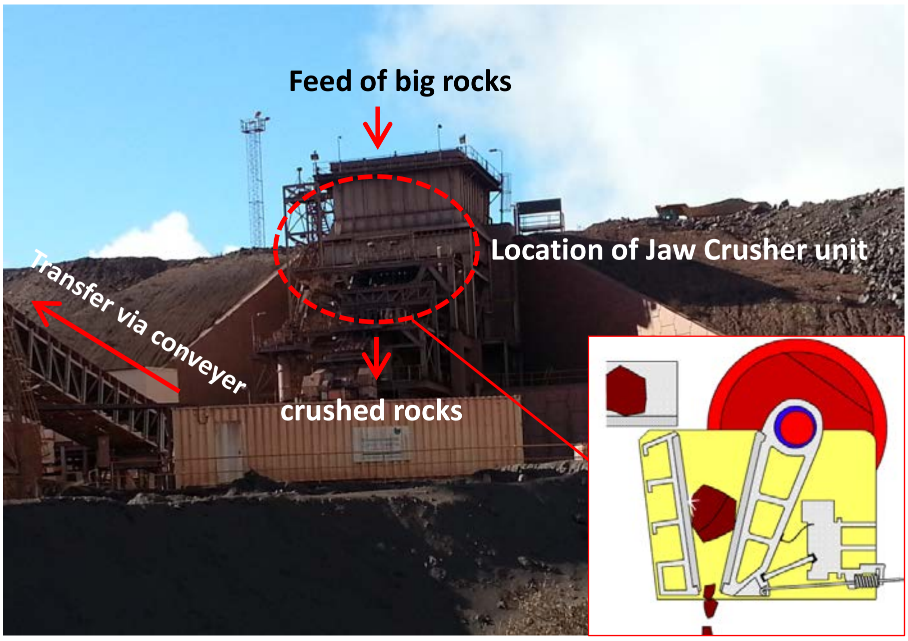

Figure 1: Example of illustration of jaw crusher at OneSteel mine site

Implementation in the classroom

As a trial, the first iteration of the project was in Semester 2, 2013. In this iteration it was not possible to collect feedback from students. The current paper focuses on the improved implementation in 2014.

In Semester 1 2014, the project was again implemented through a two-hour laboratory session in the Engineering Dynamics course at the University of South Australia. Engineering Dynamics is a second year course offered for mechanical engineering students. The unit provides students with an appreciation of fundamental concepts of engineering dynamics and useful skills in modelling and analysing motion (e.g. velocity, acceleration, momentum, work done, energy) of mechanical systems using the dynamics principles. The main objective is to enhance students' learning outcomes by connecting theoretical knowledge learnt in the classroom with real world applications.

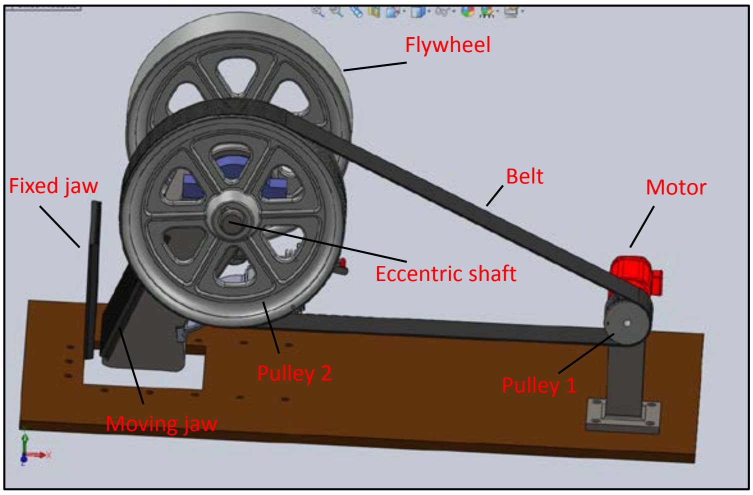

Figure 2: Solidworks™ model of jaw crusher

Based on data and information from OneSteel, a simplified prototype model of the jaw crusher was developed using Solidworks software. Figure 2 shows an illustration of the model. As can be seen in Figure 2, Pulley 1 is coupled with a driving Motor with the bearing and Pulley 2 and Flywheel are coupled with an eccentric shaft at both ends. The eccentric shaft rotates against two roller bearings at both of its ends. The motor transmits rotational power through a pulley and belt to the eccentric shaft which causes the moving jaw to move back and forth, hence breaking the rocks against the fixed jaw. In the laboratory session, students were at first presented with the use of a real world jaw crusher, its underlying working principles and dynamic interactions among different components. Photographs and videos of the actual equipment were shown and explained to help students to appreciate the complexity and key factors that may influence motion and energy involved in rock crushing.

In this project, students had the opportunity to study two dynamics problems based on the model using Solidworks™ motion analysis tool. As an example, below is the definition of 'Problem 2' used in the lab session.

Problem 2: In order to start crushing operation, the motor drives the Pulley 1 to linearly accelerate from the rest to 500 rpm in 50 revolutions. Assuming no friction between the belt and pulleys, and between the eccentric shaft and the bearings, and the moment of inertia of the rotating system is 2.51 kg-m^2. Determine:

(a) required torque and power of the motor
(b) angular kinetic energy of Pulley 2 and Flywheel after 50 revolutions

The Solidworks™ motion analysis tool has the capability to simulate and determine various motion parameters when the model is subject to certain motion as an input. In order to justify simulation results obtained from the software, students were required to determine the values of the same parameters using standard motion equations they had learnt in the theory class. Students were given hypothetically assumed actual results for various output motion parameters of the jaw crusher to enable them to compare these with hand calculation and simulation results. They were then asked to present the results in a report, identifying and discussing factors which possibly caused the discrepancies in results obtained using the calculation methods. Twenty-three students completed the laboratory session.

Data collection

Human research ethics approval was obtained for evaluation of this and other industry-inspired project developed as part of the same overarching project. Data were collected using a student questionnaire and a questionnaire completed by the laboratory demonstrator.

A 10-minute student questionnaire was developed in which the students rated their agreement with 14 statements on a five-point scale (1 = *strongly disagree*; 5 = *strongly agree*). Anchor descriptors were identified for the scale endpoints only, so that it could be assumed that the participants mentally spaced the points on the scale evenly. The first five statements were directly linked to the objectives of the project: understanding connection of theory to an application, improved understanding of a concept and improved ability to use an engineering tool. The remaining statements related to indirect anticipated benefits including improved motivation, communication, and teamwork skills; and enjoyment. Students were invited to submit text comments at multiple points in the questionnaire.

The questionnaire included demographic questions with two purposes. First, the significance of providing a real-world example was expected to vary depending on the extent of previous exposure of the students to industry. Therefore the duration of engineering-related workplace experience was collected. Second, the class was small, and therefore the demographic data could be used by others to help in gauging the transferability of the results to their context.

The questionnaire was implemented online using Qualtics™. At the conclusion of the laboratory session, 19 (83%) of the students completed the questionnaire. The second author independently collected and collated the data.

A questionnaire was also completed by the laboratory demonstrator. This was emailed to the demonstrator by the first author and unit coordinator. The questionnaire included eight open questions about benefits to the students and the demonstrator; and challenges, risks and suggested improvements.

Results and Discussion

Demographic characteristics of the students who completed the questionnaire are reported in Table 1**.** Participants ages ranged from 23 to 32 with 14 (73.7%) students aged 23 to 25 years. The age and gender of the students are not unusual for Australian university engineering students. Therefore, although the numbers are insufficient to generalise the results, the demographic data indicate nothing about the sample that could be expected to restrict transfer of the results to many other engineering dynamics classes.

Table 1: Demographic characteristics of participants in student evaluation survey of Engineering Dynamics project (*N* = 19)

Questions and responses	*Frequency*	*Percent*
Gender		
Male	17	89.5
Female	2	10.5
Do you have a close relative or friend who is an engineer?		
No	5	26.3
Yes	14	73.7
Time you have worked in an engineering-related workplace before or during your degree (in weeks)		
0	3	15.8
3	1	5.3
6	1	5.3
12	1	5.3
16	3	15.8
24	3	15.8
32	1	5.3
36	1	5.3
48	2	10.5
70	1	5.3
80	1	5.3
250	1	5.3

Twelve (26%) of the students had fewer than 12 weeks of experience in an engineering workplace and five did not have a close relative or friend who is an engineer. Furthermore, those with engineering workplace experience were possibly in offices rather on a minesite. Therefore it is likely that many of the students had no familiarity with a rock crusher.

Students rated their agreement with 13 statements. Mean ratings are graphed in Figure 3. At each statement the students were able to enter comments. Seven brief comments were received from students. With the exception of a request for faster computers:

> *It helps with my understanding better and faster*
>
> *Proves that I need to brush up on my SolidWorks skills*
>
> *All good!*
>
> *Good for student to learn this subject*
>
> *its a good class where I can apply my knowledge and double check it with the software.*
>
> *well done*

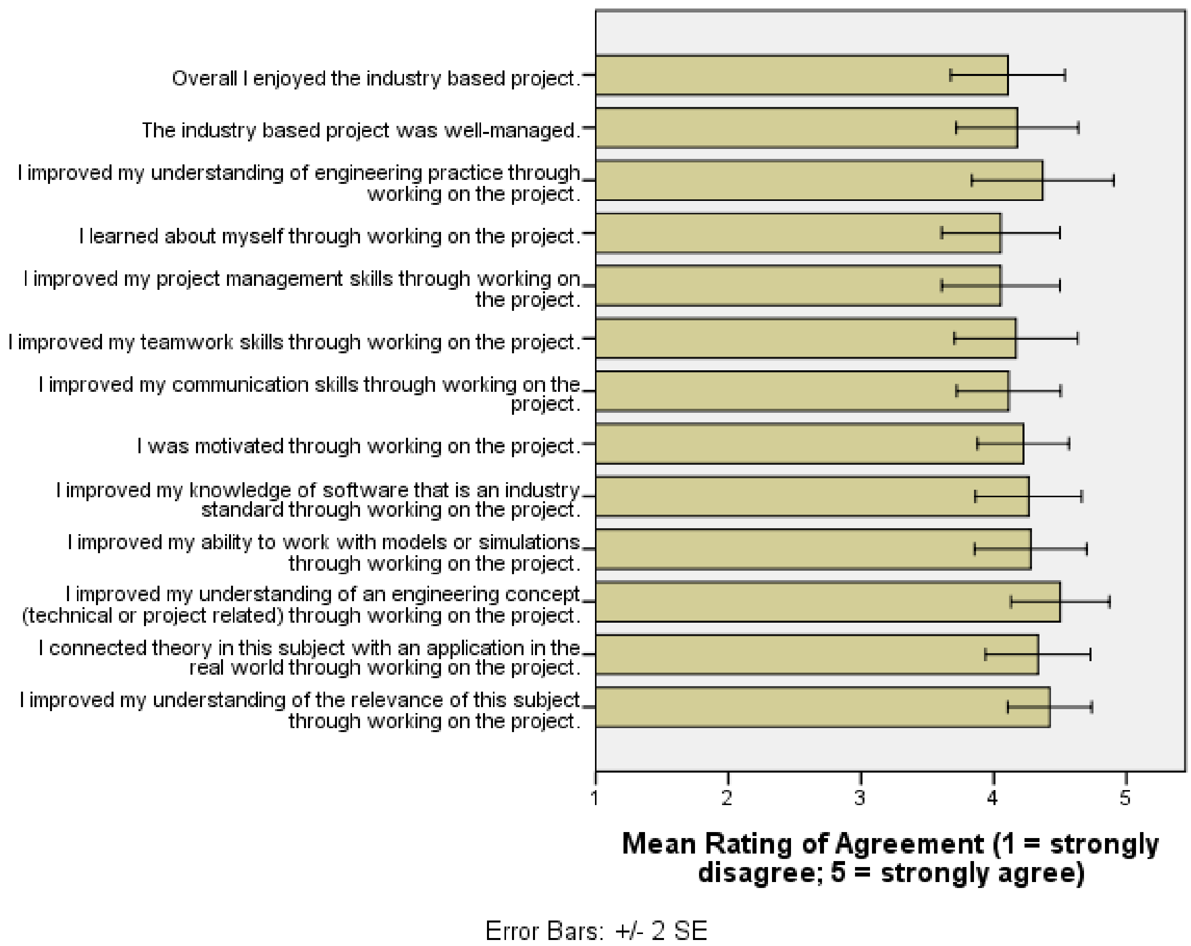

Figure 3: Mean evaluation ratings by Engineering Dynamics students Semester 1 2014 (*N* = 19)

The laboratory demonstrator's responses included only praise (below).

> *This session was very interesting finding out how to connect the theory of knowledge to practical work.*
>
> *[Students] gained a number of benefits such as improving their understanding of theoretical concepts and demonstrating their knowledge in engineering dynamics much more easily in this session.*
>
> *This session provided me with much invaluable experience working to improve the students' performance in the future.*
>
> *The session was powerful, exceedingly relevant to engineering dynamics concepts.*
>
> *Expand this session and make it even more applicable to real life solutions.*

Discussion and limitations

The qualitative responses collected using questionnaires were brief and the quantitative responses are from only a small class. It would be ideal to interview students and the laboratory demonstrator in future evaluations. It will also be valuable to collect data from a larger number of students as more students undertake the unit.

Despite the above limitations, there is no doubt that the students and laboratory demonstrator appreciated the opportunity to apply dynamics principles to real applications. The mean ratings for the first five statements, which were directly linked to the project objectives, were 4.26 and higher. The quantitative responses, the first qualitative student response "It helps with my understanding better and faster", and the demonstrator's response, "a number of benefits such as improving their understanding of theoretical concepts" are directly aligned with the intended purpose of enhancing students' learning of concepts through an industry-inspired project.

The mean rating for the statement, 'I was motivated through working on the project.' was 4.22 (SD = 0.73). Parkinson noted that engineering students in the unit he studied were motivated by understanding the purpose of their learning. This result is consistent with his finding.

The statements related to indirect benefits received mean ratings of 3.83 and higher. The students perceived that the project assisted them in many additional ways including developing generic skills such as teamwork and communication, and importantly, they enjoyed the project.

As noted above, many of the students had limited experience in engineering workplaces and several had no close family-member or friend who was an engineer. Therefore an industry-inspired project such as this was probably one of few opportunities these students had to be exposed to engineering industry.

The demonstrator's comment that the session provided him with "invaluable experience" is significant. Without industry-based experience it is difficult for many engineering educators to provide context and relevance. As more educators use the project material, the benefits will be carried through educators to students in other classes. Furthermore the enhanced relationship between the employer and the university is likely to lead to further engagement.

Developing this project was a substantial investment. It required the privilege of the opportunity provided by OneSteel, time and skills invested by the university staff and the OneSteel engineers, to date two iterations to develop and test the project, and financial support. The rare event of these coming together combined with the benefits discussed above demonstrate that industry-inspired projects such as this are precious.

Conclusions

The industry-based laboratory project described in this paper achieved its primary objectives. Students perceived improved learning of engineering concepts and tools through working on the task.

The project is a ready-made and tested laboratory session for engineering educators with access to Solidworks™. It was developed as part of a national project 'Enhancing Industry Engagement in Engineering Degree Programs' led by the Australian Council of Engineering Deans, and notes are available for other universities to use (Male & King, 2014).

The laboratory session will run again in second semester 2014. We plan to further enhance the students' exposure to industry through the project and gain deep understanding of the students' survey responses through additional qualitative data collection.

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