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# Are We Evolving “Strictured” Design Engineers?

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## Abstract

This discussion paper is meant to stimulate debate among design engineering colleagues with a view towards reimagining how design engineering students may evolve their experiential knowledge with respect to how product designs [things] work, and more importantly how they may creatively develop new product designs [things] that *should* work. After introducing and framing the background of this paper the discussion turns toward the core issues found within the way design engineering problems are “typically” contextualised and framed in relation to “expected” solutions. In short the problem is the problem. This in turn shapes the nature of how students currently practice and hone their problem-solving skills. Subsequent discussions turn towards both the strengths and limitations of the experiential knowledge. It is argued that if we reimagine and introduce new perspectives and heuristics, our future design engineers may develop more creative and more considered designs. While the core intent of this paper is to initiate discussion on this, we will show an exemplar of how this has worked in a University setting at the University of Technology Sydney. We will contend this may also work within other institutions as well.

*Keywords: Problem solving; Design thinking; Design engineering education*

Given the technological growth over the last few years it may be argued technology has grown rapidly. Indeed the literature surrounding technological change supports the idea that technology has been advancing at an exponential rate.  In drawing from the work of Kurzweil (2005), he explains his perspective relating to the law of accelerating returns. He argues the acceleration of the pace and exponential growth of the products of a technological evolutionary process extends beyond what has become known as Moore’s law. Moreover, he is not alone in his discussions relating to technological complexity and convergence, the work of Schmidt (2008) notes that much of our past has been shaped by a number of convergences that had their beginnings as separate and independent domains of knowledge. These appear to be converging.

When drawing upon the literature surrounding technological change [see: Porter, et al. (1980); Girifalco (1991); Karamchedu (2005)] it becomes exceedingly clear technological change is not just about the technologies and patents increasing at an exponential rate. Broadly speaking, Technological Change encompasses more than mere changes in technologies, it also includes many other related and indeed interwoven contexts beyond mere questions of engineering. Following on from this, Borgmann (1995), in his discussions relating to the depth of design, reminds us of the twin tasks of the designer in relation to notions of *Trusteeship* [a responsibility to society] of designing products systems and environments, and *Artisanship* [making things and making things work]. Essentially this suggests a need for our students to develop a deep understanding of design theory and design praxis [*thinking and making/doing*].

Returning to the work of Schmidt (2008), he notes our previous generations [even our current generations – Gen Y and Gen X students] would consider we are living and working in a “science fictional” age filled with complex converged technologies. A simple example would be the “smartphone” currently found in use by our Gen Y and Gen X Design Engineering students. In a real sense these complex converged technologies do not exist in isolation they exist in diverse and complex contexts. This begs the question; are we properly preparing our design engineering students for this future by requiring them to practice answering what may be perceived as very narrow and strictured questions/problems?

For all the above, given technologies are becoming more complex, and converged our Gen Y and Gen X Design Engineering students may indeed conceive of these as being mysterious “black box” technologies. In previous generations, design engineers often grew up tinkering and taking things apart. Moreover, activities of our youths at that time allowed them to develop an understanding of core principles of how things work. Some simple examples would be learning to fix a car or indeed rebuild a car engine. It may be argued our current generations show little interest in knowing what makes things “tick”. This suggests they may have a poor previous pattern of experience in taking things apart. In point of fact there is literature that suggests interest in technologies is actually decreasing as interest in obtaining a tertiary education is on the rise.

In reviewing an OECD report [Apostel et. al (1972)] it was noted a very worrying trend that while over the past fifteen years most OECD economies have experienced rather large increases in the numbers of students in higher education, the absolute numbers of students in the fields of technology and science has decreased as a proportion of the overall student population. That is to say over the years a steady decline of interest in technology and science has occurred and indeed continues to occur. This is echoed in the work of Campbell and O’Connor (2009) when they discuss a similar trend occurring in Australia. They point out that in Australia over the past 25 - 30 years there has been a significant decline in the number of senior and secondary students electing to study the core areas of science and math needed for further technical education in areas such as design engineering. This is indeed a very worrying trend and unquestionably problematic for design engineering educators as we move into the future.

It is becoming very clear student interest and understanding/experience in building new technologies appears to be decreasing at a time when technology and scientific knowledge is increasing exponentially in terms of amount, variety, and complexity.

Consequently, in the future it would appear a student's capacity for, and experience in, making things work and building things will diminish significantly. That is to say, as suggested earlier, the capacity for knowing how things work and how things should work may be considered exceedingly limited. Accordingly, a student's capacity for using both theory and praxis in this future will need to be addressed as a matter of urgency. It is imperative we act now if the requisite tools and skills to assist them to thrive, survive, and operate in a technologically turbulent future are to be properly developed. In this context, tools and skills relate to both cognitive skills and physiological skills [thinking and making]. It should be noted that there is literature to suggest even some of the world's most prestigious universities, such as MIT, are not immune to the issues discussed above in relation to theory and praxis. This begs the question where do we go from here. It may be argued the types of problems we give the students, and indeed more importantly how we frame these problems, may in fact be a core problem. Added to this is the fact, more often than not, design engineering students are not given the opportunity to develop a rich experiential knowledge base by "making" and testing their design ideas. More to the point, typically they are given very strict parameterized problems. In a real sense design engineering students are not practiced in creatively solving design problems. Given the above it now makes sense to turn our attention to the idea of the problem being the problem.

## A problem is the problem

It is a generally accepted view creative problem solving forms an important part of engineering education. However, when discussing the historical phases of engineering education in western countries, the working hypothesis of Kourzanian and Foley (2007) was that creativity is not valued in contemporary engineering education. Moreover, engineering students are not often exposed to practices that foster a creative educational environment during their academic life. In fact traditional engineering teaching practice tends to focus on the technical aspects of engineering (Andersson and Andersson, 2010) rather than what may be considered creative thinking skills. As suggested in the work of Kourzanian and Foley (2007) it may be argued a barrier to developing and fostering a capacity for resolving complex open problems in engineering students may rest in the fact they are predominantly marked for the correctness of the final answer/product, and NOT for the creativity shown in the process or the final product itself.

On the one hand there has been much literature over a number of years arguing the need for more creativity to be embedded in in engineering curricula, and yet as suggested in Stouffer et al. (2004) individual engineering courses that offer students opportunities for creativity are rare but successful. Unfortunately to date these courses remain the exception rather than the rule. At first blush the ideas raised in this discussion paper may appear “old fashioned” or “outdated”. However, if one argues “significant” progress has been made, the findings in the recent work of Beghelli and Prieto (2015) suggest there remains much room for improvement. In essence they introduced “open problems [not unlike those found in a typical Industrial design course] to one cohort of engineering students in a computer programing course in contrast to a cohort of students in a “normal” computer programing course. They found a significantly higher percentage of students projects of the modified course were classified as of high/medium novelty than those in a normal Computer Programming course. Given the nature of their findings it may be argued it is the nature of the way problems are set which help shape the results.

Given the above, and as suggested earlier, possible core issues might lie in the repetitive use of “closed” questions and the consistent drive for engineering students to “get the right answer”. In a sense this is not unlike using closed or open questions in a research survey, the use of closed or open engineering questions needs to be well considered. In engineering many of the Closed-ended questions come in a multitude of forms, and are defined by their need to have explicit options for students. Thus, each question, irrespective of type, does not allow the engineering student to provide unique, divergent, creative, and unanticipated answers. It must be remembered questions that are closed-ended are conclusive in nature as they are designed to create data that is easily quantifiable so the academic may more easily assess the engineering student. Conversely, Open-ended questions are exploratory in nature. Furthermore, Open-ended questions can reveal a variety of creative responses from the student cohort.

In a real sense Design Engineering “texts” [i.e.: Field (2006); Norton (2004); Norman (2000)] characteristically utilised in many design engineering subjects at institutions around the world are used to illustrate the nature of “design” problems. In general these texts require the students to solve, what are arguably, simplistic and highly-structured problems with strict / limiting parameters. In short, Closed-ended questions are predominately given to the engineering students. Moreover, the students are not required to “build/make” anything to develop their experiential knowledge. In a real sense they may be considered well-strictured problems not well structured problems. Hence, the design engineering student assiduously practicing “solving” these “design / design analysis problems” develops a pattern of experience that may be considered “Strictured”. A typical type of design problem would be as follows:

Given **Mass X** in **Position A**, [as illustrated on the left side of the diagram in Figure 1 below] we want you to move it to **Position B**. Moreover, given the Four-Bar link [as illustrated on the right side of the diagram in Figure 1 below] we want you to “design” the

Four-Bar link system. That is to say you will need to "design" the length of the arms, specify the appropriate materials, determine the cross-sections of the bars, determine the moments about the pins, the forces involved, the energy required, ETC…..

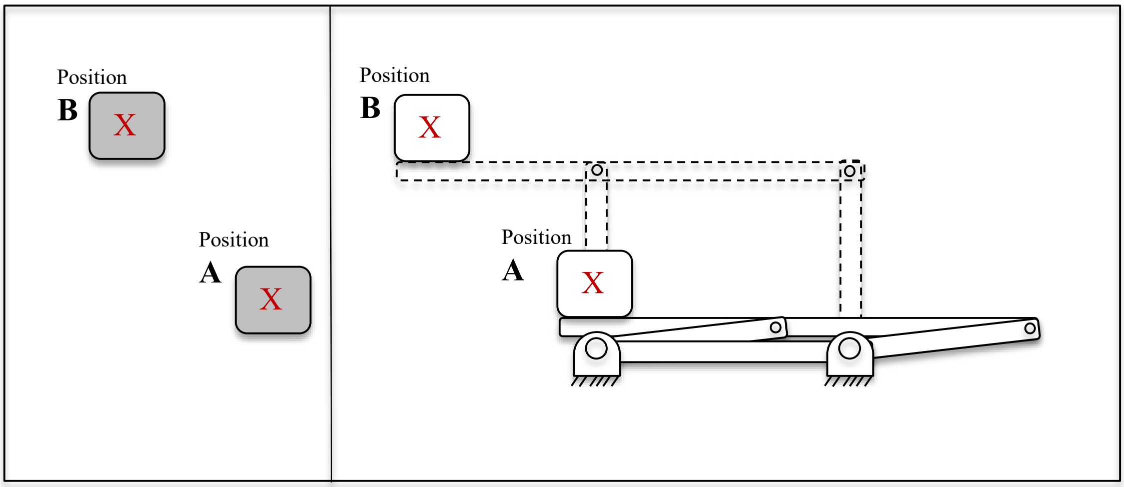

Figure 1: Graphic diagram of an example "design" problem ["The Mass X problem"]

Given what we label as being the "Mass X problem" it is exceedingly clear the student was very limited in exploring and designing a creative solution to the problem. That is to say, conceivably it is possible for a design engineering student to explore the possibility of using helium filled balloons affixed to the mass and explore designs to develop a guidance system. Alternatively, one could explore designing a device that would use an explosive system that would "fire" the mass to position B. Further, irrespective of solving the problem via the four bar link, the helium balloon or the explosive system, the student would not be in a position to build and test any of their ideas.

In a real sense, one may argue that how the term design problem is framed, imagined, and understood by both the academic and the student is exceedingly important. The term design in this instance predominantly revolves around practicing calculations as opposed to developing creative experiential knowledge and then doing the calculations to make the idea work. Accordingly, the kinds of design decisions the design engineering students learn and indeed practice may be considered extremely narrow. Given the problem above, it is argued there is a considerable lack of rich experiential knowledge development opportunities offered to the Design engineering students in this case. It is not difficult to reimagine how one might restate the problem and associated parameters in order to develop a new, richer, and more creatively engaging Problem statement. As it is clear the "Mass X problem" type design problem lacks "Richness", one may ask: is this problem of the problem really problematic? Given this query it now makes sense to turn our discussion towards the need for Rich experiential knowledge.

## The need for "Rich" experiential knowledge

As suggested earlier a prestigious institution like MIT is not immune to the issues discussed above. Given the trajectory of a technological future, the balance of Theory and Praxis by necessity will become increasingly important. When reviewing the research of Mount-Miller (1995) it was found he asked a simple question – "so can you build one?" The answer was Design engineering students had difficulty. To demonstrate this, in his study Mount-Miller (1995) found a serious gap in the technical understanding of some MIT engineering students. Students were given a set of design and build tasks. He compared the results of a few cohorts of students, some in the early stages of their mechanical engineering design degree and other students in the later stages of their academic studies and other students in other majors. In his comparisons he found major gaps in the ability of mechanical engineering students to apply theory into the actual physical making of relatively simple structures and machines. They were not statistically different from the non-major cohort [*non- designers*]. Moreover, it was revealed that as they progressed in the curricula they got worse. This research emanating from MIT suggests that Design engineering third year students tend to get worse at making things work in contrast to their first year counterparts. Given our discussions earlier in relation to the problems design engineering students around the world are given, it is not difficult to see how this can impact a design engineering students capacity for designing and making things that work.

In order to be prepared for using both theory and praxis in the future our students and professionals will need to have an appropriate previous pattern of experience to draw upon. It is argued that the narrow previous pattern of experience design engineering students have as they work through the design engineering texts which contain the types of problems discussed above, this may have given rise to the findings of Mount-Miller (1995). In essence much of their academic life relates to calculations and theoretical knowledge at the expense of experiential knowledge. More recently, this is essentially echoed in the work of Kourzanian and Foley (2007). It may be argued that we have known of this problem for many years, yet it would seem little has change over time.

Given the above, a review of the work of Atman & Bursic (1996) and the more recent work of Beghelli and Prieto (2015), reveals they questioned the value of a heavy reliance of reading a textbook. Recognizing that often design engineering students are introduced to the engineering design process through a chapter in a textbook. Their research questioned this passive approach to teaching design, which is essentially seen as an active process. To test this they divided a cohort of design engineering students into half. One group read the text prior to solving three open-ended engineering design problems, as the other half solved the same problems before they read the text. Both cohort's process in solving the problems, as well as the quality of their solutions (the end product), were assessed.

The nature of the design problems selected by Atman & Bursic (1996) centered on problems having the ability to provide insight into different aspects of engineering design skills. They used the following:

> Problem 1 (ping-pong) gives subjects the opportunity to use mechanical and analytical skills.
>
> Problem 2 (street crossing) allows subjects to consider a real world problem in a familiar context.
>
> Problem 3 (Midwest floods) allows subjects to consider the larger context of a real world problem and to do more extensive problem scoping.

The findings revealed the “textbook problem solvers” spent significantly more time solving the problems, were more sophisticated in their problem solving strategies, and scored better when judged on the quality of their approach to the problem. However, of significance here is the fact the “textbook” subjects did *not* score better on a quality measure of the final solution. In a real sense these findings are not dissimilar to that of the third-year design engineering students in Mount-Miller (1995). At the end of the day they were *not* as good in delivering quality workable final solutions.

In a real sense the above discussion is hardly surprising. In their work relating to technology mining and strategies of technology innovation, Porter and Cunningham (2005) noted that technology information [i.e. heavy reliance on learning about design problems in a textbook] does not equal technology. It can be argued that just because someone understands a physical principle in theory does not necessarily suggest that they would be able to apply that principle in a design context and embody a complex product, system, or environment and make it work. This problem of not being able to appropriately apply technical theory to praxis [applying their thinking/design skills to making things work] suggests they lack the previous pattern of experience in how things work and how things should work and be made.

This paper argues that as technologies become increasingly complex to the point where students do not have experiences in, and knowledge of, designing and making, and as the technological change issues become increasingly complex, Design/Design Engineering education will need to address this. The question then becomes how we should address the complex technological change issues facing us. We would say a good first start would be to address the problematic issue of; *The Problem is the Problem*, as suggested above. Consequently, in the subsequent discussion it make sense to turn our attention to a simple example.

Drawn from the work of Field (2006) below is a “Design Analysis” problem which may be considered typologically typical of Design Engineering texts. In this example design engineering students are given the following textual, and graphic information in Figure 2 below for their “Design Analysis” problem.

They are shown an adjustable pipe wrench. The geometry of the mechanism is arranged so that the jaws clamp more tightly as the handle is pulled downward. Friction between the jaws and the pipe transfers the torque from the jaws. Also note you are to: (a) Find the lowest value of the coefficient of friction between the pipe and the jaws for the wrench to work properly *in the position shown*. (b) Select the diameter of the pivot pin. Additionally note the following:

1.) The required coefficient of friction may be different for each jaw. The solution depends only on the geometry and not the actual size of the parts. You will need some geometric constructions. Measure the friction angles or components, then calculate the coefficients.
2.) The pivot pin is a rivet. A suitable material for this is CS4140 four which SU=540 and SY = 300 MPa.
3.) The strategy for finding the required diameter of the pin is (i) identify the mode of failure for the pin, (ii) find the maximum loading for the chosen failure mode (this will involve assumptions about the applied force on the handle), (iii) choose the failure model (mathematical formula) for the pin, (iv) select the failure stress, (v) work out a suitable factor of safety, (vi) calculate the maximum allowable stress for the failure mode, (vii) select a suitable pin diameter using preferred numbers and stock sizes (see appendix B)

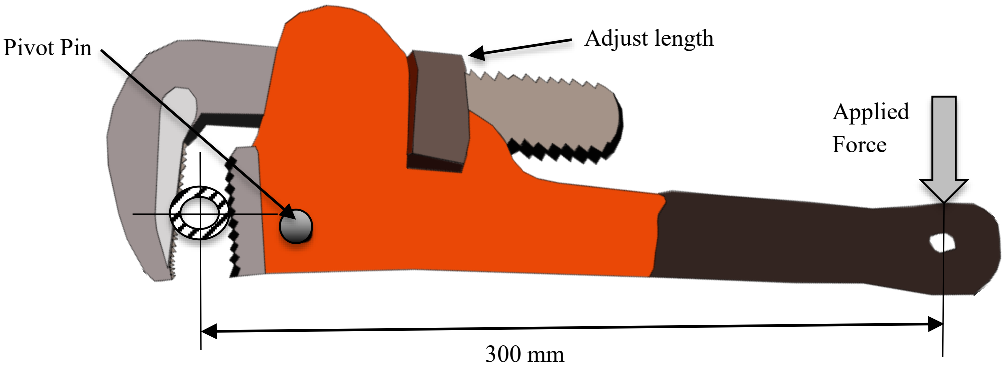

Figure 2: Graphic diagram of an example “design” problem [Drawn from Field (2006)]

Given the above problem, it is argued there are a great number of missed opportunities for evolving a more well-rounded design engineer when using the types of problems this example serves to highlight. Furthermore, it is not difficult to see why a student may have difficulty in taking the knowledge gained from this problem and applying it to another type of pipe wrench, such as the strap type pipe wrench shown in Figure 3 below. When comparing and contrasting the wrench in Figure 3 with that found in Figure 2, different coefficients of friction may not be consistent with those identified in the exemplar the student would’ve worked through in the pipe wrench problem above. Moreover, indeed it is exceedingly obvious other aspects are absent in these types of problems. One simple example is in relation to notions of the different rituals of use between the wrenches shown in figures 2 and 3. In addition, the resilient strap in the pipe wrench in Figure 3 may not function appropriately in an environment with temperatures down to -40° C. This suggests a notion environmental contexts should be considered during the “Design” phase *prior* to building and testing. Drawing from the work of Dorner (1999) he suggests issues outside the immediate problem as given need to be considered. Moreover, he argues designing a piece of machinery requires much careful thought and detailed consideration, at least in most cases. He contends the whole machine is considered to be one system. Consequently, the addition of one single element to one part of the machine could dynamically affect the function of the whole system. Accordingly it is not only necessary to analyse the functions of single parts, but to analyse the machine in the context of being a larger coherent system. A simple example he cites in relation to questions about the ‘environment’ of the machine, where a plan for a wonderful machine is purely senseless if certain parts cannot be manufactured because the appropriate facilities are missing. Indeed one may ask how will the machine perform if it is put in an oven?  How will the machine work when you put it into a fridge? These issues were framed in the context of a brewery-machine for a Bamberg brewery-machine factory that faced similar problems after it had delivered a complete brewery to a Russian town in Siberia. Returning to our example, another design consideration for the wrench that needs to be explored and developed relates to the ergonomics of the handle and the associated issues of human force and grip, which are, in turn, linked to material selection etc….

Figure 3: Alternate Pipe wrench example for a  “design” problem

Continuing on in relation to comparing and contrasting the two pipe wrenches, in the problem drawn from the work of Field (2006) is predominantly concerned with doing calculations, and not *designing a new tool for facilitating the rotation of a pipe*. When imagined and framed in this way [i.e. the problem is to design a new tool for facilitating rotation of a pipe] provides more open explorations for the student to utilize their creative design talents in addition to performing calculations and making models which allow them to develop their experiential knowledge. This is especially true it the students were required to build and test their designs. Furthermore, if we were to add to this new problem reimagining/framing by explaining their new tool for facilitating the rotation of a pipe within the geometries of the pipe framework shown in Figure 4 below, must be able to operate it the context shown, this serves to further allow the students to develop a broader understanding and not merely work on calculations from a textbook.

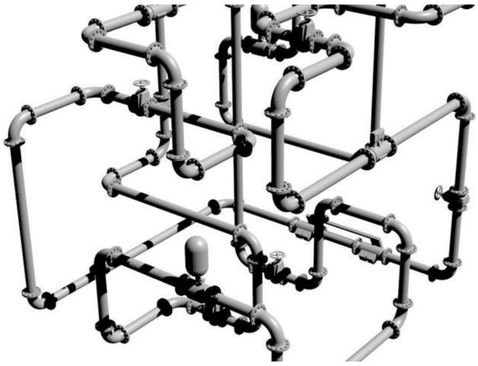

Figure 4: Graphic image setting a new context for the new reimagined Pipe wrench “design” problem

At this juncture it should be made quite clear this is not to say they should not do calculations, they will still need to do that to make absolutely sure their newly “designed” tool will actually function in the new context shown. Moreover, the new tool needs to operate in a large variety of contexts. In order to verify this, the students will need to use their imagination and creativity to imagine a large variety of use scenarios. These range from rotating pipes at temperatures -40° C in Alaska, to turning pipes in the searing heat in Saudi Arabia. It is quite clear, the “design” problem given in Field (2006) would not facilitate an appropriate opportunity for a design engineering student to enhance their experiential knowledge. Whereas it may be argued reimagining the problem as above goes some way to opening up the problem so we may address our design students’ lack of experiential knowledge. However, one may ask, in general what might be some typical characteristics of a reimagined design engineering problem be. It now makes sense to turn our attention to a discussion of these.

## On the Nature of Reimagined Design Engineering Problems

Given the discussions above the issues raised here are not significantly different from those highlighted in the work of Kokotovich (2010). In this work a quasi-Delphi study was conducted. A number of themes emerged.  Relation to those themes and the themes raised in this paper, it may be argued new “design” problems based on the ideas highlighted above will need to have the following characteristics:

- Provide Structure without Stricture
- Require students to build and test design ideas [Note: there needs to be the experiential knowledge building/making components to the design activity and not in an Ad hoc manner, as it is argued this tends to lead to amateurish/hobbyist results.]
- There must be a requirement for a holistic treatment in relation to developing an appropriate workable design solutions
- Require reflection and critical analysis skills to be utilized in demonstrated

- Development of use Scenarios – Technical and User/Human
- Provide an opportunity for Product deconstruction/Product Autopsy/Bug Fixes to learn what make things "tick"
- Learn and demonstrate new Communication skills and tools
- Be forced to consider Context changes
- Participate in group work to learn and develop collective understanding strategies

Given the reimagined example of a "Textbook" problem and the nine characteristics above, one may ask is there an illustrative case study where this type of experiential knowledge is shaped and developed. When reviewing the Mechanical and Mechatronic Engineering curricula at the University of Technology in Sydney Australia we may find the answer is yes. We now turn our discussion to an example case study drawn from the UTS Subject: 48610 Introduction to Mechanical and Mechatronic Engineering.

## Illustrative case study: UTS Engineering

In order to demonstrate how reimagining a Design Engineering problem, that requires the students to balance theory and praxis in a university context, it makes sense to turn our attention to a real-world example by moving through and highlighting some of the problem /project requirements.

Within the Faculty of Engineering and Information Technology, at the University of Technology Sydney, there is a subject entitled: 48610 Introduction to Mechanical and Mechatronic Engineering. Moreover, within that subject students are to complete a group project that is to be done in groups of 4 or 5. The project is worth a total of 37% of their subject marks. The objectives of this group project are:

- to encourage students to creatively approach a mechanical design problem
- to allow students to experiment with a variety of solutions to a problem
- to encourage teamwork and to allow students to learn from their colleagues
- for students to implement engineering design methods in a practical problem
- for students to learn and apply mechanical and mechatronic engineering fundamentals

Fundamentally, it is a self-directed learning activity. However, students are given some background information, guidance and assistance to get them started. It is important to note how far they take it is up to them. In laboratory classes they receive some guidance in the use of basic workshop hand tools. Additionally, students will make turbine blades they may use for the team's vehicle. In Tutorial classes they receive assistance and guidance with the mechatronics module of the subject. Students who choose to not attend these classes do not receive any assistance outside class times.

The core remit of this subject is to introduce the student to engineering sketching and drawing, computer-aided design and solid modelling, engineering design, engineering mechanics, mechanical systems and components, mechatronics, and wind power and energy conversion. Fundamentally, students learn to graphically represent engineering components by sketching, using drawing instruments and/or computer methods using standard representation techniques such as orthogonal projection. Additionally, students learn basic engineering mechanics and how to apply this to analyse simple machines, mechanisms and structures. They also learn basic mechatronics principles and apply them in a mechanical system that they **design and build themselves**.

In terms of how this subject contributes specifically to the development of the student, following course intended learning outcomes are listed:

- Identify, interpret and analyse stakeholder needs
- Establish priorities and goals
- Identify constraints, uncertainties and risks of the system (social, cultural, legislative, environmental, business etc.)
- Identify and apply relevant problem solving
- Design components, systems and/or processes to meet required specifications
- Apply decision making methodologies to evaluate solutions for efficiency, effectiveness and sustainability
- Implement and test solutions
- Demonstrate research skills
- Apply abstraction, mathematics and/or discipline fundamentals to analysis, design and operation
- Develop models using appropriate tools such as computer software, laboratory equipment and other devices
- Evaluate model applicability, accuracy and limitations
- Manage own time and processes effectively by prioritising competing demands to achieve personal goals
- Communicate effectively in ways appropriate to the discipline, audience and purpose
- Work as an effective member or leader of diverse teams within a multi-level, multi-disciplinary and multi-cultural setting

In this group work problem it is contextualized via the following Scenario:

The “Federal Government's Sustainable Technologies Department” is looking to provide funds to support small companies in developing sustainable technologies. They currently have a project that requires a company to design, develop and manufacture several small wind powered prototype vehicles. It is expected that in later stages of the project the vehicles will be developed further to be autonomous. As a first step towards implementing a mechatronic system to eventually control the vehicle, teams are required at this stage to demonstrate their ability to implement a mechatronics control system by sensing, measuring and recording the vehicle‟s displacement and turbine rotation using onboard sensors and a logic circuit. The selection of the successful company will be based in part on the performance of the vehicle in a competition between rival companies. Supporting documentation in the form of a design report and the ability of the company design team to explain and demonstrate the strength and weaknesses of their design will also be taken into account in selecting the successful company. This project is offered to small companies with a design team of 4-5 engineers.

Accordingly, the Design task is as follows as highlighted in Figure 5 below: Design and build a vehicle that starts from rest and travels into the wind using the power of the wind as its only source of energy [refer to the information found in the figure below.

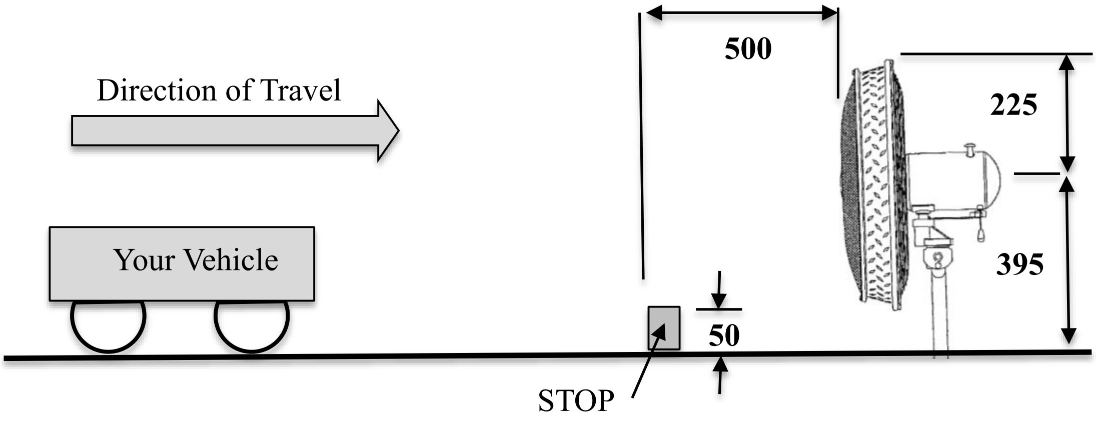

Figure 5: Graphic image setting a new context for the new reimagined Pipe wrench "design" problem

Following on from this are the project specifications below:

It has been estimated that the strength of the wind in the location where the vehicles must operate is about the same as that produced by a domestic electric fan. The wind source will be a domestic electric fan and will be set to the MEDIUM speed setting. The fan will be available for testing in the Product Realisation Laboratory (PRL CB02.02.12). Your design must be robust enough to cope with small changes in angle and direction of the fan as the direction and location of the fan in the competition cannot be guaranteed to be the exactly the same as in your testing. DO NOT adjust the fan relative to its base.

Anemometer measurements indicate that the maximum wind speed at 0.5 m from the fan is approximately 4.0 m/s and at 2.5m from the fan it is approximately 1.7 m/s. The wind speed varies depending on the vertical and horizontal position of measurement.

The vehicle must carry a "payload" across a "track" a distance of 2m.

The vehicle design should maximise the ratio of "payload" (m) to time (t) taken to cover the distance of 2m, i.e. (m/t).

The vehicle should not take longer than 3 minutes to cover the 2m distance.

The payload must be a separate entity and easily removed from the vehicle to facilitate weighing but must be wholly contained on or within the vehicle and must travel the full 2m with the vehicle. The vehicle must be operational both with, and without, the payload on board. Teams are to provide their own payload, however, some generic weights will be available in the workshop before and during the competition.

The starting position is approximately 2.4m from the front of the fan.

All parts of the vehicle must start from behind the start line and no part of the vehicle is allowed to be moving before timing begins.

No part of the vehicle may be further than 0.5m behind the start line. (If it is it may not sit on the track and a penalty of 10% per 20mm or part thereof will be applied to your m/t ratio)

The "track" will be a hard flat surface (MDF board or similar). There may be a small (a few mm) step across the middle of the track where the two halves of the wind tunnel are joined. Your vehicle will need to be designed to be robust enough to cope with this.

The track will be inside a „wind-tunnel" that has a rectangular cross-section and is approximately 0.9m wide and 0.8m high.

The vehicle is to be ground based and remain substantially in contact with the ground at all times.

Overall dimensions of the vehicle are to remain essentially unchanged throughout the travel.

Most commonly available materials may be used in the construction of the vehicle. Materials which may NOT be modified or worked on (e.g. drilled, sawn, filed) in the PRL CB02.02.12 include foam and carbon fibre. If you are not sure, check FIRST.

No other source of energy may be used to propel the vehicle, eg batteries, pre-compressed or extended springs (or “gentle nudges” by participants).

*** The requirements for the mechatronic system will be provided in a separate document.***

Unfortunately, because we have so many teams, there is limited provision for storage of your vehicles at UTS other than team’s own arrangements such as individual team member’s lockers.

The competition performance criteria:

To carry the heaviest "payload" (m) across a distance of 2m in the least amount of time (t), i.e. the greatest m/t ratio.

The fan and will be set to the MEDIUM speed setting.

The fan will be available for testing

If you are unsure about the legality of your design concept, check with your tutor before continuing.

The students are also required to develop a Design report, and supporting documentation in the form of an engineering report. It was to be delivered to their tutor during their tutorial at the end of the semester [semester duration equals 14 weeks]. Each member of the group needed to make a fair contribution to both the report and the vehicle.

A detailed review of the project described above revealed the core intent of this project was to allow the Design Engineering students to evolve their design thinking. Moreover, it disclosed the students did in fact move towards developing the nine (9) characteristics highlighted in the work of Kokotovich (2010) and listed earlier.  Given the above Design Problem we are of the view while it may not be as open as one might hope, it does go a long way towards addressing the issues highlighted in this discussion paper.

## Conclusion

While the case study presented does not parallel the problems utilised in Atman & Bursic (1996), it clearly begins to move away from the “by the book” / “textbook” methodology typically found in numerous Design Engineering schools around the world. It should be remembered the students in the work of Atman & Bursic (1996) were not required to build and test, however, in addition to the case study presented here the more recent work of Beghelli and Prieto (2015) did require the students to design, build and test their creative ideas. While we would like to see significantly more design engineering problems similar to the ones discussed here, equally we see the need to require the students to build and test designs as in the UTS case study discussed. Moreover, while some institutions may argue there is no need to change from a “textbook” focused pedagogy, with respect to Design Engineering, the core purpose of this paper was to stimulate debate, and initiate meaningful discussion among our colleagues in relation to how we may move our profession forward in these technologically turbulent times. Additionally, the intent was to initiate meaningful discussion in relation to how we may recognize and indeed address *"The Problem of the Problem"*. As with the work of Beghelli and Prieto (2015), a sincere effort is being made at the University of Technology Sydney to address *"The Problem of the Problem"*. It is hoped our colleagues draw inspiration from, and find value in, the core ideas presented. After all it may be argued from small changes, big changes may occur.

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