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The CSU Engineering Topic Tree: The First Four Years

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ABSTRACT

The Charles Sturt University (CSU) Engineering programme is a new course (degree programmme) established in 2016 by a university that had not previously taught engineering. This start from scratch occasion was taken as an opportunity to build an all-new programme structure and philosophy. Students at CSU Engineering complete a sequence of three semester-long Project-Based Learning (PBL) style challenges across their time face-to-face at the university; after this point, they commence four yearlong paid industry-based work placements and continue studies in an online mode during evenings, weekends, and scheduled study days.

The underlying technical curriculum for the engineering programme at Charles Sturt University is delivered mostly on-line via the RealizeIT platform and is based on a philosophy of just-in-time, self-directed learning. Students have freedom in deciding when, how and, to a large extent, which elements of the curriculum they engage within the online environment. This freedom, along with the PBL-style challenges, is enabled by the structure of the technical curriculum which is broken down into fine-grained learning activities called 'topics'.

In this paper, we summarise our experiences during the first four years, and the insights gained into student behaviours when offered an opportunity to engage in self-directed learning.

Key words: on-line learning; just-in-time delivery; self-directed learning

INTRODUCTION

The Charles Sturt University (CSU) Engineering programme is a new course established in 2016 by a university that had not previously taught engineering. This start from scratch occasion was taken as an opportunity to build an all-new programme structure and philosophy [1]. Students at CSU Engineering complete a sequence of three semester-long Project-Based Learning (PBL) style challenges across their time face-to-face at the university; after this point, they commence four year-long paid industry-based work placements and continue studies in an online mode during evenings, weekends, and scheduled study days. Thus the PBL challenges are replaced by *real, paid* work, and the academic subjects associated with the work are replaced with portfolio subjects focused on helping students to document their accumulated competencies with evidence for the work place.

The underlying technical curriculum for the engineering programme at Charles Sturt University is delivered mostly on-line via the RealizeIT platform [2] and is based on a philosophy of just-in-time, self-directed learning. Students have freedom in deciding when (as inspired by current events, as required for a project, etc.), how and, to a large extent, which elements of the curriculum they engage within the online environment. This freedom, along with the PBL-style challenges, is enabled by the structure of the technical curriculum which is broken down into fine-grained learning activities called 'topics'.

In addition to the PBL *half* and the Topic tree *half* of the curriculum, there is a performance planning and review thread that continues for the duration of the curriculum. Whilst this strand comprises only 5-10% of the credit points in the degree, it serves to help prepare the students to be productive in an engineering work environment in the early semesters, and to help them become reflective practitioners as they progress through progressively more challenging work placements.

WHAT IS THE TOPIC TREE?

Topics on the Civil Engineering Topic Tree represent *all* of the technical content typically included in a civil engineering degree. These topics are arranged as leaves on a tree structure where the branches represent sub-disciplines (such as water resources or structural engineering), and recommended learning order is made explicit by the arrangement of the topics/leaves on the branch [3], see Figure 1. Hard prerequisites are rare (students are able to access the learning content in a topic whether or not they have mastered the prerequisite topics), and usually are limited to safety related issues such as lab preparation (labs not completed during the first three semesters can be completed on campus between work placements or during study days). Each topic has its own

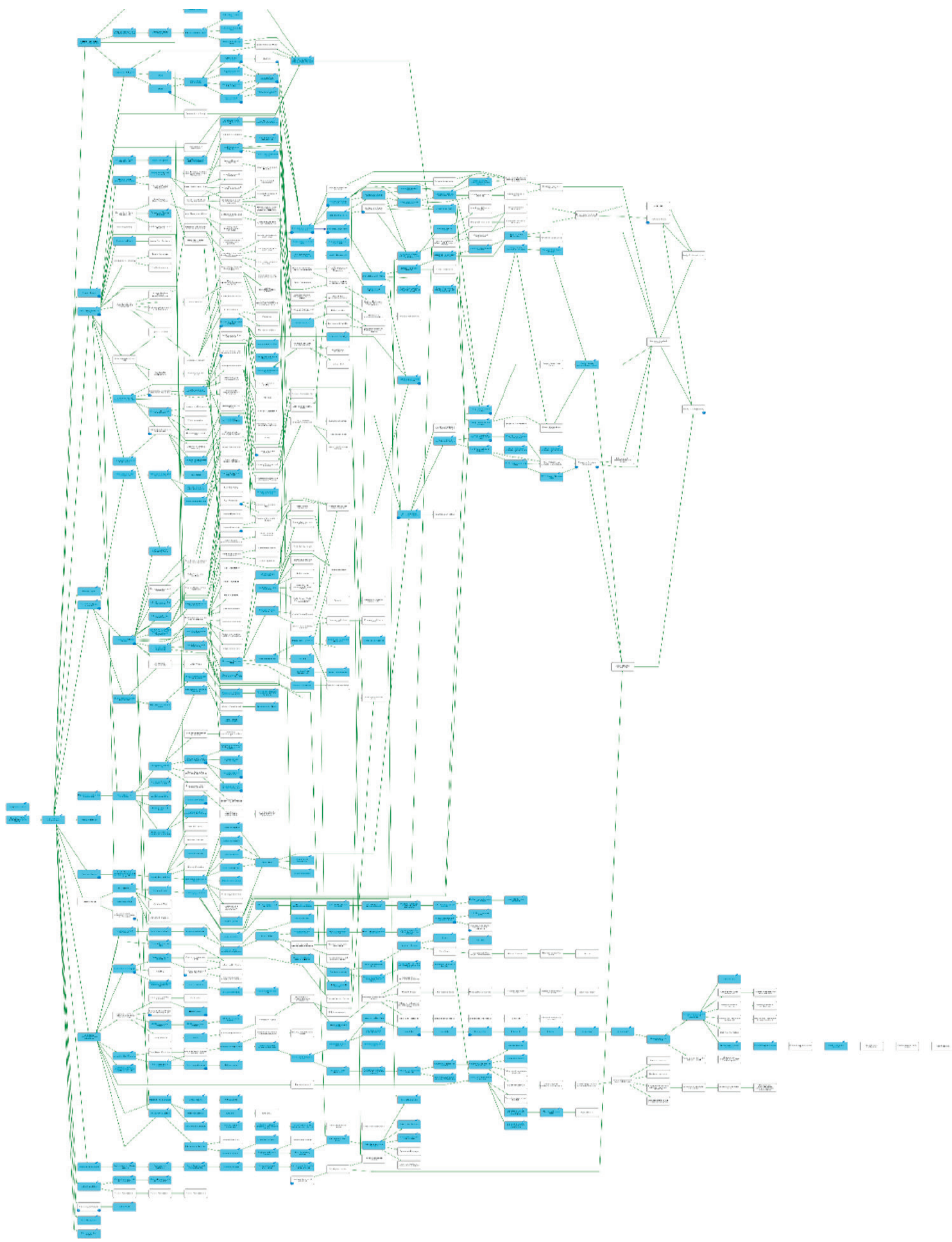

Figure 1. Topics in the Civil Engineering Topic Tree.

learning outcomes, learning resources and assessment, and is intended to take a typical well-prepared student approximately three hours to complete (i.e., a student who has completed the prerequisite topics). Many topics are automatically assessed online; however, some require submissions that are marked by faculty.

HOW DO THEY PROGRESS THROUGH THE TOPIC TREE?

A key feature of the engineering course at Charles Sturt is self-directed and self-motivated learning [4, 5]. Student engineers must successfully complete at least 240 topics from the Topic Tree (including 80 required before starting their first work placement) in order to complete the multi-session subject ENG271 (taken during the first 3 semesters). The topics are presented to the students in a recommended order, but there are few fixed prerequisites – students can jump ahead and skip topics if they wish, but they must still accumulate a total of 240 earned topics in the first 15 months [6]. The topic tree portion of their studies continues a further four years beyond these first 15 months with a total of 600 topics (approximately 1/3 of these required topics) required by the end of the third work placement.

This paper will focus on the first three sessions of our programme. Whilst several cohorts have commenced work placement and continue to accumulate topics, no one has yet matriculated (first graduates are expected in June 2021). The students have approximately 15 months in which to accumulate the required topics for their first paid work placement. In addition to the three sessions, they also have access to the materials over the summer, and other non-teaching periods during and between semesters. In total they have roughly 64 weeks from the commencement of the subject to the deadline for completion of the topics; of these 64 weeks, approximately 36 are explicit teaching weeks [6].

The pacing is consequently very simple. Students who wish to complete topics continuously over the period, including holidays, need to complete around 4 per week; whereas, students who wish to only complete topics during teaching times during semesters will need to complete about 6 per week. Although this pacing is made clear to all students at the commencement of their studies, and while this may be clear and logical, their behaviours indicate that they have not internalised this expectation [6].

The first cohort effectively bifurcated on the basis of their ability to learning independently [3]. Student engineers (engineers in the student phase of their career) with good internal management skills planned well, and worked consistently throughout the three semesters. *Engineering students* (university students who picked engineering for now) typically lacked the self-directed learning skills and consistently put off the work – utilising the flexibility not as to *when* they did the work, but rather as to if they did significant amounts of topic work (most undertake the project work – perhaps because of the team nature of the projects).

The behaviour described above results in two sub-cohorts – a group of student engineers who were up to date, and on track to successful complete the subject, and a group of engineering students that were well behind, and unlikely to complete. The structure of the program, however, meant that

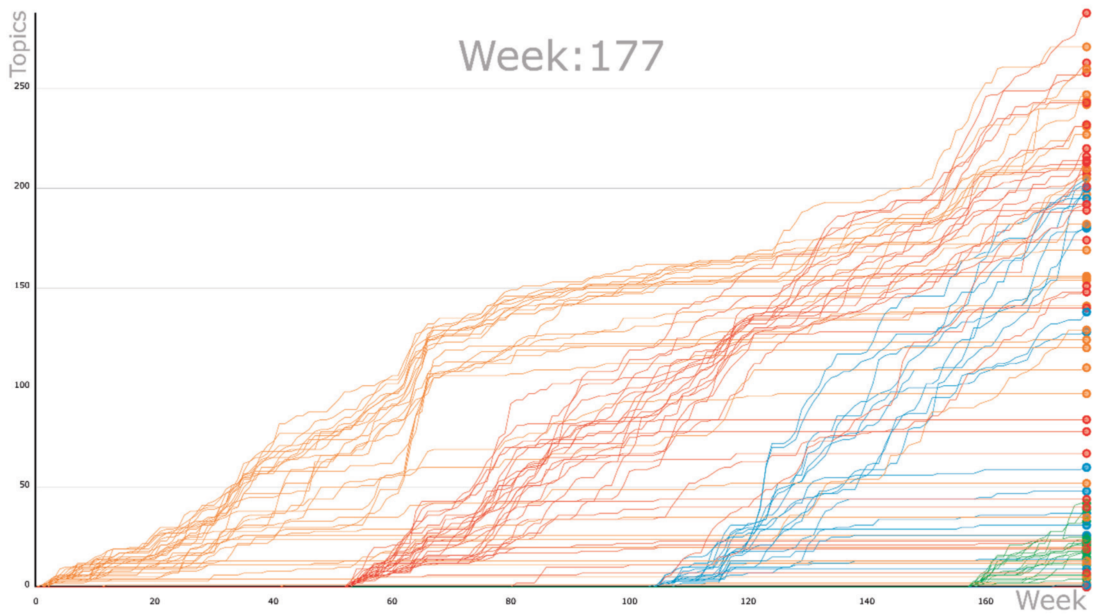

Figure 2. Topic count versus weeks from 29 February 2016.

there were no explicit differences in the way that these two groups were treated in other aspects of the programme. This was perceived as an injustice on the part of the up to date students, who felt that they were entitled to better treatment across the board, based on the fact that they had worked harder (overall) [3].

Topic progress for each of the first four cohorts is presented in Figure 2. Week 0 represents the commencement of the first cohort of student engineers where each student engineer had 0 topics completed. Also depicted in Figure 2 are the commencement dates for the second (week 53 for the first cohort), third (week 106), and fourth cohorts (week 159). Of note in the graph are:

- The horizontal lines too often tracking all the way to the right edge of the figure (these line represent students who have stopped progressing on topics half, and eventually leave the programme);
- The second cohort has a relatively higher average initial slope (note that they are roughly in the same place as the first cohort by week 140) – perhaps from observing the panic of the first cohort trying to do *all* of the topics in the third session – the third cohort has an average initial slope even higher than that for the second cohort (nearly catching the first two cohorts by week 177); and
- The various behaviours of individual student engineers (each line in figure 2 represents a unique student):
    - Turtles – plod along at roughly 4 topics per week regardless of anything else going on in the course or in their life (~straight lines progressing up to the right on the graph);

- Frogs – a series of small hops (steps) with progress stopping during assessment due dates in project subjects, or during mid-session breaks, etc.; and
- Kangaroos – essentially no progress for long periods of time broken by huge leaps of productivity (such as that seen for several in the first cohort at ~60 weeks).

WHAT IS A METROGNOME?

Gamification [8, 9] was chosen as the solution to encourage engagement in the topic tree and to moderate the unproductive behaviours observed above.

There is a range of learning styles amongst any cohort, and their response to deadlines varies. Three archetypes were identified within the cohort: Turtles, who plod along at a constant pace each week and reach the goal steadily and inevitably; Frogs, who make a series of small hops to get to target; and Kangaroos, which make infrequent large hops to reach the target. The individual progress for each student engineer in cohorts 1 through 4 are depicted in Figure 2. All behaviours are clearly evident amongst members of cohort 1. Some student engineers stay true to form throughout, whilst others exhibit all three behaviours at time during their first 300 days. And some roos are still waiting for their first big jump even 300 days into the session [7].

Enter the Metrognome (Figure 3). The progress of the MetroGnome was intended as a clear signal as to the minimum acceptable progress level for the cohort; a signal that any student who was not

Figure 3. Metrognome.

keeping up with the MetroGnome was at risk for non-completion, and thus could be targeted for intervention and support. Cohort 2 (starting from 0 topics at week 53) exhibit overall the behavior of Turtles, with relatively few and smaller jumps. Unfortunately, based on the results, the Metrognome progress was not perceived as intended. Rather than being a minimum threshold, *his* progress became the target and was normalised as an acceptable or even expected performance – liken the yellow line (world record pace target) in a pool (seen by students), to the back of the peloton in a race (as intended by the academic team).

The presence of the MetroGnome and regular reminders of *his topic count* did make the progress issue visible where it had previously been silent. However, whereas most students understood that they need to be "ahead of the MetroGnome"; rather than embracing this and progressing, many haggled over whether the official count was correct, and obsessing on it being unfair that topics submitted but not yet marked couldn't be counted towards being ahead of the MetroGnome.

Significant numbers of our students struggle to keep up with the MetroGnome, and it is possible that constant reminders are serving to demotivate rather than to encourage [10]. While students need a realistic appraisal of their progress at various cross roads during the course of their degree. The MetroGnome was deeply unpopular amongst a subset of the cohort. He was found placed in a corner facing the wall; he was hidden from the academics; excluded him from meetings, etc. - he did not become the cherished mascot that we had hoped he would be. In summary, the Metrognome didn't mitigate the behaviour as desired. **Student engineers** stayed well ahead of the Metrognome and **engineering students** tended to view the Metrognome as a slightly unreachable goal rather than as the minimum successful performance you ***must stay ahead of***. The Metrognome has been abandoned.

DISCUSSION

Lindsay and Morgan [3] observed that students progress through the topic tree much as many people watch series on Netflix: they watch all episodes (topics) of a series (branch). Perhaps much of student engagement with the Topic Tree is basically a Netflix phenomena, however, recent studies [11,12] indicate that the actual behavior might be a bit more complex.

The first thing some students (46%) do when they complete a topic is to start all over again with the same topic [11]. Perhaps they were not successful in obtaining the score they want, or perhaps when they see the assessment, they realise they need to study a bit more. Revision and self-testing are well established and effective study behaviours. Students moving to a new topic are more than twice as likely to pick a topic from another branch than another topic on the same branch [11]. These observations fit in well with Carroll's model for school learning: some students need to spend more time on a topic to master it than others and some students have more effective study behaviours than others. Although these findings in reference [11] may not seem significant, we believe they are: in this innovative curriculum it is up to the students to make decisions regarding their study behavior. It is still important to understand student behaviour to monitor the effectiveness of the environment, but also to be able to spot students who may be at risk and think of interventions that are appropriate in this unique context.

The CSU curriculum is unique and learning to understand the students' behaviour is a first step to understanding what behaviours lead to academic achievement in the programme. In reference [11] we studied how students move through the topic tree using total distance traveled on the tree and time gap between activities. This work was enlightening as we established that students do a considerable amount of revision, but we did not distinguish between the various directions students took. In reference [12] the analysis was extended to consider the distance traveled, the direction through the tree and the purpose of the activity.

It was found that most students attempt the same topic multiple times on the same day. Revision (revisiting activities previously attempted and/or redoing assessments) is as likely as starting a new topic if the next activity takes place on the same day. Furthermore, the proportion of Learn activities versus Revise activities is approximately 10:1. Most revisions concern topics that are direct prerequisites to the activity on the same branch of the topic tree. This indicates that students tend to finish and revise within a branch before they move to the next branch on the tree.

Students tend to stay on the same activity and the same branch and often repeat the same topic before moving on, but they do not only move forward. They also review previous topics before they attempt something new on the same branch and they often go back on the branch to check out parts of other topics.

This more detailed analysis of the patterns of topic acquisition has somewhat undermined the previous "Netflix"-style understanding of student progress as being too simple a model to explain the various ways in which our cohorts learn, and not taking into account the differences in students' patterns of engagement with entertainment vs education. Future work will allow us to expand the model to capture these nuances more fully [12].

Next steps in this endeavour are to explore the dimensions that are underlying for this behaviour, to create a link with student performance. This future research must include surveys, focus groups and interviews with student and cadet engineers to start a dialogue with the students about these study behaviours: what motivates them to study in this way, what do they feel they gain through these behaviours and how does that tie in with their other educational activities in the curriculum? We intend to pursue these questions further in future research.

Growing The Tree - What's a Topic Tree Alliance

The biggest challenge is writing it all. Writing the topics just in time becomes unworkable because of one of the primary advantages of the tree - by allowing almost complete flexibility in accessing topics from the tree, student engineers want to access the *typically third year* topics most useful for their projects. This combined with the variety of projects undertaken by different teams of student engineers means that we cannot roll out the tree one session or one year at a time – it should all be there whenever and as soon as desired/required.

Looking at options to outsource – in addition to looking at partners to write/provide topics, we are looking for partnerships to graft whole branches onto the tree. These partnerships are envisioned especially at the advanced topics portion of the tree – specialties not available amongst our small staff - perhaps granting 15 or 20 or more topics upon successful completion of a MOOC from anywhere around the world or a postgraduate level specialised subject at a university near your work placement.

CONCLUSION

The 24 hours per day, 7 days per week, 52 weeks per year nature of an online all-you-can-learn topic tree model is very effective for self-directed, self-motivated students. It offers massive flexibility that the students take advantage of when required to complete an engineering challenge or project; when inspired by current events such as an earthquake, a bridge collapse, or a landslide; and when driven by personal interest such as wanting to know more about artificial islands.

Getting it in place is immensely challenging - even with the academic team in place 3 to 6 months ahead of the first student engineers, it was impossible to have all of the leaves on the tree before the student engineers commenced. Of course, the energy of the team was diverted from mostly topic writing once the teams of student engineers began working on challenges, and some topics remain unwritten – the first cohort has not reached the final year of their programme as of yet.

More study is required especially in the realm of helping students become self-motivated and self-directed — perhaps helping engineering students become student engineers.

Starting from a greenfield is exciting and rewarding and challenging.

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AUTHORS

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