The Warman – Looking Beyond 30 Years

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SESSION C1: Integration of theory and practice in the learning and teaching process

Context

Our collective experience over 30 years of organising, fine-tuning, creating unique projects and running what has become known as the Warman Design and Build Competition (WD&B) is presented. The competition is for students in the second year of undergraduate courses in mechanical engineering, broadly defined, in Australian and New Zealand universities. The idea of running a variant of the WD&B as a high school STEM project is being considered.

Purpose

We wished to establish firm data supporting the efficacy of the WD&B and indicate ways in which the current project and competition might be promoted and extended in its reach.

Approach

Ongoing assessment of student response to the competition since its inception, and the scope of experience students gained has been conducted, over what has been a period of rapid industry transition, and links between the WD&B and the development of Engineers Australia's Stage 1 Competencies are shown.

In 2017, more extensive surveys than in the past were conducted seeking the opinions of:

- Students competing at Campus level,
- Students competing at the National Final,
- Campus Organisers, and
- Members of the Mechanical College, EA (part of a broader survey of design practice).

Results

The conclusions drawn from all surveys are highlighted with strong support and evidence for positive learning arising from the WD&B.

The adoption of the WD&B at the University of Melbourne in 2010 and reflections on their experience provide an exemplar for the continued expansion of the WD&B. It is clear the project is successful in:

- integrating practical engineering with coursework,
- developing 'work readiness', and
- providing a 'coat-hanger' to support the engineering sciences.

Conclusions

The WD&B has been an outstanding success over its 30-year life. In the changing educational world, the plan is to ensure that it continues to meet educational needs and course structures and, if necessary or desirable, make appropriate changes. The question of entering the STEM array by creating a modified 'Warman in Schools' is currently unresolved.

Keywords

Student D&B projects, Warman, Mechanical Engineering Design

Student Design and Build Projects

With the exception of ‘farm kids’, engineering undergraduates in the 21st Century generally have had little practical experience in engineering construction, maintenance or repair. It is no longer the age of DIY repairs to home, car or other equipment. Practical, hands-on experience has many benefits, providing relevance to the engineering-science content of typical courses and, equally importantly, helping to achieve some semblance of ‘workplace readiness’. A now widely used method to promote this benefit is to use student design and build projects or competitions as part of coursework. Careful consideration and good judgement are needed to ensure that such projects justify the course time they expend. Careful matching of project complexity and assessment of their learning benefits is also essential, as is the need for fresh new projects, year by year.

As discussed in (Smith 2013), *“from an engineering educator’s perspective, the purpose for presenting students with project-based experiential learning scenarios in a curriculum is to replicate real world activity in the profession they have chosen. Many authors have addressed these issues (including (Dym, Agogino et al. 2005); (Counce, Holmes et al. 2001); and (Dutson, Todd et al. 1997)). In such projects, students are given an opportunity to safely develop their domain and professional skills and grow in confidence and experience. Students are led through processes of divergent and convergent thinking while applying basic science and engineering principles. This naturally sits well with university education which seeks to equip students with the ability to respond to open problems and uncertainty which while pushing them beyond their comfort zones prepares them for their future.”*

The Warman Design and Build Competition Described

The Warman Design and Build (WD&B) is an experiential, systems realisation challenge. The WD&B provides a unique project-based problem-solving experience annually for teams of nominally four second-year mechanical-engineering students in Australasian universities. The project takes place on two levels, initially across individual campuses and then at a ‘National Final’. The Final, typically run over three days, brings together winning teams from participating universities. While focused on mechanical engineering, some students from other disciplines participate because various streams undertake common design courses.

Considering the impact of the project, approximately 2,500 students in 20 universities experienced the WD&B in 2017. It follows that over 30 years it has influenced the education of tens of thousands of engineers, while directly supporting many academics who have implemented the project at their own universities.

Devising of the original project tasks and rules for each season is not a trivial creative task. The requirement is to design and implement a project for the engagement of all students that challenges the ‘best-of-the-best’ (at the National Final) yet stimulates and excites ingenuity at the local level without discouragement. It is important to ensure that tasks are open to multiple competitive design concepts and different solutions. Therefore, some apparent ambiguity in the formal project specification is intentional while clearly defining which boundaries should not be crossed. Consequently, the devices at the National Finals typically represent widely different concepts. The fact that the best teams across 20 campuses have not converged to the same solution reaffirms the evolved strategy.

Cost and student skill levels are considerations in writing the rules. Each campus takes a different approach but the rules state students shall manufacture their prototype device themselves using commonly available materials, components and methods. The production skill exhibited between teams varies greatly as does the investment made. However, at whatever level a team becomes involved, significant learning has always been clearly demonstrated. Feedback from stakeholders indicates that students achieve key learning outcomes as they tackle technological, fabrication and integration issues, possibly for the first time. This can be as simple as students learning to work with friction. When they want it, they cannot get enough and when they do not want it, there is always too much. Campus organisers have found it satisfying to watch students engaging in valuable peer-to-peer learning, teaching each other about aspects without prior formal instruction on them. This is clear evidence of the growth in both maturity and technical competence of the students.

In establishing the rules, the real objective for the device performance is based on a unique scoring algorithm. A range of measures is used including mass, size, speed, reliability and transport efficiency. Over time, the algorithms have become more complex. This has been a conscious decision to challenge all students to make some value judgments about their target score and their realisation capabilities. With the rules expressed in the context of designing for use on the mythical planet Gondwana, students are sometimes confused by a client value system, which is at odds with their own. While this is not as evident at the National Final, at the campus level it has caught some teams out, teaching a valuable lesson about listening to the voice of the customer. Through observation, and sharing across teams, albeit in a competitive environment, this and other similar lessons can also be taught to the whole class. When students find the going tough, they do accept reassurances that they are investing in their future, that nothing of value is easy, and that they need to balance the difficulties with the positives. At the end of the experience, almost all students acknowledge that they learned a lot about themselves as well as about design, that they benefited from being pushed outside their comfort zones, and that they had fun in the process.

Details of universities which have competed over the years, together with much other data for the Competition, may be found in (Churches and Smith 2016). As shown in Table 1, the maximum number of campuses competing in any year was 24, in 1995. The lowest number of competing campuses was 14, in 1989, 2008 and 2010. The campuses of the UNSW Canberra (at ADFA), Adelaide, and Newcastle have been the most consistent participants, with 29 attendances at National Finals. The average number of participating campuses over the Competition's history has been 17.6.

Universities returning in 2017 after a significant break are CQU, QUT and University of Tasmania. The University of Tasmania entry though is from the AMC (the Australian Maritime College) that represents a first time involvement for this campus. While foreign campuses of Australian universities have been involved in the past (Monash Malaysia and UTS Singapore), 2017 sees Shandong University from China representing the first independent entry beyond Australasia in 30 years.

Measuring Effectiveness

In essence, the objective of the WD&B has been to assist Universities offering Mechanical Engineering programs (broadly defined) to produce more rounded undergraduate student capability. It does this by providing a complete practical exercise requiring creative conceptual design, leading to prototype construction, testing, refinement, reconstruction (manufacture) and proof testing. It is no accident that the skills built up in the WD&B closely match Engineers Australia's (EA) Stage 1 Competencies and that the students perceive these competencies being developed through the WD&B project. This coincidence is a powerful argument for the Warman to be considered as part of any undergraduate Mechanical Engineering program, preferably coinciding with the first course in design analysis. An indication of how closely the WD&B relates to the Stage 1 Competencies is given in Table 2. Engineers Australia considers the WD&B a benchmark project for enlightening our undergraduate cohort in engineering whole-of-life processes.

The testimony of RMIT students at a national final is encouraging and representative. They wrote: *"from when we began the project many months ago (at RMIT) up until the last roll of the dice on Sunday afternoon (at the National Final), we've learnt so much that we feel will be invaluable as we advance through our engineering degrees and in turn careers. … (the WD&B) will help to shape us as engineers for the future."*

Table 1: Participation in the Warman Design and Build Competition

UNIVERSITIES Participating		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	TOTAL at NF	18	14	18	18	20	17	22	24	21	21	18	18	16	18	16	18	17	20	16	17	14	17	14	15	16	17	15	15	17	18
	COUNT at NF																														
Australian National University	**3**								■	■	■																				
Auckland University of Technology	**2**																									■	■				
Central Queensland University	**19**		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■											■
Charles Darwin University	**4**																		■	■	■		■								
Curtin University	**14**	■			■	■	■	■	■		■		■	■	■			■	■	■	■										
Deakin University	**3**																											■	■	■	#
Flinders University	**7**																								■	■	■	■	■	■	■
Griffith University Gold Coast	**3**																										■		#	■	■
James Cook University	**22**	■	■	■	■	■	■	■	■	■								■	■	■	■	■	■	■	■	■	■	■	■	■	
Massey University, NZ	**5**							■	■	■	■	■																			
Monash University	**27**	■		■	■	■	#	■	■	■	■	■	■	■	■	■	#	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Monash University - Caulfield	**15**	■		■		■	■	■	■	■	■	■		■	■	■	■	■	■	Closed Engineering Program											
Monash University, Malaysia	**10**												■	#	#	#	■	#	#	#	#	■	■	#	#	■	■	■	■	■	■
Queensland University of Technology	**17**	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■														■
RMIT University	**25**	■		■				■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Swinburne University of Technology	**12**	■			■	■	■	■	■						■	■	■	■	■	■											
University of Adelaide	**29**	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
University of Auckland, NZ	**24**						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■	■	■	■
University of Ballarat	**7**												■				■		■		■	■	■		■						
University of Canterbury, NZ	**26**					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
University of Melbourne	**8**																							■	■	■	■	■	■	■	■
University of Newcastle	**29**	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
University of New South Wales	**25**	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	#	■	■	■	■	■				
University of NSW, Canberra (at ADFA)	**29**	■	■	■	■	■	■	■	■	■	■	■	■	■	#	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
University of Queensland	**18**	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■				■								
University of South Australia	**21**	■	■	■	■	■	■	■	■	■	■										■	■	■	■	■	■	■	■	■	■	■
University of Southern Queensland	**21**							■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■
University of Sydney	**7**		■	■	■	■			■	■			#	■																	
University of Tasmania	**18**	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■		■	■	■										
University of Tasmania (AMC)	**1**																														■
University of Technology Sydney	**22**	■	■	■	■	■		■	■		■	■					■	■	■		■		■	■	■	■	■	■	■	■	■
UTS - Singapore	**1**																	■													
University of Western Australia	**25**	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■				
University of Wollongong	**10**	■	■	■	■	■	■	■	■	■																				■	#
Victoria University	**12**	■	■	■	■	■	■		■	■	■	■		■	■																
Shandong University, China	**1**																														■

 # - Participated at Campus level but not at the National Final

Table 2: Engineers Australia's Stage 1 Competencies and How the WD&B Builds Capacity in the Elements of Competencies

Stage 1 Competency and Elements of Competency		How the Warman Competition Builds Capacity
1.	KNOWLEDGE AND SKILL BASE	
1.1.	Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline.	Students apply engineering fundamentals to systematically investigate and analyse a complex engineering problem, with the aim to develop an innovative and practical solution.
1.2.	Conceptual understanding of the mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline.	Students develop and apply relevant investigation analysis, interpretation, assessment, prediction, evaluation and measurement tools to evaluate the performance of their solutions.
1.3.	In-depth understanding of specialist bodies of knowledge within the engineering discipline.	N/A
1.4.	Discernment of knowledge development and research directions within the engineering discipline.	Students interpret and apply selected research literature to inform their conceptual designs, material selection and methods of construction of their prototype devices.
1.5.	Knowledge of contextual factors impacting the engineering discipline.	N/A
1.6.	Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the specific discipline.	Students apply systematic principles of mechanical engineering design to develop their solutions and gain a real-life understanding of the fundamental principles of engineering project management. Students appreciate the principles of risk management and the health and safety responsibilities of a practical engineering problem during construction, commissioning and operation.
2.	ENGINEERING APPLICATION ABILITY	
2.1.	Application of established engineering methods to complex engineering problem solving.	Students learn to partition the set problem into manageable elements for the purpose of analysis and design, and then recombine to develop a functioning solution in the form of a prototype.
2.2.	Fluent application of engineering techniques, tools and resources.	Students apply a wide range of engineering tools for analysis, simulation, visualisation and validation of their designs. These tools are often taught concurrently in the course. Students design and safely conduct experiments, analyse and interpret data, and formulate conclusions in relation to the performance of their prototype systems.
2.3.	Application of systematic engineering synthesis and design processes.	Students proficiently apply technical knowledge and open ended problem solving skills to design various elements of the prototype system to satisfy the competition specifications.
2.4.	Application of systematic approaches to the conduct and management of engineering projects.	Students work in teams to execute a relatively complex engineering project and become aware of the need to plan and quantify performance over the life-cycle of the project.
3.	PROFESSIONAL AND PERSONAL ATTRIBUTES	
3.1.	Ethical conduct and professional accountability	N/A
3.2.	Effective oral and written communication in professional and lay domains.	Students build capacity in communication with their peers, including comprehending critically and fairly the viewpoints of other team members, and expressing their own information and ideas effectively and succinctly. Courses often include the requirement to submit a written report and oral presentation as part of the project assessment.
3.3.	Creative, innovative and pro-active demeanour.	Students apply creative approaches to identify and develop alternative concepts and solutions, often from both technical and non-technical viewpoints.
3.4.	Professional use and management of information.	N/A
3.5.	Orderly management of self and professional conduct.	N/A
3.6.	Effective team membership and team leadership.	Students are required to work in a team environment of nominally four members. This exposes students to the fundamentals of team dynamics and leadership, learning to earn the trust and confidence of their colleagues, and recognising the value of alternative viewpoints.

Surveys have been conducted over the years of the opinions of students who have completed the WD&B and of design-lecturing staff at the various competing universities (the Campus Organisers). References to the bulk of these surveys pre 2017 and prior history can be found in (Churches 1989), (Magin and Churches 1992), (Magin and Churches 1994), (Field 1997), (Churches and Magin 1998), (Churches and Magin 2003), (Churches and Magin 2005), (Smith 2007), (Smith 2008), (Smith 2013) and (Churches and Smith 2016).

Students and campus organisers have been unanimous in indicating that the project makes important contributions to student learning in many respects, e.g. how to work in groups, the importance of simple design, and the practical experience of design. Each University uses the WD&B framework differently with respect to student assessment and the support students receive. However, all campus organisers agree that the activity supports their learning objectives very well. In the benign environment of the competition, both success and failure are turned into effective design learning outcomes.

In 2017, more extensive surveys were conducted gauging the opinions of:

- Students competing at Campus level (198 responses),
- Students competing at the National Final (53 responses),
- Campus Organisers (13 responses), and
- Members of the Mechanical College, EA (part of a broader survey of design practice).

Consolidating student data from similar surveys, collectively provides 1613 responses from those engaged in the WD&B from 1991 to now. The picture is very positive, as depicted in Figure 1[1]. The lowest “yes” response to “Did your experience of participation in the WD&B result in learning in …?” across a large range of issues is 67% with the highest being 86%.

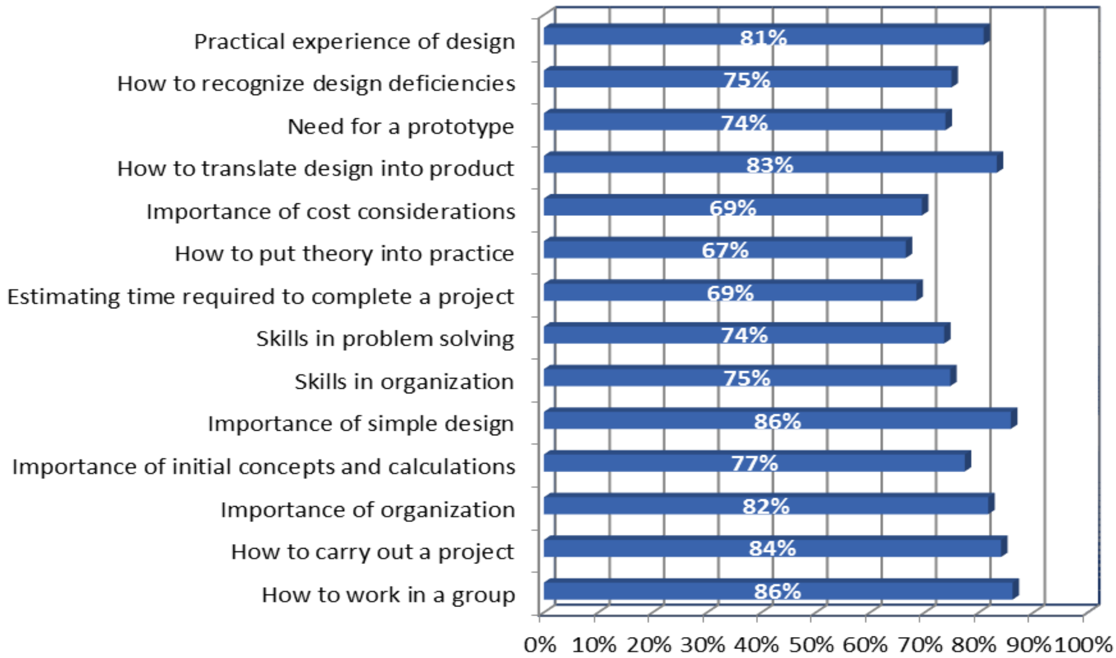

Figure1: Student survey responses of “YES” to “Did your experience of participation in the WD&B result in learning in each of the aspects listed?” (significant or some)
(responses marked ‘little’, ‘unable to say/unsure/blank’ or ‘no/none’ account for the remainder)

[1] Data: 2017 (N Finalists, 53), 2017 (National Survey, 198), 2016 (N Finalists, 64), 2015 (N Finalists, 54), 2014 (N Finalists, 50), 2010 (N Finalists, 44), 2004 (N Finalists and 3 campuses, 328), 2002 (National Survey, 345), 1997 (National Survey, 318), 1993 (UNSW, 87) and 1991 (UNSW, 72).

In 2017, the effort in reaching out to the Mechanical College members was to document College member views held of Engineering Design in general and the WD&B in particular. Questions asked and responded to by 159 members included:

- Do you consider your university program provided you with an adequate foundation in the PRACTICE of Engineering Design? - 122 said “yes”.
- What percentage of your working time is related to Engineering Design? – The average of responses was 44% but with 26 respondents identifying zero.
- What percentage of your working time is devoted to actual Engineering Design? – The average of responses was 24% but with 41 respondents identifying zero.
- Did you participate in the WD&B at the Campus Level (conducted 1988-present)? – 80 said “yes”.
- Did you participate in another significant ‘Design and Build’ activity? – 16 said “yes”. Responses included FSAE, SAE Baja, Solar Boat Challenge and a range of thesis and work related projects.

The 80 Mechanical College members that experienced the Warman were also asked to respond to the same instrument used with students since 1991 and summarised in Figure 1. The results for the college members are shown in Figure 2 where the banding of positivity in reflection towards the WD&B spans 61% to 93%. In both cohorts the highest ranking “yes” response was for learning how to work in groups. The importance of simple design was also highly rated by both. In contrast, the importance of cost as a learning outcome was lowly rated by both. Perhaps this highlights the efforts of the national organisers to eliminate the financial investment of students as a discriminator of system performance in the WD&B.

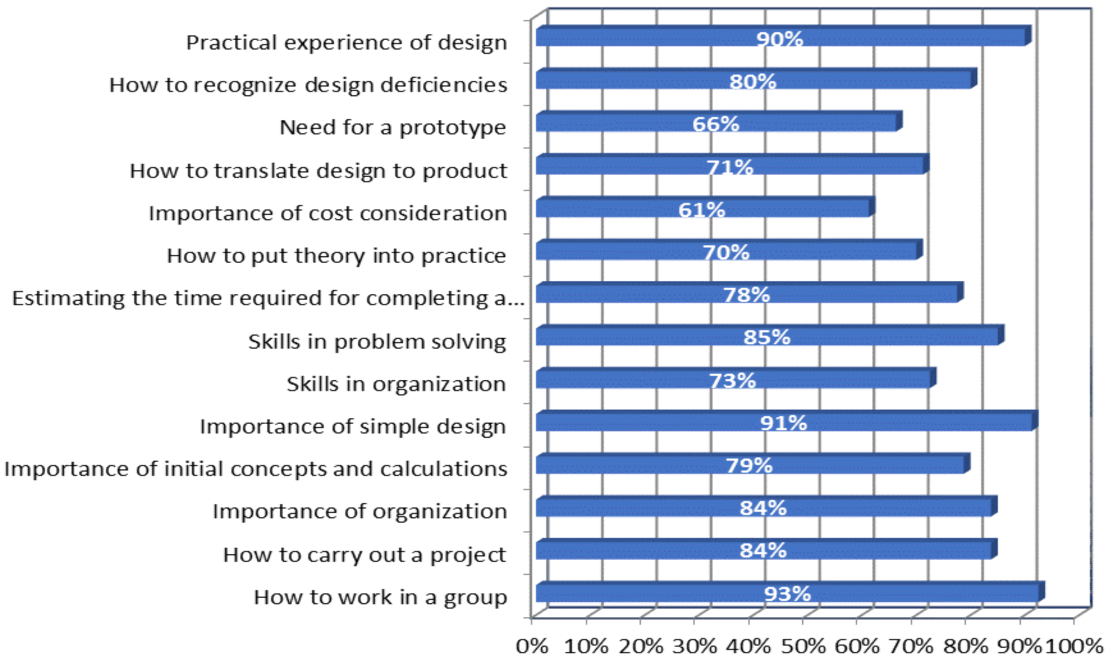

Figure2: Mechanical College responses of “YES” to “Did your experience of participation in WD&B result in learning in each of the aspects listed?” (significant or some)
(responses marked ‘little’, ‘unable to say/unsure/blank’ or ‘no/none’ account for the remainder)

In further reflection (for those Mechanical College members who experienced the WD&B):

- Do you consider the WD&B experience valuable to you? – 73 of 80 said “yes”.
- What do you remember most about your WD&B experience? – many comments were provided including one from a 2002 participant which read: “*It was real, and results*

depended on something actually working, not the theory. You could invest a lot of time into something only for it to be wasted. You needed to put a lot more effort in to get it to work. The camaraderie of our team mates was also brilliant, as was the competition and rivalry aspect."

- Please comment on how the WD&B experience has impacted your design thinking? – again, many comments were provided including from a 1993 participant: *"It reminds me of what failure looks like, and how to avoid it."* It is noted that not all students are successful in the competition aspect of the WD&B but learning can still be achieved.
- Can you connect your WD&B experience in anyway with your subsequent engineering career? – While some indicated not really in a direct way, a perceptive comment in respect of tacit knowledge came from a 2002 participant who said: *"Not consciously, but I think it definitely helped."* Others were more explicitly positive stating "*I'm still using that experience (1997)*", and that it helped them in "*working as a team, and the need to be resourceful (2000)*".

The distribution of the 80 Mechanical College respondents' WD&B experience across the 30 years of the competition is shown in Figure 3. The mode fell on 2000 with 6 and two respondents failed to identify their year of involvement. There were only three years of the competition unrepresented in the sample, namely 1988, 1990 and 1995. Of the 80 respondents, 23 identified themselves as also being National Finalists.

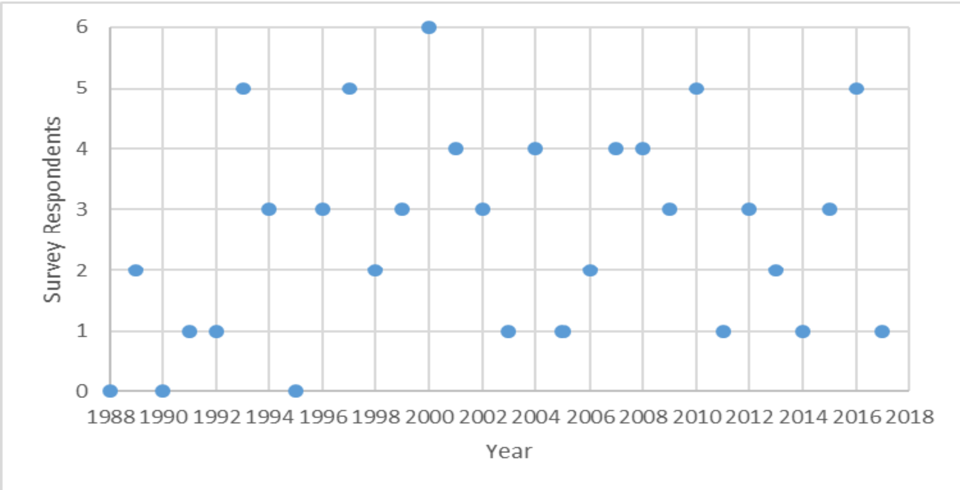

Figure3: Mechanical College respondent involvement in the WD&B across 30 years

Reflections on the University of Melbourne Experience

As shown in Table 1, The University of Melbourne first engaged in the WD&B in 2010. Reflections on this decision to enter the competition (in the competition's recent history), and the subsequent experiences of Melbourne's students highlight messages and lessons for further expansion of the project to other universities.

In 2008, the University of Melbourne introduced the 'Melbourne 3+2 Model'. It consists of a 3 year Bachelor's degree (in 'Design' or 'Science' for Mechanical Engineers) followed by a 2 year Master's degree. (As a recent experience in major course revision, it may provide useful data on design-learning issues.) Design is first taught in the second semester of year 3 in the BS capstone course (MCEN30014) with over 200 enrolled students annually. Design as a disciplined activity is then built upon through the Masters. With the introduction of the 'Melbourne Model' came the opportunity to innovate the design teaching and learning curriculum. The School of Engineering academic executive understood the importance of practical experiences in concept realisation, and this enabled the design discipline leader to successfully negotiate the inclusion of WD&B into the mechanical engineering curriculum, entering the National Final for the first time in 2010.

The design leader, like many involved with the WD&B is passionate about design and preparing students for their professional industry careers. Students typically do not find design easy. There is often no right or wrong answer. Focusing upon experiential learning and the integration of student theoretical understanding blends content from other disciplines, such as statics, dynamics and strength of materials, to achieve realistic goals. Students need to work in teams, and this offers a distinct set of possibly new soft-skill challenges and opportunities. A WD&B assessment task associated with team development reflections encourages student engagement. Students are introduced to the research of Bruce Tuckman and Meredith Belbin as a foundation conceptual framework for teaming.

Within the BS program, students have few practical experiences (i.e. design, build, trial, revisit design) in the prerequisite subjects. This deficit has the potential to be detrimental to student experience in the eight-week WD&B that is the team-based focus of this subject. Despite concerns about students resenting the lack of a graded skill development program within the overall Bachelor course, student feedback for the WD&B is positive.

Optional seminars are scheduled outside normal lecture times for students who have no prior experience but are interested in additive manufacture (3D Printing) and inexpensive controller programming (Arduino). The emphasis to the student cohort is that the use of these technologies is not mandatory but rather an option that the team can choose to pursue.

Melbourne students, in the main, have appreciated that the WD&B offers an engineering experience closer to the 'real world' than has been offered anywhere in their prior studies. It is emphasised to the student cohort that performance in the WD&B trials have little bearing on overall honours calculations. The students are told from the outset and repeatedly that 100% for all the three written tasks (Initial Appreciation, Morphological Analysis, Final Report) and a minimum finite WD&B trial score would earn a minimum of 80% corresponding to first class Honours. The WD&B is valued at 50% of the overall subject (with two other minor assignments and a 40% exam). These weightings give the student a strong indication from coordinating staff, and the School of Engineering as a whole, that *"WD&B is important"*. The associated pedagogy, where the student is given the twin messages, *"Practical design realisation experiences are critical to your professional development"* and *"There is no need to be anxious about the impact of your performance during WD&B trials on your overall course honours calculation"* is critical to student engagement.

In fact, the overall marketing aspect of the WD&B experience cannot be overvalued. This includes marketing to the students, to colleagues, to the many managers in the academic world who are at best advocates, but who must never be allowed to be less than neutral about the program. It is nigh impossible for School of Engineering academic executives to be anything but supportive when the arguments associated with WD&B are articulated.

- Marketing the WD&B to teaching and learning academic executive: *"If every student were able to realise a design that completed the task perfectly, we could be confident that coordinating staff have compromised the learning opportunities available from a more challenging task that necessitates more struggle from more students."*
- Marketing the WD&B to the fabrication workshop manager: *"Open your doors and let me fill your workshop with students. Any future review of your workshop cannot but identify the essential design-realisation support function."*
- Marketing the WD&B to academic colleagues: *"The WD&B does cost a lot more than the average subject, but WD&B will offer our students an advantage in the competitive job market for graduate engineers."*
- Marketing the WD&B to university leadership not currently participating: *"The WD&B is an exclusive elite club that any Engineering School can join."*

- Marketing the WD&B to colleagues considering whether to champion the introduction of WD&B: *"In this era, practical skills that can facilitate a successful graduate career are ascendant. There is evidence that university engineering executives are searching for means by graduate competitiveness can be enhanced. The WD&B is one opportunity. In addition, there is evidence in this era in Australia that career progression can be achieved through academic leadership of practical and professional 'soft' skill development in the student cohort."*

Of course, the evangelical message has to match the audience. However, at the University of Melbourne, the WD&B is now fully embedded with future planning for 'Fab-Lab facilities' predicated on supporting the WD&B experience. It is being used as a foundation success from which other departments and disciplines are encouraged to launch their own design-realisation initiatives.

A final reflection is that the performance of the majority of systems is not great but students are always congratulated for participating and reminded of the underlying active learning pedagogy from which profound learning outcomes are available from WD&B. For example, from communications with 2017 students following the WD&B Melbourne trials:

Dear MCEN30014 Student,
Congratulations to all teams on the endeavour, blood-sweat-and-tears, and struggle that was on display during the Warman Performance Trials this afternoon!
As I stated at the start of the semester, the actual performance of your device will not have a significant impact on your overall course outcome in MCEN30014 but it is an excellent opportunity to learn practical issues associated with our profession. The 'biggie' is that, in practice, what we design eventually has to be built, or more generally, 'realised'. Everyone now has a deep understanding of this fundamentally important concept. … Thanks to all those who supported the Warman Performance Trials this year! … (especially those who) offered students many learning outcomes, some simple and others subtle.
Of great importance, I know that many of you have been made aware of appropriate behaviour in potentially dangerous environments, especially with respect to Occupational Health & Safety (OH&S) requirements. This learning will serve you well in your future careers.
It is my personal opinion that the 2017 Performance Trials has offered MCEN30014 students an excellent 'Warman' active learning experience. Again, congratulations to you all! CB

Dear MCEN30014 student,
Following the 'crescendo' of last Thursday, … Each and every team that was able to place a device at the start zone of the track (irrespective of what happened next) should feel proud. You rose to the challenge, dealt with the steep learning curves of designing and fabricating a complex system, and likely learned many important lessons along the way. CB

Looking Forward

As discussed in (Churches and Smith 2016), the life of the WD&B has seen marked changes in Australia's university system. One of the most significant has been an increasing emphasis on research, with university funding heavily linked to research outcomes. We conclude and believe the result has been a focus on educating graduates in 'engineering science' to the detriment of 'engineering practice', with practical engineering design the big loser. Whilst Engineers Australia's National Committee on Engineering Design (NCED) believes there is sufficient current pressure, through the EA Accreditation process, to increase the practical engineering content of Australian engineering courses, in 2018 and beyond the need for the WD&B experience is as great as it has ever been.

The WD&B has moved with the times. From the specification of a purely mechanical device in its first few years, projects are now written to be suitable for inclusion in mechatronics courses, while still not excluding purely mechanical devices. There remains keen interest from the Campus Organisers and the student cohort present at each National Final is judged to be as enthusiastic as were those in 1988.

Warman in Universities

The aim of the WD&B competition is to present a challenge that requires students to conceive, develop, implement and test a mechanical system (a machine) in a way that can be integrated within the coursework of their first undergraduate engineering design course, whether mechanical, mechatronic or any other mechanical specialisation. The WD&B competition greatly assists Universities offering Mechanical Engineering programs (broadly defined) to build undergraduate student capability in Engineers Australia's (EA) stage one competencies by providing an exercise that requires students to develop and apply many of these competencies in a practical situation.

Furthermore, developing 'work readiness' skills for graduates is a mandate for all universities by the employers of their graduates. The WD&B competition exposes students to the reality of their engineering discipline by exposing them to open-ended problems and uncertainty, enhancing a student's ability to transition into the workforce. The nature of the design and build team project often pushes students beyond academic and social comfort zones, enabling students to develop and enhance skills in a safe learning environment, where team dynamics and design errors do not result in costly or potentially dangerous outcomes.

In addition to the student benefits, the WD&B competition provides a unique opportunity for Campus Organisers to meet and collaborate with other engineering design educators. A forum is held as an integral part of the National Final's weekend where engineering design educators share teaching methods and resources, meet key representatives of Engineers Australia's Mechanical College Board and members of the National Committee on Engineering Design. These networking opportunities provide important links between academics and representatives from industry and Engineers Australia.

Warman in Schools

There is the possibility of extending the reach of 'the Warman' into secondary schools, as part of the available 'STEM' array aimed to excite high school students towards science and engineering careers. The concept is to run a simplified WD&B competition based on the preceding year's university rule set focused on years 10 and 11. This would include universities making tracks available and offer opportunities for university students to be part of a mentoring program. A small-scale pilot engaging Adelaide Schools was run in 2015. It was initiated and implemented by A/Prof Sandy Walker, of Flinders University, with support from EA's NCED. An attempt was made to expand the project to more schools with the other Adelaide universities involved in 2016, but achieving traction proved difficult. As with any successful outreach activity, it becomes dependent on supportive school principals, enthusiastic teachers and available university staff and students. It is believed that if the framework is built, the high school students will come. Weir Minerals (the principal sponsors of the WD&B) enthusiastically support the 'Warman in Schools' concept but a method for delivery with limited resources remains an uncertain future aspiration for NCED.

Conclusion

In general, the immediate future of the University based WD&B looks secure. However, in a rapidly changing educational environment, with pressure from rapidly increasing course content and changes in engineering technology, it seems clear that the WD&B will need constant vigilance, ongoing creative input and 'tweaking' if it is to maintain its present and to date enduring useful role. Ensuring that outcome requires maintenance of a strong, enthusiastic and creative National Committee on Engineering Design.

The WD&B has been an outstanding success over its 30-year life. In the changing educational world, the plan is to ensure that it continues to meet educational needs and course structures and, if necessary or desirable, make appropriate changes. The question of entering the STEM array by creating a modified 'Warman in Schools' is currently unresolved.

References

Churches, A. (1989). A National Design-and-Build Competition: a Review. Conference on Engineering Education for Advancing Technology, Sydney, The Institution of Engineers, Australia.

Churches, A., D. Boud and E. Smith (1985). "An Evaluation of a Design-and-Build Project in Mechanical Engineering." Int. J. Mech. Engg Education **14**: 45-55.

Churches, A. and D. Magin (1998). The Warman Student Design Competition: Ten Years on. Waves of Change: Proceedings of the 10th Australasian Conference on Engineering Education, 5th Australasian Women in Engineering Forum, 5th National Conference on Teaching Engineering Designers, Rockhamton, QLD, Central Queensland University.

Churches, A. and D. Magin (2003). "The Warman Student Design Project and Competition in its Mid-Teens." Australian Journal of Mechanical Engineering **1**(1): 55-61.

Churches, A. and D. Magin (2005). Student Design-and-Build Projects Revisited. International Conference on Engineering Design, ICED 05, Melbourne, Australia.

Churches, A. and W. F. Smith (2016). A History of the Warman Student Design-and-Build Competition, 1988-2015, Engineers Australia.

Counce, R. M., J. M. Holmes and R. A. Reimer (2001). "An Honors Capstone Design Experience Utilizing Authentic Industrial Projects." International Journal of Engineering Education **17**: 396-399.

Dutson, A. J., R. H. Todd, S. P. Magleby and C. D. Sorenson (1997). "A Review of Literature on Teaching Engineering Design through Project-Oriented Capstone Courses." Journal of Engineering Education **86**(1): 17-28.

Dym, C. L., A. M. Agogino, O. Eris, D. D. Frey and L. J. Leifer (2005). "Engineering Design Thinking, Teaching and Learning." Journal of Engineering Education **94**(1): 103-119.

Field, B. W. (1997). The Australian/New Zealand Warman Design Competition. International Conference on Engineering Design, ICED97, Tampere, Finland, (Schriftenreihe WDK; 25).

Magin, D. and A. Churches (1992). "The Warman Student Design Competition: What Do Students Learn?" Transactions of the Institution of Engineers, Australia, Mechanical Engineering **ME17**(4): 207-212.

Magin, D. and A. Churches (1994). Design-and-Build Competitions: Learning Through Competing. AAEE Annual Conference, Sydney.

Smith, W. F. (2007). Perspectives of the “Warman Design and Build Competition”. International Conference on Design Education (ConnectED-2007), Sydney, Australia, UNSW.

Smith, W. F. (2008). Twenty-One Years of the Warman Design and Build Competition. 19th Annual Conference of the Australasian Association for Engineering Education (AAEE-2008), Yeppoon, Australia.

Smith, W. F. (2013). A Pillar of Mechanical Engineering Design Education in Australia – 25 Years of the Warman Design and Build Competition. ASME 2013 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference Portland, OR, ASME.

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