A preliminary investigation of student collaboration to create resources that motivate the relevance of mathematics to first year engineers

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BACKGROUND
Many engineering students don't see the relevance in their mathematical studies in the first year of their degree. This lack of understanding of the importance of mathematics often leads to a loss of interest and disengagement with mathematical studies early on. It may also result in the need to re-teach first year mathematical concepts in later engineering subjects as the students did not acquire the skills from their mathematics subjects.

PURPOSE
In this paper, we report on a summer semester project that gave final year engineering and multi-media students the task to "*make mathematics relevant*" to first year students. The collaboration that ensued across disciplines resulted in two high quality animated videos, one on the use of mathematics in building construction and the other on improving the aerodynamical properties of a vehicle. In this paper, we provide an initial investigation into the interdisciplinary collaboration between the final year students who produced the resources, from the point of view of the engineering students. We want to closely follow student views to understand better what contribution students can make to the production of resources for first years.

In particular, we answer the two research questions

1. How did the engineering students approach their brief and how did they collaborate?
2. How did their thoughts evolve following interaction with the multi-media students and how did they collaborate with the multi-media students?

DESIGN/METHOD
In this case study we use an ethnographic design approach to understand the students' experiences. This qualitative research study includes the evaluation of an interview with the two engineering students held while the students were working on the project, complemented by researcher observations.

RESULTS
We show how final year engineering students have collaborated with each other, and with multi-media students, to produce quality video resources for their peers. In fact, we argue that it is the interdisciplinary nature of the collaboration that resulted from the addition of the multi-media students to the team that has resulted in high quality resources.

CONCLUSIONS
This study is a first step to research student contribution to demonstrating the relevance of mathematics. We provide a preliminary evaluation on Stage 1, the first iteration resulting in two resources produced, with more analysis (also including the multi-media students' perspective) to be communicated elsewhere once all data is analysed. Stage 2 of our project has just commenced, with the next cohort of engineering and multi-media students collaborating on resources to explain the relevance of first year mathematics in robotics and biomedical engineering. Following our very positive experiences, we call for more research in this area!

KEYWORDS

mathematics relevance, first year, student contribution, multi-media, animation

Introduction

How often have we heard a first year engineering student ask "*what do I need this for?*" about a mathematical topic? Anecdotal evidence suggests that mathematics educators, as non-engineers, often struggle to justify the practical relevance of first year mathematics to a future engineering career. This is not necessarily because they are not aware of how mathematics is used in engineering, but rather because mathematics is usually taught in a "*pure*" way with a focus on mathematical concepts and understanding rather than applications. The applications are covered later in their engineering studies.

To get the message across to first year engineers that their mathematical studies are vital for their later success as engineers, we introduce a faculty-funded pilot project that involved higher year students in explaining the relevance of first-year mathematical content to first year students. Two engineering students and a team of three multimedia students (the latter included to ensure a quality outcome) were awarded scholarships over the summer break with the brief to "*use multimedia to make mathematics relevant*". The two authors of this paper are a mathematician and a civil engineer, who were guiding the students during the period of the project.

In this study we take a qualitative research design approach, where the collected data includes researcher observations and an interview with the two engineering students as well as responses to a short survey from students enrolled in a preparatory course preceding their first engineering mathematics unit. From a thematic analysis of the data we investigate how the engineering students approached the project, how the two engineers collaborated, but also how their thoughts changed once they started interacting with the multi-media students and how they collaborated with these students.

We also briefly introduce the outcome of this collaboration: Two animated videos, one from a civil and the other from a mechanical engineering perspective. The produced videos are of professional quality. In addition to showing the relevance of first year mathematics to first year engineering students, it is now planned to also use these videos to promote the engineering and multimedia degrees at Swinburne University of Technology.

This paper describes our initial investigation into the contribution higher year engineering students can make to engage first year students in their mathematical studies from the outset. The paper is relevant to those who are interested in making mathematics relevant, and also for those who would like to involve students in the creation of material for their peers, for example for motivating the relevance of mathematics. It is organised as follows: After reviewing relevant literature and introducing the project and our methodology, we present results from the qualitative data we collected and analysed, and we conclude with a discussion and outlook to future research directions.

Literature

Two main fields of the literature are relevant to this study: Student perception of the relevance of their mathematical studies to their engineering studies, and the involvement of students as co-creators of resources for their peers. We will give a brief overview of the literature of both fields.

The relevance of mathematical study to engineering students

Engineering students' perception of the relevance of mathematics to their studies has been investigated in an Australian context by Coupland, Gardner & Carmody (2008), and more recently by Flegg, Mallet & Lupton (2012). Coupland et al. ask whether engineering students "*are aware of the connections between the mathematics they study early in their degree and the later engineering subjects*". They find that students in the later years of their engineering degree recognize the relevance of mathematics to their engineering studies to a higher

degree than students in their first year of study. This is to be expected as the higher year students have seen the application of mathematics in their further studies. Coupland et al. also observe a difference in responses between engineering disciplines, where mechanical engineers rated the relevance of their mathematical studies much higher than other engineering disciplines, while civil engineers rated the relevance lowest of all.

Flegg et al. (2012) motivate further investigation of this topic as "*it is in the interests of both mathematics and engineering academics to understand how students view the relevance of mathematics to engineering.*" Flegg et al. find that first year students seemed to agree that mathematics is relevant to their future career and study, however in follow-up interviews, it became clear that some students don't see this relevance, while others may see some relevance to their studies but not to their future workplace in the industry.

The two papers conclude with suggestions to increase the number of practical engineering applications in the teaching of mathematics to engineers (Coupland et al., 2008), to design the mathematics curriculum "*to specifically target using mathematics as a tool for dealing with real-world problems*", or to embed the relevance of mathematics in the curriculum "*by designing mathematical subjects in collaboration with engineering staff*" (Flegg et al., 2012).

Our project moves away from potential curriculum improvement to investigate additional opportunities to emphasise the relevance of mathematics as called for by Flegg et al. (2012). We facilitated the production of videos by higher year students who have seen where the mathematics they learnt in first year is used in their following years of study. These videos demonstrate the relevance of mathematics both in mechanical and in civil engineering, and were facilitated in collaboration between a mathematics and an engineering academic. The videos are produced for first year students to increase their interest in their mathematical studies by showing them the relevance and importance of even the lower level topics they already encountered at school.

Engaging students in the production of resources for their peers

While there are studies on the involvement of students as co-creators of material, most of these are not in mathematics. Bovill, Cook-Sather & Felten (2011) outline the theoretical background to argue for the involvement of students in course design and give examples of successful collaboration between course design staff and students. Other papers focus on particular types of resources produced by students, for example student-created podcasts, in the areas of engineering and education (Alpay & Gulati, 2010), in genetics (Nie, Cashmore & Cane, 2008), information technologies (Lee, Chan & McLoughlin, 2006) and in accounting (Wakefield, Frawley, Dyson, Tyler, & Litchfield, 2011).

In tertiary mathematics education more specifically, students are often not included as co-creators of material. An exception is a series of projects from Loughborough University in the UK. The first of those involved four second-year students working on an internship to produce material for their peers (Duah & Croft, 2012a; Duah & Croft, 2012b). The particular contributions that students can make, benefits for the students from this process, and the reasons for the resistance of lecturers to use student-generated screencasts in their material, were investigated following interviews with both students and academic staff involved in the project (Croft, Duah & Loch, 2013). It was found that students gained "*deeper mathematical understanding, improved technological skills and develop[ed] other generic skills required of today's graduates*." On the other hand, while "*lecturer reservations pertain to students' lack of mathematical maturity and concerns over the mathematical integrity of the content that students produce*", Croft et al. conclude that "*close collaboration between students and lecturers during the design and production phases of screencasts may help lecturers overcome reservations, whilst preserving the benefits for students.*"

A second project at the same university involved an engineering and a mathematics undergraduate student in the improvement of the conceptual understanding of the material of an engineering mathematics course (Hernandez-Martinez, 2013). In collaboration with the lecturer, two student interns produced a series of teaching and assessment tasks on

mathematical modelling. Certain benefits for the interns were observed, including an improved understanding of other disciplines, when students "*step[ped] outside of their identities as "mathematician" or "engineer" to what "the other side" could positively bring in*." The students also felt "*accountable*" for the material, which led to them putting sustained effort into the work to create a product of high quality.

Making mathematics relevant is important as we have just demonstrated. We have also established that students may benefit when they are involved in the creation of material for their peers (although this material so far has been of a discipline content nature, not to motivate relevance). In fact, we have not been able to find literature on peer-produced resources to motivate the relevance of mathematics.

We will now introduce our project which involved higher year students in the production of multi-media material to demonstrate the relevance of mathematics to first years.

The maths relevance project

"*Make maths relevant to first year students*". This was the brief given to two engineering and three multi-media students in their final year. What ensued was a collaboration across disciplines that resulted in two high quality animated videos.

The project was initiated in late 2012 through faculty funding. While the initial plan had been to involve three engineering students, funding conditions by senior leaders in the faculty required the inclusion of an IT or multi-media student in the project to ensure a high quality product. This reduced the number of scholarships for engineering students to two. The six-week scholarships were advertised among the higher level engineering students, resulting in a series of interviews and selection of a civil engineering and a mechanical engineering student. The third scholarship was shared between three multi-media students from another faculty as these students requested to work in a team. These students had been recommended by their lecturer following successful completion of a multi-media project.

The scholarships commenced in December 2012. The engineering students had already commenced before the multi-media students joined. The students were given the brief to produce a multi-media object to make maths relevant to first year students, that was reusable and didn't require a presenter. The expectation of the project team was that the students would produce some sort of video, possibly based on a PowerPoint presentation, a video interview, or a screen video recording. For this reason, the students were asked in their scholarship interviews to give a short PowerPoint presentation on how they would demonstrate the relevance of mathematics to first years. The students were made aware of MathsCasts, the support videos used for mathematical study at Swinburne (Loch, Gill & Croft, 2012) as an example of what could be produced. They were issued with tablet PCs, headsets and recording software to give them flexibility with their production. The decision on what to produce was left to the students, but regular meetings were arranged to ensure the project team agreed with their direction and ideas.

The students produced two animated videos of high quality. The first video shows the use of first year mathematics in the construction of a high-rise building (see Figure 1) and the second shows the mathematics used to improve the aerodynamical properties of a car (Figure 2). The two videos have been issued with a Creative Commons license (BY, ND, NC), and are available for download via Swinburne's iTunes U presence (Civil Engineering Video, 2013; Mechanical Engineering Video, 2013).

Methodology

This paper reports on our preliminary evaluation of the first stage of the maths relevance project. We use an ethnographic case study approach (LeCompte, Preissle & Tesch, 1993) to investigate the perceptions of students creating resources for their peers. We are interested in "process rather than outcomes, in context rather than a specific variable, in

discovery rather than confirmation" (Merriam, 1998), as such an investigation has not been undertaken before.

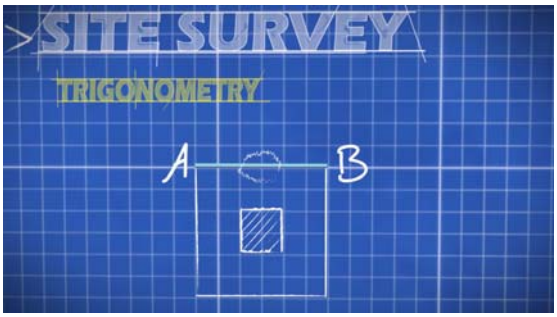

Figure 1: A screenshot from the civil engineering animation

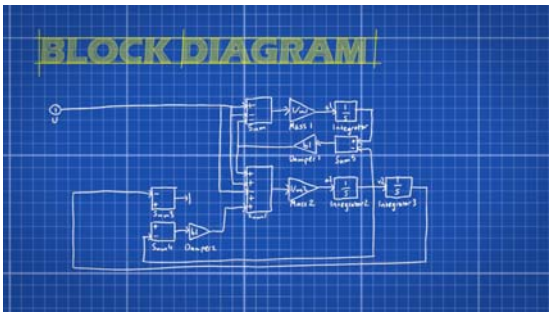

Figure 2: A screenshot from the mechanical engineering animation.

This qualitative research study includes the evaluation of an interview with the two engineering students held while the students were working on the project, complemented by researcher observations. Our thematic analysis of the data focuses on answering the research questions:

1. How did the engineering students approach their brief and how did they collaborate?
2. How did their thoughts evolve following interaction with the multi-media students and how did they collaborate with the multi-media students?

Since part of the collaboration was facilitated through technology we report on this component separately. We also provide a summary of survey responses from a group of first year students who were asked to comment on the videos when they were nearly completed.

This study is part of a larger research study to investigate how students can contribute to making mathematics more relevant to first years.

Results and Discussion

How did the engineering students approach their brief and how did they collaborate?

The engineering students ("the engineers") started by listing all first year mathematics topics from the textbooks of their two first year mathematics units covering calculus, linear algebra and discrete mathematics on a whiteboard, and added their thoughts and ideas to this. As final year students, it has been a while since they were first year students themselves, which is reflected in the comment, "*some we remember, some we don't because we haven't used them since. But you look at them and you recognise them*". They made connections between the topics and where they had later encountered them, "*and then we could start*

seeing – okay, vectors, yep. Straight away, we use that everywhere. Algebra, we use everywhere. So we could start to see these links and automatically ideas were starting to pop into our heads". On the other hand, they also discovered topics they had not come across again, as the civil engineer commented: "*then instantly I could say, "Okay, matrices. I haven't done past Maths 1, Maths 2 – or Maths 3."*"

The students then reflected on their strengths and weaknesses and how to determine the direction to go into by building on the strengths, as the following comment shows:

> *And I found my strengths are obviously the building. His strength is a mechanical and vehicle base. So that was – straight away, we knew which direction we wanted to go. And that's when we were able to start breaking down even further the individual topics within those. So in vectors, how much of 2D do we use - 3D do we use? Do we use the product rule? […] So you're able to actually break it down with the textbooks to try not to miss anything.*

The project team suggested to the students early in the project to meet with mathematics and engineering teaching staff to discuss how to go about their project. The students saw this as very beneficial, as they were able to watch others demonstrate the relevance of mathematics to them. For example, they commented on a meeting with a chemical engineer: "*I loved the links he was drawing with what he does now with ordinary differential equations and partial differentiation for different things and all the computer simulations they're running."* However, they thought that while they gained some ideas from the chemical engineer, his research area was far removed from their own engineering disciplines and the type of mathematics predominantly used was different. The students also commented on the passion the lecturers were showing for their work, and they seemed to find it inspiring.

The students received encouragement from a first year mathematics lecturer, which they described as follows: "*he had a good feeling about it. He said, "It sounds like you guys are going in the right direction.*"" The students felt it was important to produce something that this mathematics lecturer "*would be happy incorporating […] in his class*". The students said "*We wanted these guys to accept this, not just be a little bit standoffish*".

The two engineers worked closely together as described above when they searched for topics to be covered. They had a common start with the first year mathematics but were surprised to discover that each in their disciplines had later found different uses of the mathematics they had learnt at the beginning. The students looked for synergies and ideas to find different angles for the two videos and learnt about each other's discipline by teaching each other. They were provided with open office space next to each other, and we observed that they were not working in isolation, but collaborating constantly by discussing ideas.

How did their thoughts evolve following interaction with the multi-media students and how did they collaborate with the multi-media students?

While the two engineers were high-performing students and would have been able to create a quality resource by themselves, it was the engagement of the multi-media students that led to the production of a high quality resource. Early in the project, the engineers had been planning to create one video, which could be broken up into individual components, for example to be shown in class when a particular mathematical concept is covered. This had been discussed with the mathematics lecturer and seemed to be a reasonable approach. However, after meeting with the multi-media students this idea changed:

> *The ideas that we had at the time, after talking to you guys on Tuesday, was the overall video and then the individual ones broken up. After talking to the media students yesterday, Jim and Lex felt that we just wouldn't have enough time for them to produce the individual ones."* [student names changed to preserve student anonymity. Jim and Lex were two of the three multi-media students]

Another concern that the multi-media students had voiced was regarding the flow, which would have been difficult to achieve had they followed through with the initial idea. While the engineers could see the content and the type of message they wanted to convey, the multi-

media students approached the project from a production perspective, "*time was their biggest issue*". The engineers realised the value and expertise that the multi-media students were bringing to the project, as reflected in the two comments "*that's why we've got them onboard" and "they've got that gut feeling*".

Following discussions with the multi-media students, the engineers organised their thoughts into writing draft storyboards, something they would not have thought of by themselves. The following comment shows their inexperience with video production, and how they learnt from the multi-media students: "*Media requirements – here we go […] they think of it in terms as a story, which we didn't. We just thought we'll produce something that's catchy*."

From the story boards followed the decision to create animations rather than screen recordings or shooting real video. Here, the multi-media students' expertise became very useful, as one of the engineers commented:

> *Just thinking of stuff that you don't really ever think about. [..] they're really good at trying to put you in – like if you're watching this movie, you wouldn't like seeing just a random picture of something coming up. To me, that would – I wouldn't have thought about that sort of stuff. Just general flow and – they are really good. It will be even better when they start animating as well. That will be good.*

Further notes on the collaboration – the use of technology

We now comment briefly on how the students collaborated and communicated electronically with each other and how they interacted with the technology we provided. The two engineers were located in the same room and could talk face to face to each other during working hours. The three multi-media students mostly worked from home, each separately, as they were relying on specialised equipment for animation and audio production. We expected the students to use social media technology to communicate with each other, and were not surprised when they immediately created a shared Dropbox folder to access files from anywhere and anytime, and a Facebook site. Email did not appear to be their major mode of communication – to send SMS or to "*write it on Facebook*" was more common. The project team, however, mostly communicated with them via email, if not during one of many visits in person to enquire how they were going, but also to guide, support, and challenge their ideas.

After the engineers were shown how to write on the tablet PC, they moved entirely across to this platform from the whiteboard they had initially used, and mostly used Microsoft Office OneNote for writing down ideas. One of them noted: "*when we first started off, we used the whiteboard […], to try and get this maths stuff out of the way. […] But I suppose the serious work started when we started using the OneNote features on this*." They searched the Web for existing resources and added links to YouTube videos, pictures, files and other Websites to their documents, giving them a one-stop project environment to explore ideas. We had expected the students to use the equipment for the actual production, but did not expect a complete reliance on the tablet PC for all project work.

While both engineers were used to working with pen and paper to solve engineering problems, the tablet PC allowed them to be more creative, as one of them commented on the topic of writing on the computer, "*we're now getting something where we require so much creativity*". The student use of tablet PCs is an area we want to explore further in the future.

Early reactions from first year students

While the focus of this paper is on the production of the videos, particularly on collaboration between the higher year students, we will also give an overview of some early reactions from first year students. As part of a "*screen test*", the multi-media students showed the civil engineering video to a group of thirteen students who were enrolled in a preparation course before studying the first engineering mathematics unit. The students answered an anonymous survey which asked if they felt encouraged to learn mathematics after watching the video and if they were interested in seeing more videos of this type. There was

consensus that the pace of the video was too fast, which is something that was addressed in the final production. The mathematical calculations were intentionally displayed only briefly giving just enough time to recognise them but not to check for correctness or follow each step as focus was on the relevance of the mathematics not how to find a mathematical solution. Some of the students commented that they would have preferred step-by-step explanations of the mathematics. The views were split when it comes to the usefulness of the video: One student commented that

> *The video breaks something down in terms of maths but (for me at least) does little to encourage learning of maths. It does however show its relevance*.

This comment appears to indicate that we might need to investigate further the connection between motivation to learn maths and its relevance. Other comments related to the level of mathematics, which was seen as "*way beyond my skill*". Although these students had completed a level of high school mathematics that corresponds to the mathematics shown in the video (for example: integration including volumes of revolution and trigonometry including Pythagoras' theorem), their reaction is not surprising as they had self-identified as needing a refresher before undertaking first year mathematics. Positive comments were received such as "*Useful demonstration*", "*Yes [would like to see] more applications of learning*" and "*Videos like this would definitely help as they would allow us to see what is expected*".

Conclusions

This paper reports on a preliminary evaluation of the maths relevance project. It is a preliminary evaluation as we focus only on data collected during the planning and early production stages of the project. From this, we can already see that a very productive collaboration ensued between the engineering students, but also between the engineering and multi-media students.

We believe that all participating students benefited greatly from this experience, and have gained additional skills such as teamwork and communication across disciplines, but also technical knowledge of the other engineering discipline. While the engineers had already had team work experience as part of their studies, their previous team members had always been other engineers. Also, the students clearly talked about their excitement (which was also visible), as they knew they were producing something of lasting value. We plan to investigate in more detail what exactly the significant outcomes were for the students, to compare to those stated in (Croft et al., 2013) for mathematics students.

A key point for the success of this project, although not originally thought of by the project team, was the involvement of the multi-media students. We are also further investigating what other factors are vital for a successful student project to motivate the relevance of mathematics (Lamborn & Loch, 2013).

There are several other directions for our research. For instance, we did not show the views of the multi-media students in this paper, as they were not interviewed until the end of the project and this data is still being analysed. We plan to further investigate the role of the multi-media students, and how this cross-disciplinary collaboration influences the outcome and the dynamics of the project as it develops. The multi-media students differed from the engineers, as they had already experience working together in a team and knew they complemented each other. They had an established team leader and had each specialised, in project management, audio production and animation. This means they could focus on their area of expertise, relying on the others to do their job. The two engineering students didn't know each other until they commenced the project.

We will also consider development of a framework to evaluate the level of success of the animated videos to get the message across to first year students that mathematical study is vital to becoming an effective engineer. This evaluation will include a focus group with first year students and an evaluation of the reaction of a whole cohort of first years to the videos. We will need to investigate how best to use the videos (e.g., show during orientation week, in

class early in the semester, repeatedly in class when a mathematical concept is introduced that is covered in the video, or place on the units' learning management system sites).

Furthermore, it appeared that when the engineers talked to the chemical engineering lecturer, they "*switched off*", as the application of mathematics was too far removed from what they had experienced in their studies. We conclude from this that it is indeed important to make explicit the relevance of mathematics for students in different engineering majors, as also indicated by Flegg et al. (2012). Stage two of our maths relevance project has commenced, in which we extend production of resources to the disciplines robotics and biomedical engineering with a new cohort of engineering and multi-media students.

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