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Perspectives of the “Warman Design and Build Competition”

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ABSTRACT

The philosophy of the “Warman Design and Build Competition” and some of the challenges of running it are described in this perspective by its National Coordinator since 2003. In particular, the need is for the competition to work effectively across a wide range of student group ability. Not every group engaging with the competition will be competitive nationally, yet all should learn positively from the experience. Reported also in this paper is the collective feedback from the 2006 campus organizers in respect to their use of the competition as an educational experience in their classrooms. Each University participating uses the competition differently with respect to student assessment and the support students receive. However, all academic campus organizer responses to the survey suggest that the competition supports their own learning objectives very well.

The competition which was first run in 1988 will have its 20th anniversary final in September this year. While the projects have varied widely over the years, the intent to challenge 2nd year university (predominantly mechanical) engineering students with an open-ended statement of requirements in a practical and experiential exercise has been a constant. Students are faced with understanding their opportunity and their client’s value system as expressed in a scoring algorithm; they are required to conceive, construct and demonstrate their device with limited prior knowledge and experience, and the learning outcomes clearly impact their appreciation for teamwork, leadership and product realization.

The competition has been successful due in part to its underpinning by the National Committee on Engineering Design (Engineers Australia), the sponsorship of Weir Minerals and the commitment of many engineering design educators across Australia and New Zealand.

INTRODUCTION

The annual Warman Design and Build Competition has provided a significant learning experience for a large number of undergraduate engineering students in Australasian Universities during its 20 years. The competition’s main focus is on educational issues and identifying and encouraging the designers of the future (NCED, 2007). The “father” of the competition, Alex Churches, from the University of NSW, took it to the national stage following his local experience with 10 years of similar competitions. It was formalised through the work of the Panel on Engineering Design (now the National Committee on Engineering Design – NCED). As a body of Engineers Australia, the panel gained sponsorship funding to support the competition through the generosity of Dr Charles Warman. This connection with Warman has continued uninterrupted, albeit that the commercial entity providing the support has changed its name a few times. The competition is now sponsored by Wier Minerals Australia Ltd, the manufacturer of Warman® pumps.

The National Coordinator for the Warman Competition is a member of The National Committee on Engineering Design. The Committee, “aims to promote design excellence and awareness through media of publications, conferences and both national and international exhibitions. Engineering Design addresses issues of creating and delivering innovative, useful, reliable and economical technical solutions to meet human wants or needs. A main objective is to promote links between industry, and tertiary and secondary learning institutions, for the strategic development of design learning and experience in all aspects of design” (NCED, 2007).

I. THE COMPETITION

Teams of up to four, nominally second-year mechanical-engineering students in Australian or New Zealand universities (or other universities by arrangement), may enter the competition. Each university campus involved conducts a local competition and the local winners are then invited to participate in a final, traditionally held at the Powerhouse Museum, Sydney, in September each year. While the focus is mechanical engineering, many engineering students from other streams undertake common introductory design courses. As a result, students studying across a range of engineering disciplines (for example mechatronic, aeronautical, industrial and naval architecture) may experience the Warman competition during their undergraduate program.

Prior to the author’s time as National coordinator, he observed Bruce Field (Monash University, 1998-1999) and Chris Snook (USQ, 2000-2002) fulfilling the role. The author’s projects have been:

- Project ESCAPE, 2003 (18 Teams at the Final) – “Engineer for a Safe and Clandestine Ascent of imPrisoned Expatriates.” Students had to design a device, which transported a payload representing personnel and equipment along a horizontal tunnel and up a vertical shaft to safety. The shaft had a centre "fireman's" pole that could be climbed to effect a timed escape.

- Project PEP 2004 (17 Teams at the Final) – "Potential Energy Propulsion." Students had to use the energy of a falling mass to provide energy for a device to travel as far as possible up a track comprising three inclined planes. The challenge was to design the most efficient device and associated infrastructure that stored and utilised the energy released by the falling mass.
- Project SCAD 2005 (20 Teams at the Final) – "Safe Collection and Delivery." Students had to transport "citizens" safely across a crevice following a quake, to a significantly safer plain below. Two inclined planes with a gap between them represented the terrain and golf balls sitting on varying height golf tees represented the citizen awaiting transportation.
- Project ABC 2006 (16 Teams at the Final[1]) – "Autonomously Beautify Countryside." Students had to design a device to accurately and rapidly distribute seeds along the planet's highways. Fields for seeding were defined by small fences and fragile trees lining the road were not to be damaged.

This year, in 2007, there is Project REACT – "Reliable Effect At Critical Times". This project is asking students to design a device to deploy emergency response packs and recover valuable equipment in the event of a disaster. The track, incorporates a dry pond representing a potentially volatile environment. Due to the (hypothetical) risk of explosion (and to avoid a scoring penalty) devices should only source their electrical energy from AA dry cell batteries and carry no more than 4 such cells. A full set of the rules can be found at (ACME, 2007).

II. Challenges for the National Coordinator

In posing these projects, the broad perspective is that design is learnt through "doing" and that the act of designing involves both art and science. Of course, there should be much thinking in the early stages of doing and a key outcome is for students to understand the importance of planning and teamwork. The rewards in design are associated with addressing "open problems" with limited resources and this is mirrored in the competition specifications. As such, the processes the students explore in engaging the project lead them through a discovery process, part of which is that not every perceived good idea works in practice or can be made to work with the skills and tools they have available. Ultimately, and in response, the campus organisers have the opportunity to nurture and instil design practice that is rooted in systems thinking and reality. An important aspect is using both success and failure of a plan or a fabricated device as a learning tool.

At the UNSW@ADFA, in addition to the Warman competition, students are exposed to a range of design and build / experiential exercises across a range of courses. For example, they build structures tested to destruction in first year statics and later year structural design courses, and they can engage in the excellent integrated design activities facilitated through Formula SAE and Aero Competitions.

Returning to focus on the "Warman", writing the rules for the competition represents the major challenge to the National Coordinator. As with any competition where rules are defined, participants will push the boundary of the letter and the intent of the rules. Fortunately, through comment on the drafts by other members of NCED, the rules over the years have proved to be quite robust. In the main, as the competition has progressed, the need has only been to provide further explanation and expand the list of frequently asked questions and responses. In one sense, because each year represents a totally new and unique scenario, the rules are also new each year and afford little room for evolution from one year to the next in their detail. However, in another sense, the approach to the rule development process has evolved from one year to the next and in part it is getting easier.

The task of designing and implementing a project for the engagement of all students that challenges the "best-of-the-best" but does not discourage the rest, is for the author a very rewarding and creative exercise. What has been important is to ensure that there are multiple competitive solutions to the problem. One approach taken in this regard is to intentionally leave some ambiguity in the specification while clearly defining the boundaries. It has been pleasing that the devices presented at the finals represent different concepts. The fact that the "best" have not converged to the same solution is encouraging.

In conceiving and designing the competition specification, functions to be performed by the student's device represents the starting point. A feature of the Warman Competition has always been the spectacle of the competition itself. Therefore, some visible movement and translation becomes attractive. In all recent competitions, this has led to a scenario involving transportation and materials handling upon a defined track.

The geometry of the tracks have varied but broad issues considered include affordability, duplicability, material choice and size (different campuses have different resources and facilities for staging the competition and providing students access to the track during product development). What has become the norm is for a track made up in some way of two to three sheets of MDF (typically 2400 x 1200). While it would be interesting and challenging to use water in some way, the logistics of doing so seem difficult to overcome at both the campus and final levels.

In respect to standardizing the tracks at different competition sites, students are warned that the tracks they engage will be made with reasonable care but because they are real engineering objects, the campus and national final tracks may vary. For example, "horizontal" surfaces may carry some slight slope or curvature and surface finishes may differ. Teams are expected to consider these possibilities in

[1] *The drop in participation from 2005 to 2006 is accounted for through the consolidation of one University's offerings to one campus (previously two); another University while using the competition locally not fielding a team to the final; and two other Universities who appear to participate every other year not running the project in 2006.*

their design. However, track differences do lead inevitably to some discussions with teams at the final in relation to the finer details of such things. A further aspect to designing the track is what "aids" might be provided for the use of the teams. Given that the philosophy for the devices is that they be autonomous (no external control once activated), guidance mechanisms such as fences, walls, pegs and track edges have been made available.

In respect to the devices that students create, their costs and their skills also need to be considered. In this, each campus takes a different approach but the rules are clear that students shall manufacture their prototype device themselves using commonly available materials, components and methods. The skill of hand exhibited between teams greatly varies as does the financial investment they are prepared to make. However, at what ever level a team elects to become involved, significant learning can and has been demonstrated to take place.

Key learning obviously occurs as students tackle technological, fabrication and integration issues which for them are new. This, as afforded in every competition, can be as simple as students learning to work with friction. When they want it they can't get enough and when they don't want it there is too much. Such discovery outcomes can also be guided in part by the rules through forcing purely mechanical solutions or opening the door to allowing highly mechatronic devices. It has been observed that students often teach each other about electronics without them having had any formal classes addressing relevant material. As commonly indicated in the literature, this peer to peer learning is viewed as highly effective.

Finally, in establishing the rules, given that the constraints have been specified, the real objective for the device performance is based on the scoring algorithm. A range of measures can be and have been 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 in respect to their target score and their realization capabilities. In the competition context of a mythical planet of Gondwana, students are sometimes confused by a client value system which is at odds with their own. While perhaps this is not evident at the National Final so much, at the campus level it has caught some teams out and taught a valuable lesson about listening to the customer. Through reflrction, this lesson can be taught to the whole class. One example from 2006 was a device called "Old Bull". Presented at the local UNSW@ADFA competition, it worked like clockwork seeding every field. However, the evolution took in excess of 40 seconds. To achieve a "perfect" score in accordance with the rules, the time needed to be less than 10 seconds. During the competition the team was disappointed when they realized time was as important as it was. They had not recognized fully what the client wanted as articulated in the rules. They assumed that planting success was more important than time and had not recognized the trade-off between the two.

Once the rules have been formulated, the challenges for the national coordinator become the same as those of a campus organizer, running the competition locally. With the campus experience as a rehearsal of sorts, the National Finals have run smoothly, and while the Final is a big and busy weekend event, its success is based on the collaborative spirit of those attending, students, university staff and others.

During the campus level activity, students naturally attempt to push the boundaries of the rules. What has proved valuable is maintaining and publishing a set of frequently asked questions and answers. It is obviously important to work to ensure each campus organizer is disseminating the same rulings.

Complaints from some students are inevitable: that the problem is too hard, too time consuming, too costly and it does not reward their effort. Standard responses include 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 they had fun, that they learnt a lot about themselves as well as design and that they benefited from being pushed outside their comfort zones.

III. Student perspectives

In a formal sense, a number of surveys have been conducted reporting on the student perspectives of the competition. The most recent of these is reported by Churches and Magin (2005). Five near identical surveys in all have been conducted (1991, 1993, 1997, 2002 and 2004) showing "high proportions of students claiming significant learning in all of the 14 listed aspects of engineering design" (see also Section IV). Churches and Magin (2005) document some student comments as being:

- "It's one thing to design something on paper, but until you try and build it yourself you don't learn anything about designing for the project to be built (2002)",
- "(the competition) was fun and taught valuable lessons in group working, time management and organisation (2004)", and
- "We learnt to learn from our mistakes (2004 Finalist)".

Churches and Magin go on to strongly recommend the competition and the value it appears to provide to students. So what do the campus organisers think? To answer this question, they were surveyed in 2006.

IV. Survey of 2006 Campus organisers

The collective feedback from the 2006 campus organizers in respect to their use of the competition as an educational experience in their classrooms has been positive. Over the last 4 years, 23 campuses have attended the finals and of those, 12 have participated in the final in each of those years. In some years, while campuses have run local competitions, a representative team has not participated in the final. Of the 16 campuses represented at the 2006 final, 13 surveys were returned. Across those 13 campuses, over 1600 students experienced the Warman Competition that year.

On all 13 campuses, mechanical engineering programs include the competition in their curriculum. However, on some campuses, industrial, aeronautical, mechatronic, automotive, manufacturing, robotics, product design and even forestry engineering (at the University of Canterbury, NZ) students are included in the Warman cohorts. Twelve campuses offer the course in 2nd year (1 in 3rd) and the majority do it in 1st Session. Eight of 13 campus organizers classify their course as the first course in design. At those campuses where it was not the first, almost all identify the lead in course to one in graphical communications.

At every campus except Auckland and Monash, all students are involved in the design and build activities. At Auckland, all students are involved in the design activity but not all build. This is the case on the basis of limited resources. At Monash, some students are exempt from the Warman activity as a function of their alternative involvement in Formula SAE.

A number of the campus organizers reported that some students complained that the competition was too hard, takes too much time, costs too much and/or does not reward their effort. However, while there may be some negative reactions, all campus organizers expressed that there were far more positives.

Asked to respond to the same questions put to the students in previous surveys (see Section III), the twelve campus organizers who replied to this section of the survey were unanimous in indicating that the competition makes significant contributions to student learning in respect to how to work in groups, the importance of simple design and practical experience of design. As shown in Table 1, the lowest rating was given to the learning outcomes related to the importance of initial concepts and calculations and the importance of cost considerations.

Table 1 Campus Organisers' responses to Learning Outcome Survey

Is the competition in your opinion making SIGNIFICANT contributions towards these outcomes?

Q	Aspect	Yes
1	How to work in a group	100%
2	How to carry out a project	92%
3	Importance of organization	92%
4	Importance of initial concepts / calculations	50%
5	Importance of simple design	100%
6	Skills in organization	75%
7	Skills in problem solving	75%
8	Estimating the time required to complete	75%
9	How to put theory into practice	83%
10	Importance of cost consideration	50%
11	How to translate design to product	92%
12	Need for a prototype	75%
13	How to recognize design deficiencies	67%
14	Practical experience of design	100%

As a partial explanation of the initial concept issue, one campus organizer wrote "I feel my students are far too keen on (their) 'initial' concepts. One of my messages to them is to have more than one idea, develop more than one solution to a high level and be prepared to throw your 'darling' solution out and start again." Another suggests that "most students do not follow their initial concept." In the heat of the week before the local competition, many devices change, often radically, in an attempt to develop something that scores some points. It is here that the lessons on say the importance of organization and the importance of simple design are learnt the hard way. On cost, typical budgets for teams as set by the teams are in the order of a few hundred dollars. Perhaps for most teams, this is not a major concern.

Each University participating uses the competition differently with respect to student assessment and the support students receive. The emphasis placed on the competition score in relation to course grade in which the project is embedded varies widely. Some campuses build a whole course around the project while others use it as only one module in a larger course. Understandably, the structure of engineering programs is not consistent across the range of universities that participate. Nor are the spaces and facilities available to students mirrored across institutions. However, all academic campus organizer responses to the survey suggest that the competition supports their learning objectives very well. Success and failure in the "benign" environment of the competition can be both turned to effect good practical design learning outcomes.

V. Conclusions

Seeing the competition from a national perspective and leveraging the learning outcomes in the classroom is and has been a very satisfying experience. This appears to be shared by all those involved in delivering the competition. Those campuses not involved are encouraged to become involved.

As stated, design is an activity learnt through doing. Design comprises both art and science and the Warman Competition has provided and will continue to provide an enduring vehicle for student experiential and project-based learning.

Acknowledgment

I wish to thank all those who have gone before me and worked with me in delivering a competition that has touched many of Australia's engineers over the last 20 years. This competition which has become an icon in Australian and New Zealand university engineering education has been successful due in part to its underpinning by the National Committee on Engineering Design (of Engineers Australia), the sponsorship of Weir Minerals and the commitment of many engineering design educators. These organizations are to be thanked.

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