# Rube Goldberg Machines as a Transition to University Tool

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**CONTEXT**
Transition into the university learning environment is an often difficult challenge. An effective transition into university study can have a strong impact upon students' later success – by establishing clear expectations of the university environment, and by connecting students to their peers.
In the CSU Engineering context, this transition is potentially further confounded by the nature of the degree program. The curriculum includes neither lectures nor exams; the cohort has been deliberately selected to promote diversity of backgrounds and experience. As a result the "typical" expectations of a university degree do not apply, and even have the potential to be counter-productive. This non-traditional context thus requires a non-traditional approach to orienting students.

**PURPOSE**
This study examines a method to incorporate all students' effort in an integrated multifunction project – the construction of a Rube Goldberg Machine. The purpose of the paper is to show how the approach improves student engagement in an authentic process with a formal final exhibition. In particular, the orientation process is intended to highlight the distinct expectations of the CSU Engineering degree program.

**APPROACH**
The first assessment task for all CSU Engineering students is the construction of a Rube Goldberg Machine. This paper reports on the experiences of the inaugural student cohort with this project, and on their resultant skill development and engagement with their degree.

**RESULTS**
From the very first moment of the project, students understood that they participated in an integrated, interdependent project, where a deficiency in any step can potentially cause the whole project to fail. As a result they were forced to accept responsibility not only for their own work, but also for the work of their colleagues, leading to a greater sense of shared responsibility and cooperation throughout the cohort, which in turn helped establish social networks throughout the student cohort. The necessity of delivering to a fixed schedule also promoted unusual levels of resilience to change amongst the students, adapting well to changes in expectations throughout the course of the project.

**CONCLUSIONS**
Students' engagement in their first project was substantial; during the first two weeks of their study in the university, they knew each other in a professional environment, which caused a smooth transition to university. Requiring students to interact with other team members resulted in both self-awareness and social awareness of the composition of their cohort. In addition to a rapid adaptation to the university environment, they faced important issues in the management of projects such as time management, risk management and team leading and participation.

**KEYWORDS**
Transition to university, first year students, Rube Goldberg Machine.

# Introduction

First-year study is critical. It prepares students for their future studies and helps to establish a lifelong learning style, equipping them to face new challenges and issues after graduation. As discussed by Biggs and Tang (2011), a greater proportion of school leavers is now in higher education, so a strong first year curriculum is very important to decrease the attrition rate in both first year and upper levels of university.

Transition to university must be considered in curriculum design – it is essential aspects to orient students from the previous environment to the new environment in university. The curriculum and its delivery should be designed to be consistent and explicit in assisting students' transition from their previous educational experience to the nature of learning in higher education and learning in their discipline as part of their lifelong learning (Kift, 2009). Teachers need to clearly articulate their expectations and students responsibilities; Students need time to accommodate to their new environment and to understand that it is important to "raise their hands" to ask questions given that other students may have the same questions. They have to know how to monitor and judge their learning process with expected standards and to know how to work without teachers to manage their time and use university facilities (University-of-Newcastle, 2013).

Charles Sturt University has recently introduced its first ever engineering degrees, with the inaugural cohort in Civil Engineering commencing in February 2016. At CSU Engineering, the traditional expectations of a university degree do not apply (Morgan and Lindsay, 2015); this non-traditional context thus requires a non-traditional approach to orienting students. The program has no lectures, instead being built around a project based learning framework; as such the orientation must also be built around a project approach. Similarly the philosophy of the program is very strong on accountability and ownership of tasks; as such the orientation needs to emphasise the need to deliver against fixed deadlines. The very first task in the curriculum is intended to establish these expectations clearly through the construction of a Rube Goldberg Machine (RGM).

# Rube Goldberg Machines

Rube Goldberg (1883-1970) was an American Cartoonist and inventor renowned for his cartoons of overly complex systems to complete simple tasks. His name has since become synonymous with "comically involved, complicated invention[s], laboriously contrived to perform a simple operation" (Webster's New World, 2013).

Rube Goldberg Machines periodically appear in popular culture and the media, even if they are not known by those names. Two key examples are the Honda "Cog" commercial (https://www.youtube.com/watch?v=NsDEgxmH8wI) and the "This Too Shall Pass" music video by the band OK Go (https://www.youtube.com/watch?v=qybUFnY7Y8w).

Recently, Rube Goldberg competitions have become increasingly popular, particularly for STEM outreach to high schools, and for first year engineering students. Rube Goldberg Inc (2016) run a national competition each year in the USA, which draws in students as young as 11 in high schools.

RGMs appear at first glance to be an effective engagement tool for prospective engineers; however upon deeper inspection there are grounds for concern. The greatest downfall of a RGM is that ultimately they are bad engineering. Good engineering is about people; deliberately seeking to overcomplicate a design draws the focus towards the technology, rather than the users.

This focus on the technology leads to one of the greater criticisms of RGMs as a STEM recruitment tool: do they attract new people to engineering, or do they simply appeal to people who are already likely to select a STEM career? While it is valuable to ensure that we do not lose interested young people to other professions, a headline message that engineering is about creating overly complex solutions to simple problems is unlikely to be effective in expanding the diversity of student cohort. This issue is potentially problematic when the opportunity costs of outreach activities are considered – time and money spent promoting a Rube Goldberg Machine competition, and the potential sponsorship dollars / partnership contributions it may attract, may more constructively be used in other areas.

While there are substantial potential drawbacks to RGMs as a recruitment tool, these issues are not necessarily flaws with regard to orienting new students to an academic program. These students have already committed to an engineering career, and the lack of technical design required makes them accessible to first year students regardless of their pre-university preparation.

# ENG160

The CSU Engineering curriculum is very different to traditional engineering programs (Lindsay and Morgan, 2015). This distinction is emphasised at the outset through the first subject that the student engineers undertake – ENG160 Engineering Challenge 0. ENG160 is a two point subject, representing 1/16$^{th}$ of a full time course load. It only runs for the first two weeks of semester, and it is the only subject that runs during that time period. This structure is designed to highlight the different nature of the degree by explicitly and immediately challenging students' expectations of a traditional engineering curriculum:

> *"By focussing immediately and fully on a single project that exemplifies the principles of CSU Engineering, the incoming students are familiarised with the culture and expectations of CSU Engineering, while also taking the opportunity to establish their relationships with other members of the student engineers" (Lindsay, 2016).*

The subject centres on the development of a single Rube Goldberg Machine comprised of steps provided by the entire student cohort. Students work in teams of three, each required to design and build at least four steps of the overall RGM – steps that must interact with at least two other teams. In this way a chain reaction of linkages between the students is developed, and the students are required to meet and become familiar with the broader student cohort. The project exposes the student engineers very quickly to some key elements of the engineering work context:

- Concrete, immovable deadlines – the final machine is demonstrated at 3pm on the Friday of the second week ("Rube Goldberg Day"), with the broad university community and the general public all invited to attend.
- Interdependence with other engineers – the overall machine only works if other teams' sections work
- The importance of communication – the RGM cannot transfer smoothly between its steps if the students do not communicate between and within teams
- Multiple possible correct solutions – there is no single correct answer that they need to find; rather they are free to explore a range of options.

The subject also requires the student engineers to engage in icebreaker-style activities that introduce them to the whole cohort, rather than just the members of teams with whom they are interacting directly. In this way the culture of a single cohort, rather than a collection of teams (let alone single students) is further reinforced.

The students are also expected to establish their electronic portfolios using PebblePad, and to have as their first entries a number of reflective activities (e.g. a "Me in a minute" video). This allows for them to start developing an understanding of the engineering process, and to demonstrate this understanding to themselves, their academic mentors and their future selves.

## Outcomes

The overall project was a near complete success, with a 65-step Rube Goldberg Machine demonstrated to a crowded building at the end of the second week. The RGM was not able to run through cleanly, requiring a minimum of two "touches" on each run; however the overall task was a success.

The whole machine occupied a substantial proportion of the Engineering Building, as well as venturing into the courtyard (Figure 1). Video of the full multistage machine is available online: https://www.youtube.com/watch?v=YYJyvpadmNo

**Figure 1: Some parts of final Rube Goldberg Machine**

Each of the nine teams contributed at least four steps to the overall RGM. The teams are each mentored by a randomly-assigned academic staff member to proceed through sketch and design to testing and implementation. They began their project with some brainstorming sessions for capturing their ideas. Then they sketch their project within their team and checked the connection between each step. They communicated with mentors frequently throughout the two weeks, providing up to date progress reports; through this interaction, they understood that they have to plan their activities, allocate their work to every team member, and consider safety of the project as well as its cost and budget. Some teams made a timeline of target deadlines for each step and worked with each other to be in front of the deadline.

As the requirement of the project was to trigger the first step of the project of the other team, they had to engage with two different teams to adapt that connectivity. They held some cohort meetings in the makerspace to arrange the machine sequences and to identify their project place. In the first week, almost all of the teams completed the sketching and design of their project, continuing some parts of the construction in the weekend.

Diversity in the cohort made them engage very well during the first two weeks. Each team member brought a different set of skills and experiences, which was important to communicate properly to achieve the best outcome. Some students had background in construction, welding and carpentry and applied their skills in building a complex system and some other made simple stages with the residual parts of substances. There were some students that used their past experience in sport teams, which benefited the team to be productive and proactive.

Linking each 4-step machine segment to other segments increased students' engagement and interaction. They had to communicate with other teams to make sure that the last stage of the previous machine could trigger their first stage and the same for the next machine. This communication improved with familiarisation of the cohort. Every team realised that it was not just their own project, but rather the whole project has to work smoothly. For instance, they interacted with other teams in order to remove any faults and deficiencies from their project; there were groups, physically building on the project at 1:30 am the night before Rube Goldberg day. The engagement changed their focus away from solely on their components to a much broader whole project perspective. As every team had their own characterised steps in the machine, everyone had sense of ownership for the final project.

The students were expected to reflect upon the event, the project itself and their team members and to capture these in their e-portfolios. Here, we present some short discussion of this first cohort and the benefits of the project for their engagement:

> *"…I still believe we did an impeccable job at constructing the designs and helped each other out when needed which depicts the forming of bond within the cohort. I have learned that commitment and communication is key to a successful project."*
>
> *"I believe it has helped to develop greater relationships between members of the cohort and further develop interpersonal skills that we as future engineers can utilise within the industry."*
>
> *"… I've learned many things from this challenge, not just about Rube Goldberg machines and materials, but about skills like teamwork and communication. I cannot wait until the next challenge, and I look forward to working with everyone in the future."*
>
> *"The Rube Goldberg machine project has overall increased the cohorts chemistry as we now have touched the surface of how our peers learn, design and problem solve."*
>
> *" … By completing the task I was able to bond, interact and share ideas with fellow peers making everyone closer as well as comfortable with sharing thoughts and ideas."*

These are just some of students' feedback for the subject and their engagement and team contribution. They also pointed some issues in connection with those survival skills for 21st century (Wagner, 2009) in their language: "the importance of working collaboratively, conflict resolution and compromise, being adaptable and open to change, the importance of good communication, understanding the implications of other stakeholders to the project and …".

A particularly powerful outcome of this process was the robustness of the students to changes in the requirements for their project. A serendipitous instance of heavy rain on the final demonstration day impacted upon both the planning and delivery phases of the project. Throughout the second week of the project the students closely monitored weather forecasts, and made the decision to move the outdoor sections of the machine back inside the building. When particularly heavy rain arrived around an hour before the final demonstration the cohort were ready with their "plan B", and were able to operate the RGM successfully despite adverse conditions, including loss of power to the building due to the storm. Commencing first year students are notoriously fragile when it comes to variations in the tasks that are set them; in this instance the opposite was observed, with the students comfortable moving the goalposts for themselves.

A further surprise outcome was the degree of comfort and fluency of the students with performing risk assessments. Traditionally risk assessments appear in the later years of an Engineering curriculum; however the strong "authentic workplace" mindset of the CSU Engineering program meant that they were part of the up-front induction process. As a result, students were able to perform meaningful risk assessments on their more ambitious ideas for steps within the RGM, and then to use these risk assessments to guide (or in a couple of cases abandon) their implementation process. This has normalised an awareness of risk and safety within the cohort at a very early point in the students' development as engineers.

# Consequences / Significance

This first subject had a strong influence on students' attitude to adapt themselves to the new learning environment in university. It had fixed deadlines, which caused them to organise their activities, plan their stages and interact with other teams to deliver their project on time. Although at the first day of the subject, some of them felt overwhelmed, but soon they learned from their mentors and other team members how to progress in the subject.

The potential negative features of RGMs such as "bad engineering" or "use of complex means to achieve simple task instead of simplest solutions to complex problems" (Klotz, 2013) did not manifest in this project as the aim of the project was context setting and encouraging students' engagement rather than solving real engineering problems. The goal was to demonstrate the students to deliver the project on-time, to guide them to use laboratory, to make them responsible for their team and to provide a platform to practice communication. Although the RGM certainly overshadows everything else in the subject, in general, the subject was successful as it caused students to adapt themselves to the specifications of the new environment.

While care must be taken in generalising from small sample sizes, all of the students who completed this subject were still enrolled in the degree as of the semester two census date. Zero headline attrition is exceptional for any program, particularly in Engineering; care must be taken, however in not solely attributing this to the use of an RGM.

# Conclusion

Students' engagement in their first project was substantial; during the first two weeks of their study in the university, they knew each other in a professional environment, which caused a smooth transition to university. They faced an example of their subjects in a short format and with specific deadlines, in which they responded responsibly. Requiring students to interact with other team members resulted in both self-awareness and social awareness of the composition of their cohort. In addition to a rapid adaptation to the university environment, they faced important issues in the management of projects such as time management, risk management and team leading and participation. All in all, the RGM as the first subject in the project-based design environment had a great impact on students' engagement and it functioned well in supporting CSU Engineering curriculum.

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