Aligning student projects and curriculum design in mechanical engineering design courses to meet the needs of local industries

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STRUCTURED ABSTRACT

CONTEXT
Industries often spend a lot of time and cost to retrain graduate engineers to be competent in their field of work. The opportunity to realign our undergraduate programs in mechanical engineering would improve students' exposure to real-world engineering projects so that they could contribute to the local industries and community.

PURPOSE
This paper reports the outcomes of an initiative to realign an engineering design undergraduate unit to include industry inputs through an Industry Advisory Panel. The report will also include a summary of how staff and students engage in local industries through training courses, design outputs and student projects.

APPROACH
A major revamp in Engineering Design II was carried out in 2016 to expose students to metrology skills, geometry dimensioning and tolerancing (GD&T) series and a major design project based on a real-world problem faced by engineers in a local engineering provider in the machine tool industry. Online surveys will be sent to three categories of past students: working graduates who have taken the unit before year 2016, working graduates who taken completed this unit after realignment was implemented in 2016 and students currently enrolled who have completed the realigned course in 2017.

RESULTS
Preliminary results based on student evaluation surveys carried out showed that students did not take the changes well when they were implemented in 2016. We hope to look into students' perception from the 2016 cohort to see if their impression changed as they enter into the workforce. The survey data collected from the other two categories will be used for benchmarking and comparative study.

CONCLUSIONS
Changes made to an engineering design unit based on industry inputs is expected to provide a positive learning experience in preparing students to work in the industry in the long run, despite not initially being well-received by current undergraduate students during the learning phase of delivering the initiative. Current students may gain appreciation of the relevance of the new course direction through invited talks given by our working graduates.

KEYWORDS
Curriculum realignment, industrial projects, local industry.
Introduction

Universities often receive feedback from the industry stating that students are not industry-ready when they graduate. As the engineering sector continues to expand at a fast pace, it is almost impossible to fully train our graduates to be equipped with technical skills in every engineering sector in the industry. Universities would instead prioritise embedding self-learning and soft skills while being selective in exposing our undergraduate students to a variety of local industries. This is where universities are often reminded about the importance of embedding relevant hands-on skills into their curriculum.

Several works between 1990 to the start of the 21st century saw the importance of industry inputs into the engineering curriculum. A larger-scaled partnership with the industry called The Learning Factory was elaborated in Luery, Lamancusa, Zayas-Castro and Jorgensen (1998), where Industry Advisory Boards worked together with the support of deans and department heads. Lamancusa, Zayas, Soyster, Morell and Jorgensen (2008) expanded The Learning Factory idea to stimulate innovation in engineering education worldwide, particularly in Latin America where where expanding enrolments and shrinking budgets made mass lectures more attractive instead of hands-on labs. Alternatively, other promising ideas can be seen in Carlson and Sullivan (1999) where a “living laboratory” was developed through exposed engineering systems and sensors integrated into the building to provide students with an interdisciplinary learning arena. Feisel and Rosa (2005) emphasised why it was crucial for practicing engineers to be capable of developing good laboratory techniques as experimental data guides design and development of a product. Subsequently, these techniques are utilised once again to test performance and compliance of a product or system. In the paper written by Mills and Treagust (2003), the authors have recommended project-based learning to cater industry needs after examining the difference between problem-based and project-based learning.

In 2016, several changes were made in Engineering Design II to introduce Metrology laboratory and Geometric Dimensioning and Tolerancing (GD&T) skills. This unit is taught in Monash University in Australia and a branch campus in Malaysia. A design project involving failure analyses, computer simulations and component sourcing, based on a real-world problem faced by engineers in a local engineering provider in the machine tool industry, was developed for project teams of four students. In this paper, the focus is on how students in the branch campus in Malaysia from previous years perceived the importance of these skills before and after they have entered the working environment in the engineering sector. The collaborative approach in this industry-partnership involves integrating industrial-linked final year projects (FYP) and having the university staff provide GD&T training for the relevant industries.

Motivation in realigning the curriculum

The Mechanical Engineering discipline in Monash University aims to produce graduates who are competent in Mechanical Engineering, responsible and effective global citizens and leaders in their chosen profession or society at large. As part of the effort to achieve the above objectives, the discipline run an annual meeting with an Industrial Advisory Panel (IAP). In 2016, some feedback from IAP members specified that most students’ design skills were not fit for the manufacturing industry.

Further discussion with one particular company headed by one of the IAP members led to the decision to realign one of the engineering design units to introduce a metrology lab and GD&T. This company was very supportive in partnering with our university in providing ideas and inputs for the major design project where the best design award was sponsored by this local company. The staff involved in carrying out these changes within the course was invited to provide GD&T training to existing staff in the same company, which benefitted both parties.

Several FYPs were based on issues faced in the manufacturing industry. Other IAP members offered their contacts for lecturers who are interested to get involved or provide industry-based projects.

Realignment Strategies

Metrology Lab

The Metrology Lab was first introduced into the Engineering Design II unit through 2 hours of laboratory sessions near the end of the semester. Students work in pairs as they take turns to visit 10 different mini stations. At each station, a set of basic measuring tools consisting of a Vernier caliper...
and a micrometer is provided along with a mechanical component such as a slotted locator bushing, spring plungers, locating keys, cone locator pins, reverse check valve, liner bushings and bullet-nosed pins. Along with the activities to measure specific features in the lab instruction, students are also probed to think about why certain features or surface finishing were introduced in these parts. The latter part of the lab was carried out in a conversational discussion with each pair of students.

**GD&T Lecture Series and Workshop**

Flipped learning was first introduced in Engineering Design I in year 2013 in Monash University and had a very high approval rate as seen in Wordley, Jones, Taylor and Pearson (2016). Subsequently, the same learning approach was fully implemented for Engineering Design II in 2016. In conjunction with the flipped learning approach, a series of 17 short online videos totaling around 63 minutes were made available to students prior to an online quiz consisting of seven random questions on GD&T. These activities are to be completed before students attempt to complete a set of worksheets through a facilitated workshop near the end of the semester. Despite having little time to implement these skills in their team project, it was convenient enough for project teams to pause and consider how they could apply GD&T into their design and include tolerance in their working drawings before the project submission deadline.

**Industrial-linked Final Year Projects**

Data collected from four staff in the Mechanical Engineering discipline in the Malaysian branch campus indicated final year projects revolve around these following sectors:

- Farming and Plantation technology
- Assisted cutting and machining processes
- Thermal performance of water heaters and water tanks
- Mobile robot manipulation and navigation

These projects were very much concentrated on local industries, although outcomes from some these projects can be extended to engineering applications in other countries. In 2016, there were at least five industrial-linked projects completed. The number of projects doubled to ten in 2017 based on data collected from three staff in the Mechanical Engineering discipline who had indicated their interest in working with industry partners.

**Training provided for a local industry**

The training conducted for 10 staff in SDMK (Malaysia) Sdn. Bhd. was based on how GD&T was taught in the Engineering Design II unit. A series of training videos and five sets of quizzes were provided to the company two weeks before a workshop was done. The participants could access training videos on GD&T and the company carried out an in-house quiz the day before the workshop. The purpose of the in-house quiz was to familiarize participants with the definitions and symbols used in GD&T. A further half-day workshop allowed participants to complete several examples and exercises using a set of worksheets on the following topics:

- GD&T symbols and Control Names
- Feature Control Frames
- Functional Datums
- Feature of Size
- GD&T Controls
- Bonus Tolerances

Participants could access training videos as appropriate. The managing director of the company requested the GD&T training after attending a similar workshop for students of Engineering Design II being held during his visit to award the best design prize to our students. He delivered positive feedback that the GD&T workshop was very relevant to the engineers working in his company as most of them were not given proper training in GD&T.
Results and Discussion

Student Evaluation

The student overall satisfaction score obtained from the Student Evaluation of Teaching and Units (SETU) quantitative survey, which uses a 5-point Likert scale, declined significantly in the year the Metrology Lab, GD&T and industry-based design project was introduced (Table 1).

<table>
<thead>
<tr>
<th>Year</th>
<th>Implementation of Metrology Lab and GD&amp;T</th>
<th>Overall Satisfaction Score in SETU</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>No</td>
<td>4.36</td>
</tr>
<tr>
<td>2016</td>
<td>Yes</td>
<td>3.81</td>
</tr>
<tr>
<td>2017</td>
<td>Yes</td>
<td>4.04</td>
</tr>
</tbody>
</table>

It appears that students demonstrate some resistance or reluctance to change whenever new content or a change in syllabus is introduced, especially if it involves additional effort to complete a particular unit. Data from qualitative SETU survey in 2016 appears to validate that there was resistance to the curriculum alignment. In the 2016 qualitative SETU feedback, a student commented that “The content of the unit is huge and wide, might consider to cut down to those relevant only (sic).”

A more detailed examination of the qualitative SETU feedback over the three-year period showed that some students were interested in more hands-on laboratory experience. When the Metrology Lab was introduced in 2016, students were still requesting more hands-on lab similar to the Metrology Lab. Statements such as “put in more hand-on labs and site visits so that we can actually know how design works in real life application” in 2015 and “Maybe more hands on classes like the GD&T lab we had” in 2016 gave the impression that students found value and were looking forward to more hands-on laboratory work.

Despite indicating they would like more real-life applications to be introduced, students also struggled with the open-ended nature of real-world design projects. A comment of “Give a proper instruction of what the project wants from us. It is very misleading and we have to keep correcting our design over and over again” in 2016 implies students have missed the point in how a good workable design is developed. This particular student may not have carried out a problem definition process to begin with, a technique taught in the first course in engineering design in second year and re-introduced in this unit. The latter part of the statement shows the student did not expect revisions to be made to their design from feedback provided by the lecturer through a preliminary submission. They may not have realized that clients in the real-world would provide more or new information on-the-go in the process of designing. Information received from the client is never complete and there are many other variables that require a good estimation and further investigation of the actual situation and environment to identify an effective solution for a particular project. Students found it a challenge to juggle with many uncertainties, limitations and parameters in an open-ended project.

There were more positive comments in the second year (2017) after the curriculum alignment was implemented, such as “I like the practical usage of the unit. We get to apply what we learn during the lesson into the project” and “This unit has helped me to understand what my job as an engineer would be one day. From designing something from scratch by applying theory, facts and also general knowledge.” Although some comments inferred some students still needed more guidance in their project, students had a better acceptance of the changes.

Student Survey

Students who had done the Engineering Design II Unit either prior to or after introducing the Metrology Lab and GD&T in 2016 were surveyed on the perceived usefulness and importance of the Metrology Lab and GD&T skills at an engineering related workplace, either in their industrial experiences (>2 months) or current job (Table 2). Although the data is limited, the older generation of students who took Engineering Design II before the alignment in the third year of their studies are likely to have had more than a year’s working experience within the engineering sector. These five graduates felt
strongly that the Metrology Lab and GD&T skills were very useful with an average rating of 4.60. They had hoped these skills were included in their undergraduate studies. Four of the five respondents inferred that these skills were relevant and three had been provided with training by the company they are working for.

One of the ex-students surveyed, who now works in a local industry as a Supplier Quality Engineer, provided the following positive statements:

“Understanding the GD&T of drawing is really important. Some designers do not implement a good practice of GD&T. This brings lots of confusion when measuring with Metrology equipment. Without a good GD&T, it might also lead to quality issue in the long run, as for e.g., a wrongly located datum will add on to the wrong calculated stack up tolerance, which will end up with assembly issue.”

“Metrology knowledge is really important in understanding the different method of taking measurement, as well as the limitation on how accurate the measurement is (Measurement Variation). With the knowledge of the proper usage and good practice of handling machine and the measuring process, it will give people the confidence in the measurement result. This is important, especially in quality checking process, or even when performing reverse engineering procedure.”

“I am glad that students now are exposed to the skills at university level. This will definitely help them a lot in the future. Great initiative!”

The average rating of the 14 respondents who have been exposed to the industry work, either through their industrial internships or in their first jobs rated relatively low on the importance of Metrology Lab and GD&T skills as seen in Table 2, averaging at 2.5 compared to their predecessors who have not taken Metrology Lab and GD&T in their courses.

Table 2: Average usefulness ratings of Metrology Lab and GD&T skills at workplace

<table>
<thead>
<tr>
<th>Year Engineering Design II Unit was taken</th>
<th>Number of respondents</th>
<th>Average ratings of Metrology Lab and GD&amp;T skills (1 – not useful, 5 – extremely useful)</th>
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</thead>
<tbody>
<tr>
<td>Prior to 2016</td>
<td>5</td>
<td>4.60 Before alignment</td>
</tr>
<tr>
<td>2016</td>
<td>7</td>
<td>2.43 After alignment (averaged at 2.5)</td>
</tr>
<tr>
<td>2017</td>
<td>7</td>
<td>2.57</td>
</tr>
</tbody>
</table>

However, Table 3 shows that the majority (11 out of these 14 respondents) were not working within the manufacturing sector. Only four respondents felt that these skills were relevant to their industry, with two of the respondents working within the manufacturing sector. The lack of respondents representing the manufacturing industry would have easily contributed to low ratings reported in Table 2.

Table 3: Relevance of Metrology Lab and GD&T skills in industrial experience for students who have undertaken Engineering Design II units after curriculum alignment was implemented (Year 2016 and 2017 combined)

<table>
<thead>
<tr>
<th>Number of respondents</th>
<th>Relevance to their industry</th>
<th>Respondent’s company provided Metrology Lab and GD&amp;T training</th>
<th>Worked in manufacturing or other engineering sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 out of 14</td>
<td>No</td>
<td>No</td>
<td>1 in manufacturing sector 9 in other engineering sector</td>
</tr>
<tr>
<td>2 out of 14</td>
<td>Yes</td>
<td>No</td>
<td>Manufacturing sector</td>
</tr>
<tr>
<td>2 out of 14</td>
<td>Yes</td>
<td>Yes</td>
<td>2 in other engineering sector</td>
</tr>
</tbody>
</table>

The limited data collected in this preliminary study indicates that most students will not need Metrology Lab and GD&T skills to be embedded into their undergraduate studies. These skills are mainly required in the manufacturing sector and most companies are currently obliged to provide the specific training required. However, introducing these skills during undergraduate courses provides a head start to those entering the manufacturing sector and are still relevant in other engineering sectors.
Through the same survey, respondents indicated that they would like to see more of the following industry-based skills to be embedded into their Engineering Design courses:

- Heavy/industrial machine operation and CNC manufacturing (five respondents)
- AutoCAD® drafting (three respondents)
- Hands-on (two respondents)
- Problem solving (two respondents)
- Procurement & project management (one respondent)

Finally, 24 out of 26 respondents indicated that Monash University should continue including Metrology and GD&T skills as part of the Engineering Design series. Despite having conflicting responses from students who have joined the workforce and those still completing their undergraduate studies, there is a strong indication that the alignment would have a positive impact through our Engineering Design courses as these skills may still be useful within the broader engineering sectors although it is known to be crucial in the manufacturing sector.

Conclusion and Future Recommendation

The Metrology Lab and GD&T skills were reported to be relevant not only in the manufacturing sector but also in other engineering sector for half the respondents surveyed. Those who strongly indicated these skills were very important who been in the workforce for more than a year. Students who had recently completed Engineering Design II in the past two years were not so convinced of the importance of these skills. One way to motivate current students to see the importance of industry-related skills, aside from inviting industry engineers as speakers, is to have alumni returning to the university to share their experiences. Further research can be done to include a larger data set with better representation of graduates who have been in the workforce longer (>1 year).

Despite having mixed responses from limited number of students surveyed, almost all the respondents were very supportive of the curriculum alignment in Engineering Design II unit when Metrology Lab and GD&T skills were introduced in year 2016. Other efforts to bridge the gap between the university and the industry includes offering more industrial-linked final year projects and providing the local industry with relevant training through resources available within the university.

References


