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Personalised Learning Framework for Enhancing Mathematics Ability

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Introduction

Mathematics is the cornerstone of many disciplines, including computer science, accounting and the sciences. However, over the past two decades in higher education institutes, it has become increasingly apparent that there is a decline in the basic numeracy skills of first year students entering third level programs (Tariq, 2002). This has been observed in numerous Irish institutes whereby unfortunately it can also be a huge impediment in student progression into second year due to failure in mathematics subjects according to the HEA report by Mooney, Patterson, O'Connor, & Chantler (2010) entitled "A Study of Progression in Irish Higher Education", "The proportion of students not presenting in their second year of study drops below the national rate for the university sector once a student has attained at least 55 points in Mathematics in the Leaving Certificate examination" (Mooney, Patterson, O'Connor, & Chantler, 2010, p.23). This shows a clear link between second level mathematics teaching and failure of students to obtain basic numeracy at this level. Rylands & Coady (2009) concluded that a student's secondary school mathematics background, has a dramatic effect on third level pass rates. In Ireland this has been further exacerbated by the change in the Leaving Certificate curriculum to project mathematics, which has in turn led to a change in the minimum entry requirements for Engineering, Computer Science, Accounting and Food Science in mathematics to H7 in Honours Leaving Certificate Mathematics in third level institutes including DIT (O'Brien, 2016). Researchers from University of Limerick have shown that although there has not been a change in Leaving Certificate marks in mathematics there has been a decline in cognitive ability and numeracy skills (Faulkner, Hannigan, & Gill, 2010). Thus students are underprepared for the challenges posed by third level mathematics (Hourigan & O'Donoghue, 2007). In addition, as lecturers we are not as informed as we should be about the changes in the Leaving Certificate curriculum which further exacerbates the problem. Prendergast, Faulkner, Breen, & Carr (2017, p.1), found that "although many lecturers are mindful of the concept of project maths, they are not aware of the changes in full and how it affects their own course content, teaching and assessment strategies".

As lecturers, collectively in our disciplines, we have observed a systematic decline in first year students understanding of basic mathematics and their willingness to engage. To support lecturers and students in DIT the Maths Learning Support Centre (MLSC) was established in 2005 with designated full-time Maths tutors to assist students in their cognitive ability of mathematics. For the past two years Cormac Breen as the MLSC manager has been carrying out a maths test at the beginning of semester one in first year to ascertain the level of competency. Although, it is not compulsory, students who undertake to do the test are assessed and given a green (all good), amber (fine) or red (at risk of not progressing past first year) light based on the result of the test. This provides the students with insight

into their strengths and weaknesses whereby they are encouraged to take specialised tutorials run by the MLSC to support their learning. The issue however is although these supports are provided there is a lack of engagement with the MLSC for numerous reasons. In Cormac's opinion the reasons for this are multifaceted "*There are several reasons why students do not attend the MLSC such as issues with locations and opening hours but one of the main reasons is perhaps a lack of motivation*". In addition, there is minimal support for part-time students who attend lectures in the evening when the MLSC is closed.

Here, we present data addressing the role of mathematics for first year student in DIT. We argue for the development of the MMEL-Machine E-Learning for Maths, a personalised online platform to support and supplement students' maths learning in first year.

Mathematics in First Year DIT

We investigated the role of mathematics in first year DIT in two ways, first we addressed whether mathematics is an important predictor of first year students' overall mark, second we investigated if there has been a change in first year mathematics marks and has there been an impediment to progression to second year over the last five years.

First, we spoke with Mark Russell the Institutional Research Analyst who had conducted research on the Leaving Certificate mathematics points and the grade point average for Level 7 Engineering Students. His data showed that students who passed their first year exams on the first sitting had a higher mark in Leaving Certificate mathematics than students who passed by compensation. Thus suggesting that mathematics ability is a predictor for student successful progression into second year.

Secondly, to investigate if there has been a systematic change in mathematics ability in DIT at first year level over the last five years. To do this we analysed summer exam marks from 2011 to 2016 of first year students in TFMT1002 Mathematics for Scientists from the School of Food Science and Environmental Health. This time period overlaps with the full introduction of project mathematics to the Leaving Certificate in 2014. This is a large number of students with over 130 observations per annum, which is a representative sample of the student population in DIT. The data in Table 1., shows the number of students, the average and standard deviation of the mathematics marks and the number of students who did not sit the final exam by year. The data shows a consistent mark in mathematics across the years. This would not suggest a decline in ability but there has been an increase in the number students who did not sit since 2014.

Year	Number of Students	Average Mark	Stand Deviation	DID NOT Sit
2012	143	67.84	26.63	4
2013	153	63.19	19.31	2
2014	170	66.33	19.22	10
2015	153	68.86	21.33	5
2016	130	69.64	20.99	10

Table 1. First year TFMT1002 Mathematics for Scientists from the School of Food Science and Environmental Health, Number of students, average mark in final exam standard deviation of marks, number of students who did not sit the final exam.

Personalised Learning Framework

To address mathematics in first year we propose tailored framework to enhance students' mathematics learning experience by employing the technology of machine learning (Beetham & Sharpe, 2013). This framework will deliver individualised instruction and will tailor the learning content to meet the different needs of the students (Balta, Simsek, & Tezcan, 2009). This will supplement the work students are completing, to complement their ongoing mathematics module. The technology would enable the learners to work at their own pace and to provide them with personalised feedback and instruction. This framework would be highly inclusive for students from different learning backgrounds (under-represented students and international students) as well as students with learning difficulties, thus creating a non-judgmental level playing field. In addition, it will provide anonymous feedback to the lectures about the students' performance and the area of improvements. This will enable the lecturer to fine tune the content of lectures and tutorials.

Machine learning technology makes it possible to reach every single student on a personal level, by delivering a fine-grained personalised feedback about their performance in context of the learning activity they are currently doing. So this framework could enhance the learning experience by capturing the learner's behaviour, interest, preferences and the learner quality of experience.

Figure 1 shows how the data flows between the learner and the framework. The initial training of the framework will be based on the questionnaire made by Faulkner. Afterwards, the learner accesses the framework by attempting a set of predefined questions. The framework captures the student performance at real time and starts to issue direct and immediate feedback.

Background

Mathematics is the cornerstone of many disciplines, including computer science, accounting and the sciences. Unfortunately it can also be a huge impediment in student progression. As lecturers, collectively in our disciplines, we have observed a systematic decline in first year students understanding of basic mathematics and their willingness to engage. This has been further exacerbated by the change in the minimum entry requirements for Engineering, Computer Science, Accounting and Food Science in mathematics to H7 in Honours Leaving Certificate Mathematics in DIT (O'Brien, 2016).

Researchers from University of Limerick have shown that there has not been a change in Leaving Certificate marks in mathematics but there has been a decline in cognitive ability and numeracy skills (Faulkner et al., 2010). Thus students are underprepared for the challenges posed by third level mathematics (Hourigan and O'Donoghue, 2007). In addition, as lecturers we are not as informed about the changes in the leaving certificate curriculum which further exacerbates the problem. Prendergast et al. (2017), found that "although many lecturers are mindful of the concept of project maths, they are not aware of the changes in full and how it affects their own course content, teaching and assessment strategies".

Maths Machine E-Learning (MMEL)

To address mathematics in first year we propose a tailored framework, we call Maths Machine E-Learning (MMEL), to enhance students' mathematics learning experience by employing the technology of machine learning (Beetham & Sharpe, 2013). This framework will deliver individualised instruction and will tailor the learning content to meet the different needs of the students (Balta et al., 2009).

Figure 1 shows how the data flows between the learner and the framework. The initial training of the framework will be based on the questionnaire made by Faulkner, Hannigan & Gill (2010). Afterwards, the learner accesses the framework by attempting a set of predefined questions. The framework captures the student performance at real time and starts to issue direct and immediate feedback.

This feedback loop (Hounsell et al. 2008) focuses on giving the learner personalised feedback on their performance and a new set of questions with new content, based on their historic performance. Each time the students get a correct answer they can progress onto the next stage of the curriculum. As the students complete a section of the maths curriculum they will receive a certificate of completion.

In Figure 1, personalised instruction refers to a question set that has been tailored and tuned by the machine learning framework. This item is the artifact that is used to give personalised instructions to the students in the feedback loop. The learners mathematics ability is calculated by machine learning so it can adapt the personalisation process. The input for the learner feedback loop is the math ability and the set of questions. The output is going to be a personalised feedback that can feed-forward to next stage.



Figure 1. Schematic diagram illustrating MMEL

Discussion

The work done by Faulkner, Hannigan & Gill (2010) would suggest the strong relationship between success in first year and mathematics ability. While DIT has been at the forefront of the mathematics learning support in third level there is uncertainty how to address the changes in leaving certificate curriculum.

Hence, we proposed the framework as an important step in addressing this issue. As the framework is anonymous and bespoke it is ideal to support the learning of students with disabilities and international students. As it is online it would be available to students at all times which is particularly relevant for part-time students who have limited access to the MLSC. This framework will give the students the ability to identify their understanding of mathematics and practice in relative safety and help them fill the 'gap' in their maths knowledge.

Furthermore, the use of an online resource such as the one proposed here would an important step in the development of the digital campus for DIT.

Future Directions

This framework could be readily deployable in other Schools and Institutes well as other disciplines to enhance and improve numeracy skills in general. We have also applied for a Teaching Fellowship in DIT to pursue this project further.

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Figure 1. Poster illustrates the impetus for the project and how the personalised framework would function.

This feedback loop (Hounsell, McCune, Hounsell, & Litjens, 2008) focuses on giving the learner personalised feedback on their performance and a new set of questions with new content, based on their historic performance. Each time the students get a correct answer they can progress onto the next stage of the curriculum. As the students complete a section of the mathematics curriculum they will receive a certificate of completion.

In Figure 1, personalised instruction refers to a question sets that has been tailored and tuned by the machine learning framework. This item is the artefact that is used to give personalised instructions to the students in the feedback loop. The learners' mathematics ability is calculated based on how many questions required to complete each stage. This value is calculated by the machine learning so it can adapt the personalisation process. The input for the learner feedback loop is the math ability and the set of questions. The output is going to be a personalised feedback that can feed-forward to next stage.

Conclusions

Our data from first year students in TFMT1002 Mathematics for Scientists from the School of Food Science and Environmental Health does not point to a crisis situation yet but the increased number of students who did not sit the final first year exam since 2014, the introduction of project mathematics, is a concern. This data requires further investigation to understand why more the students did not sit the mathematics exam. Furthermore, the work done by Faulkner, Hannigan, & Gill (2010) as well as the internal reports by Mark Russell would suggest the strong relationship between success in first year and mathematics ability. While we have seen there is departmental awareness of the change in curriculum but there is uncertainty how to address these changes. DIT has been at the forefront of the mathematics learning support in third level and hence it is an ideal candidate to lead the way.

For these reasons we proposed the framework as an important step in addressing this issue. As the framework is anonymous and bespoke it is ideal to support the learning of students with disabilities and international students. As it is online it would be available to students at all times which is particularly relevant for part-time students who have limited access to the MLSC. This framework will give the students the ability to identify their understanding of mathematics and practice in relative safety. The feedback the student receives on their own work will help them fill the 'gap' between their current mathematics knowledge and what is expected.

Finally, the use of an online resource such as the one proposed here would an important step in the development of the digital campus for DIT.

Future Directions

This framework could be readily deployable in other Schools and Institutes well as other disciplines to enhance and improve numeracy skills in general.

References

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