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# Students' and lecturers' views on mathematics resources

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**There is a general agreement that many students struggle with the transition from secondary to higher education, particularly in the context of mathematics modules. Lecturers often suggest or supply supplemental resources to give students the opportunity to overcome their difficulties. In addition, students often seek out resources independently, many of which are provided through digital-age technology. Current research in this area focuses on the effectiveness of resources that mathematics educators have developed. However, it is unclear which resource types students select themselves and what specific content they seek. In addition, the type of resources that lecturers recommend to students is not well documented. In this article, we present findings from two surveys carried out in higher education institutes in Ireland: one involving students and the other involving lecturers. In particular, we focus on the resource types favoured by students and lecturers, the specific content that they relate to and the issues they seek to address.**

## 1. Introduction

Evidence suggests that many students reach higher education without the mathematical skills necessary to ensure success in the first year undergraduate mathematical modules (Gill & O'Donoghue, 2006; OECD, 2009; Lawson *et al.*, 2012). Various interventions have been developed in an attempt to help students overcome these difficulties (e.g. Kay & Kletskin, 2012; Lawson *et al.*, 2012; Loch *et al.*, 2012). In addition, online technology-enhanced resources have been developed to support students' learning in mathematics (www.khanacademy.org; www.mathscast.org; www.statscasts.org; www.mathtutor.ac.uk; www.wolframalpha.com). Many institutions, particularly in Ireland and the UK, have introduced mathematics learning support centres (MLSCs) where students can attend and seek support from a mathematics tutor (Solomon *et al.*, 2010). However, to-date, little research has been conducted on the specific resources which students select to support their learning in mathematics.

In Ireland, service mathematics modules are taken by undergraduates who are not specializing in mathematics. In order to investigate the types of resources that are used by these students and those that are recommended by lecturers we developed two surveys in the spring of 2015: one aimed at students and another at lecturers. The purpose of the surveys was to identify mathematical topics and concepts which proved difficult for students, the resources recommended by lecturers to help

overcome these difficulties, the resources currently in use by students and suggestions for new resources. In this article, we present the findings regarding resources.

These surveys were the initial stage in a larger project whose objective is to develop and evaluate technology-enhanced formative-assessment resources to support teaching and learning in the first year undergraduate non-specialist mathematics modules. There are four Higher Education Institutes (HEIs) involved in the project; Athlone Institute of Technology (AIT), Dublin City University (DCU), Dundalk Institute of Technology (DkIT) and Maynooth University (MU).

## 2. Background

In the literature review that follows we discuss the various resource types that are available, the use of examples and solutions as a resource and then present the research questions of the paper within that context. We begin with a brief overview of the Irish education system.

### *2.1 Higher education and entry requirements in Ireland*

Undergraduate education in Ireland is provided by two types of institutes: Universities and Institutes of Technology (IoTs). The former focus mainly on honours degrees and the latter on certified career-focused programmes (Department of Education and Skills, 2005). There are 21 HEIs in the Republic of Ireland: 7 universities and 14 IoTs.

The Leaving Certificate (LC) is the state examination in Ireland taken at the end of secondary education. In this examination, mathematics is offered at three different levels: Higher (HL), Ordinary (OL) and Foundation Level (FL) (National Council for Curriculum and Assessment, 2015). Access to university and IoT courses is based on the results of the LC examination (Irish Leaving Certificate Examinations Points Calculation Grid, 2016), with entry requirements in mathematics depending both on the HEI and the student's choice of course.

### *2.2 Resources for mathematics learning*

There are many different types of resources available to aid students with first-year undergraduate mathematics modules. In the first place, lecturers may recommend textbooks, provide lecture notes or produce handouts with explanations and examples. Increasingly, the latter resources are provided through Virtual Learning Environments (VLEs) which may also be used to provide technology-enhanced resources such as recorded lectures and screencasts. Students may also use the assignments, tutorial questions and solutions provided by the lecturers. Additionally, there are generic online resources available to students in the form of mathematics websites and forums. The following sections give a brief overview of these resources and what might be learned from them.

*2.2.1 Textbooks and class notes*. There has been some investigation into how students use their textbooks in undergraduate mathematics modules. Weinberg *et al.* (2012) surveyed first and second year undergraduate students ($n = 1156$), attending non-mathematics majors B.A. or B.Sc. degrees, at three different institutions in the USA, on their use of textbooks in mathematics modules. They found that students used textbooks most when preparing for examinations or doing homework rather than in preparation for class. Students mainly used the examples, homework problems and solutions in the textbooks rather than the introductions, explanatory text and summaries. Students believed that this type of access helped develop their mathematical understanding.

Students ($n = 2473$) between the ages of 14 and 19 years attending a large public high school in the USA were surveyed on their use of resources to complete homework (Van De Sande *et al.*, 2014). Class notes were by far the most popular choice, while digital resources were rarely used.

*2.2.2 Technology-enhanced resources.* Henderson *et al.* (2015) surveyed students ($n = 1658$) attending two universities in Australia about their use of technology-based learning tools. They found that most students used technology to organize or support the management of their daily lives at university but only a few used learning technologies to engage with course material. Those they did use mainly supported strategic learning, such as reviewing or replaying recorded lectures. The small number of students who used technology to 'gauge a sense of progress' (Henderson *et al.*, 2015, p. 9) used online quizzes and/or class polling, both of which allowed instant feedback. The authors concluded that it was the broader culture and institutional practices that drove the use of technology and thus institutions needed to develop teaching and learning contexts that were 'more active, more participatory or more creative' (Henderson *et al.*, 2015, p. 12).

One aspect of students' learning behaviours is their use (or lack of use) of supplementary materials to support their learning. As part of a research study that examined mathematical preparedness of students attending first year undergraduate mathematics modules Dalby *et al.* (2013) asked students ($n = 122$) how they would like to address their mathematical difficulties. Fifteen students recommended practices that could be considered as supplemental to the mathematics modules and these practices included 'tutorials, online videos, practice quizzes, workshops and video conferencing tutorials' (Dalby *et al.*, 2013, p. 36).

However, many students are unaware of the online resources that are available as found by Van de Sande *et al.* (2014). Most students in that study had not heard of the various mathematics help sites such as Cramster (now available through Chegg (www.chegg.com), KhanAcademy (www.khanacademy.org) and Purplemath (www.purplemath.com), though about 15% of students had heard of the website FreeMathHelp (www.FreeMathHelp.com).

A number of studies have examined the effects of using some technology-enhanced resources. For example, Muir (2014) examined the use of Khan Academy by students ($n = 120$) in secondary education in Australia and found that students considered that it helped their conceptual understanding, despite Muir's observation that the resources were mainly procedural. Students liked this resource as it enabled them to 'pause and rewind'.

In a review of mathematics lecturing in the digital age, Trenholm *et al.* (2012) found that while online-lecturing was well received by students and lecturers, empirical evidence pointed towards a weak negative correlation between using technology and examination results. They suggested that this may be because it is generally the weaker students who access the online lectures and/or the facility to 'pause and rewind' allows strategic learning.

## *2.3 Learning from worked examples*

There has been a lot of discourse on the value of providing worked examples as a means of enabling student learning since Zhu and Simon (1987) carried out an experiment that demonstrated that students can learn for themselves from step-by-step solutions. Chi *et al.* (1989) examined how students differed in the way they used worked examples and found that many students were unable to generalize problem-solving to examples that were different. However, Atkinson *et al.* (2000) contended that worked examples could in fact help to develop creative problem-solving when the correct learning strategies were employed. Students who use self-explanations when working through examples have better outcomes than those who do not (Rach & Heinze, 2011). In the digital age, students can access

solutions to mathematical problems set by their lecturers in forums such as Wolfram Alpha and Cramster. In this context, Abramovich (2014) discussed the need to change the pedagogy associated with the development of mathematical problems. Rather than allow students to find solutions using Wolfram Alpha, Abramovich (2014) proposed that use should be made of technology-immune/technology-enabled problems that encourage the use of tools such as Wolfram Alpha to support knowledge construction.

There has also been some investigation into how students use solutions that are provided in textbooks. Although over a third of students reported sometimes copying a solution, most students used solutions to check answers (Weinberg *et al.*, 2012). Students reported that using examples and solutions increased their understanding.

First-year lecturers ($n = 36$) across many disciplines in the University of Southern Queensland Australia were surveyed as part of a broad study to determine the mathematical topics and skills required by students for their particular discipline and the perceived student mathematical preparedness for their courses (Galligan *et al.*, 2013). Lecturers said that students were able to calculate but did not know why they were doing so, and many lecturers bemoaned their students' mathematical skills when they were required to apply them to discipline-specific examples.

### *2.4 Research questions*

Although there are a variety of resources available for students to help support their learning and they can be used in different ways, it is not clear what resources students use and the nature of the material contained in the resources. Therefore, in this paper, we aim to answer the following research questions:

(1) What types of resources do students use and lecturers recommend for first-year undergraduate mathematics modules?
(2) Is there a difference in the resources used in different institutes?
(3) What is the type and nature of the resources that students and lecturers would like to see developed for future students?
(4) Is there a difference between the resources used and recommended by students and those by lecturers?

## 3. Methodology

At the beginning of this research project, the project team decided to carry out two surveys: one of students and another of lecturers. Questions were developed, and the questionnaires piloted and adjusted, before being distributed. The first part of both questionnaires investigated mathematical concepts and procedures which caused most difficulty for students (Ní Shé *et al.*, 2016). The student questionnaire also contained six questions which asked the students what resources they used, why they found them useful, what gaps they found in the resources and asked for suggestions on new resources that should be developed (Appendix A). There were five similar questions in the lecturer questionnaire (Appendix B).

In spring 2015, the student questionnaire was distributed to students from the four HEIs involved in the project. These students were attending first-year service mathematics modules, with 460 students completing the survey anonymously. Almost all of these were just finishing their first year in their HEI (with a small number finishing their second year) and they were registered on a range of different undergraduate programmes: Arts, Applied Sciences, Computing, Engineering and Business. Lecturers

involved in the teaching of undergraduate mathematics from HEIs across the island of Ireland were asked to complete the lecturer questionnaire via a Google form. Thirty-two responses were received from mathematics lecturers in 15 different HEIs; lecturers involved in either this project or in the pilot did not complete the final questionnaire.

The responses to the open-ended questions were initially reviewed by one of the authors to identify the most frequently mentioned resources and reasons why these resources were considered useful. As a result of both the research objectives and the analysis carried out in Nvivo, several categories of response emerged. The responses were coded into relevant categories which were continuously refined throughout the process and confirmed by the other authors. This approach to the analysis of qualitative data is known as General Inductive Analysis (Thomas, 2006).

There were questions at the beginning of both questionnaires that asked students and lecturers about their background, such as institute and course. Students' gender, mature student status and LC mathematics level were also recorded. Mature students are those students who are 23 years or over on the 1st of January of the year of entry to the higher education institution (Central Applications Office, 2016)

## 4. Results

In this section, we will outline the relevant data regarding the background of the students and lecturers who responded to the surveys, before moving on to report on both the students' and lecturers' views on the resources. Finally, we will match the relevant student and lecturer responses to the themes that emerged from analysis of the responses.

### *4.1 Student background*

The student background categories are shown in Table 1. There was a much higher percentage of students who had taken OL mathematics in both AIT (75%) and DkIT (64%) than those in DCU (13%) and MU (13%). Entry requirements for IoTs tend to be lower than for universities (Department of Education and Skills, 2011).

### *4.2 Lecturer background*

The lecturers who responded were from a wide range of both universities and IoTs on the island of Ireland. All 32 lecturers were involved in teaching first-year service mathematics modules and/or providing mathematics support. There were 16 responses from the IoTs and 16 from Universities; 9 of the IoTs are represented and 7 universities (including two from Northern Ireland).

### *4.3 Student responses to questions on resources*

Students gave a number of responses in relation to the questions on resources; we now report helpful resources they used for first-year mathematics, gaps in resources that they identified and advice on resources that they felt should be made available to future students. In any comments listed below, students are identified as S1 for Student 1 and so on.

*4.3.1 Helpful resources.* Students were asked to list any resources they found helpful in first-year mathematics, under the following headings: books, handouts, videos, websites and other (specify). There were 394 students who responded to this question. Figure 1 shows the percentage of students who selected each of the resource types, some students selected more than one resource.

TABLE 1. *Student background data (*n = *460)*

| Student background category | Number (% of overall respondents in that category) |
|---|---|
| Gender ($n$ = 453) | |
| Male | 293 (65%) |
| Females | 160 (35%) |
| Mature ($n$ = 437) | |
| Non-mature | 368 (84%) |
| Mature | 69 (16%) |
| Prior mathematics level ($n$ = 444) | |
| Higher level (LC) | 282 (64%) |
| Ordinary level (LC) | 142 (32%) |
| Foundation level (LC) | 5 (1%) |
| Did not take mathematics (LC) | 15 (3%) |
| Institute | Total student numbers |
| Dublin City University | 204 |
| Maynooth University | 107 |
| Dundalk Institute of Technology | 101 |
| Athlone Institute Of Technology | 48 |

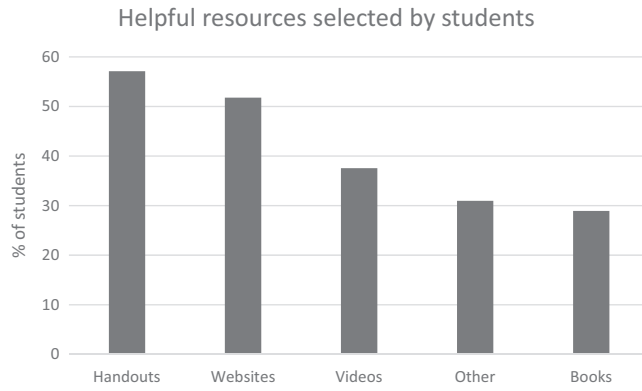


FIG. 1. Percentage of students who selected the particular resource type as helpful.

Further analysis of these responses gave a more accurate and specific breakdown of the categories of resources that students found useful. For example, students mentioned lecture notes and tutorial notes under the 'Handouts' or 'Other' options. Students mentioned YouTube videos, Khan Academy and Wolfram Alpha under the 'Videos', 'Website' or 'Other' options. All the helpful resource responses were analysed in this way and Fig. 2 shows the percentage of students who chose each of the eight most mentioned resource categories. The VLE was a different platform across the four HEIs.

This data were further analysed by HEI to determine whether there were differences in the responses between students who attended different institutes and is shown in Fig. 3.

Students were also asked why they found a particular resource useful. In their comments on books, students mainly referred to the books that had been recommended for their mathematics module, as opposed to any they had found for themselves. For example, there were 47 students who mentioned the Engineering Mathematics book, all of these students were from the same institute, DCU: 'Engineering Mathematics—Contains all the information needed for the purpose of the course' (S69).

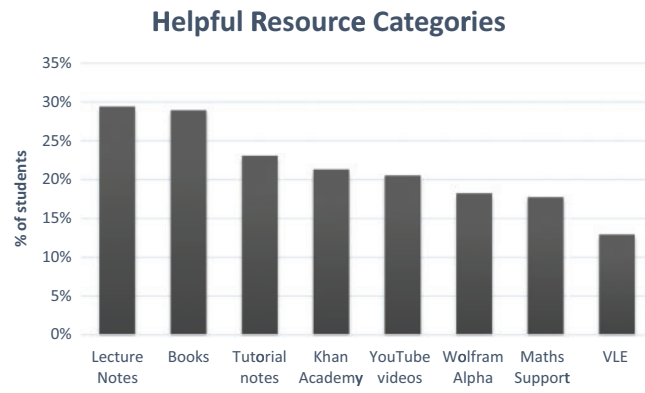


FIG. 2. Percentage of students who mentioned these resource categories as a response to the 'helpful resources' options.

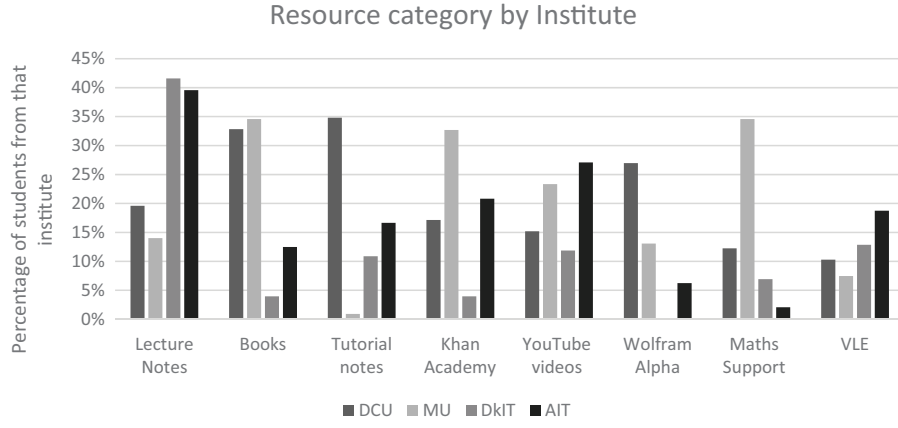


FIG. 3. Percentage of students per institute who mentioned the resource category shown.

Students stated that they liked the lecture notes as they explained the material that the lecturers covered. Tutorial notes were considered to be useful by the students when the solutions to problems were also given: 'You can attempt the questions then check if your answers are correct on the back of the sheet' (S330).

Students used videos and websites for many reasons including the availability of solutions to problems, the detailed explanations given and the fact that students can complete them at their own pace: 'YouTube is great because you can stop and replay videos, something which is easier than stopping a lecturer' (S93). Another student found YouTube channel videos useful because they 'Explain problems simply and let you go at your own pace' (S159). Over 20% of students also accessed the free online resources such as Khan Academy and Wolfram Alpha. Students referred to Khan Academy as being useful because there was a '. . . lot of information on each topic . . . . You can pick out a specific topic to work on' (S143) or it 'Explained the maths slowly and in an accessible way . . . was possible to look over multiple times if needed' (S28). MLSC services were highly rated by over 18% of the students. 'The maths learning support centre was . . . great . . . , one to one help to slowly explain concepts that may have gone at a faster pace in lecture . . . ' (S59).

TABLE 2. *Percentage of students who identified the category of gap in the resources and sample responses*

| Gap category | % students ($n$ = 133) | Sample response |
|---|---|---|
| Examples & Solutions | 34% | Solutions to tutorials weren't given?! These would help a lot with studying (S37) |
| Online resources | 22% | Online notes with a step-to-step walk through. Without a walk through . . . can seem disjointed/incoherent (S35) |
| Extra classes | 14% | More support tutorials if possible for those struggling (S20) |
| Books | 4.5% | . . . a book or some other way of finding certain information quickly. A book would also help us to (learn) write if you missed a day. (S149) |
| Applications & relevance | 4% | More joined up with other subjects, would help understanding. (S321) |

*4.3.2 Gaps and advice on resources.* In an open question, students were asked to name gaps they found in the resources that had been provided to them. There were 225 responses in total to this question, with 92 students (41%) answering that there were no gaps. The others made suggestions that fell into a number of resource categories, with some students suggesting gaps in resources in more than one category, see Table 2. This data were also examined by HEI and no significant differences were found.

Students were also asked if there were any resources they would like developed and to select the format through which they would like these resources to be made available: print-based, videos, websites and other (specify). There were 289 students who selected one or more resource formats. Figure 4 shows the number of students who selected each of the resource formats. This data were also examined by HEI and no significant differences were found.

251 students responded to the question asking them if they had suggestions for resources, 20 of whom said they had no suggestions. Almost all respondents to this question selected either videos and/or websites. One reason why students wanted videos is given by S314: 'Simpler and better explanations. Visually show how to solve'. Another example, S51 gave the following response to the advice on resources: 'Have videos on how to solve certain problems as they would be much easier to understand than reading a book' and further qualified how these videos should be made available by saying 'Put up on VLE or on YouTube'. These responses are further explored in Section 4.5.

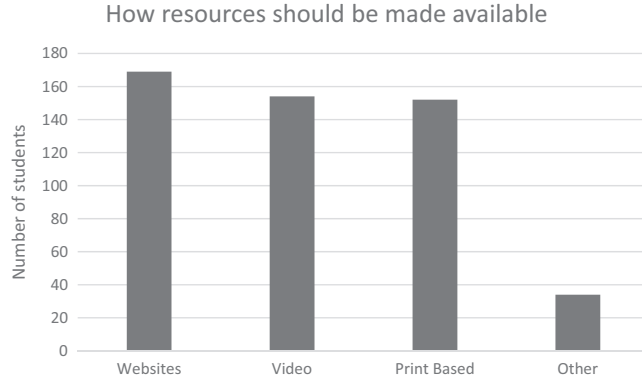


FIG. 4. Number of students who selected each format by which resources should be made available.

### *4.4 Lecturer responses*

Lecturers were also asked what resources they currently recommend to students and what resources they would like the project team to develop; their responses are given below. Individual lecturers are identified as L1 to indicate Lecturer 1 and so on.

*4.4.1 Helpful resources.* The responses to the lecturer question on helpful resources were coded by resource category and the number of lecturers that mentioned each resource category was identified. Some lecturers mentioned more than one category, the most frequently mentioned resources categories are shown in Fig. 5.

Lecturers reported that they used handouts because 'Handouts provide a focus for the students' (L1), and they were relevant to the course: 'I prepared handouts and templates that most of the students found useful. The handouts that were prepared tended to summarise the topic on one page' (L13).

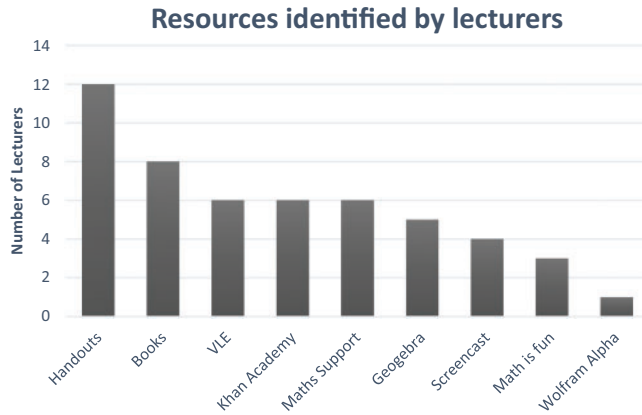


FIG. 5. Number of lecturers who recommended the resource categories to students.

The lecturers were more inclined to recommend technology-enhanced resources that they had developed themselves and provided via the VLE (15 lecturers) rather than freely available online resources (10 lecturers). For example, one mentioned 'Applets I have developed using Geogebra and get students to interrogate as part of course work' (L30). Another lecturer found the Khan Academy good 'for weak students' (L10).

*4.4.2 Gaps and advice on resources.* Lecturers were also asked about gaps in resources available, and for advice on how these gaps should be filled. The 32 lecturer responses to these questions were coded into categories, with some responses overlapping several categories. These are shown in Table 3.

Five lecturers expressed some negative views about the possibility of getting students to engage with resources. For example, one lecturer said:

> Not one of the students that I encountered had visited the library to look at or even read the recommended books on the various topics. How do you encourage students to engage fully in the third level experience?—I have not worked that one out yet. [L13]

TABLE 3. *Categories generated from lecturer responses on gaps and advice about resources*

| Category | % Lecturers ($n$ = 32) | Sample response |
|---|---|---|
| Quality resources | 25% | Free online video resources are abundant but lacking quality and brevity . . . (L1) |
| Interactive resources | 22% | . . . if the student could change parameters in equations and see the effect on the resulting response/graph, etc . . . . (L10) |
| Concepts and understanding | 22% | Basic explanations of concepts . . . followed by a real-world problem of where the concept(s) can apply. (L3) |
| Quizzes | 22% | . . . useful to students to be able to work through an online bridging unit, practicing skills . . . in particular manipulating expressions involving an unknown . . . (L24) |
| Screencast | 16% | . . . list the learning outcomes . . . of 5 minutes duration . . . one concept at a time. (L9) |

Lecturers were asked how they would like to see the resources made available for use among the mathematics community. Nineteen lecturers specifically requested that the resources should be made available online and 7 of these suggested a central portal or website that is catalogued and allows for lecturers to add resources. Three lecturers would like to see the resources distributed to HEIs and/or departments for implementation in their own modules or courses. Sample comments from the lecturers included:

> Via a website but each resource should be properly catalogued for both mathematical content and level so they can be easily searched for within the overall site [L30].
> I favor an open access model. If the resources can be added to with 'packages' from instructors in some way that could be useful for sustainability [L31].

### *4.5* Nature of preferred resource material

In order to determine the nature of the material that students and lecturers would like provided, the student and lecturer responses to the resources questions were analysed together and then categorized as shown in Table 4.

## 5. Further analysis and discussion

The responses reported above provided some rich data on the type of material that should be included in the proposed resources, beyond a simple wish-list. Two main themes emerged from analysis of the responses: resource type and nature of the resource material. These will be discussed in greater detail below.

### *5.1 Resource type*

Despite the fact that the students surveyed for this research were brought up in the digital age (Prensky, 2001), almost 70% of students used paper-based resources. Similarly, handouts and books were the resource most recommended by the lecturers as being helpful. The DCU and MU students relied more heavily on books, though some of these were required for assignments, and the DkIT and AIT students

TABLE 4. *Number and sample of student and lecturer responses for each response category*

| Response category | Number of students ($n$ = 460) | Sample student response | Number of lecturers ($n$ = 32) | Sample lecturer response |
|---|---|---|---|---|
| Examples | 141 | '. . . examples we did ''not'' do in class more complex examples like . . . on an actual exam paper' (S411) | 5 | A book gives complementary descriptions and examples to those seen in class. (L21) |
| Solutions & Answers | 121 | '.full solutions with referencing to the techniques used.' (S79) | 5 | Exploratory videos rather than explanation/solution videos seem to help more. (L1) |
| MLSC | 86 | '. . . been a lifeline for me in maths as they explain topics so well.' (S33) | 7 | One on one sessions with students are also particularly helpful. (L22) |
| Develop understanding | 81 | 'Finding limit of function via graphs, I used YouTube to understand this and found it very helpful.' (S220) | 7 | concentrate on several key concepts . . . depth of understanding for students . . . associated resources . . . students can demonstrate that they have achieved the required insights. (L30) |
| Steps | 64 | '. . . examples . . . with the reasoning for each step beside it, looking at examples is hard . . . because I don't know why it goes from a to b.' (S150) | 5 | . . . short general guide. ''Taking the first step'' . . . basic approaches or questions are given that may help the student get started. (L16) |
| Exam | 64 | 'Past exam papers = most useful learning tool.' (S323) | 4 | my own tools can create dynamic exam like questions and then provide moderately detailed answers . . . it's not ideal . . . feeds into rote learning . . . but it is popular amongst students. . . . . (L6) |
| Real-life examples | 57 | '. . . real world relevant (to my course) . . . non existent . . . would have improved my understanding and given me greater appreciation . . . if I knew where it would be applicable in the field that I am studying' (S405) | 9 | . . . a lack of example contextualised in different disciplines. (L25) |
| Practice | 35 | 'Practice of the type of questions that came up' (S12) | 5 | . . . bank of ''suitable'' online . . . questions . . . instant feedback . . . repeat the questions . . . they are happy that they have mastered the necessary skills. (L14) |

relied more on lecture or tutorial notes (Fig. 3). This may be related to the culture of the institute rather than a student preference (Henderson *et al.*, 2015). In the responses from the lecturers, four lecturers from MU stated that they recommend textbooks to their students and two lecturers from DkIT said that they prepare lecture handouts for their students.

Over 50% of students surveyed accessed freely available online resources, such as websites and videos (Fig. 1). This is not in line with the high school students surveyed by Van De Sande et al. (2014), few of whom had heard of any online resource other than the FreeMathHelp website. However, it is unclear if students found these resources themselves or were guided to them by their lecturers or for example by the MLSC website.

When advising on future resources, students were clearly in favour of technology-enhanced resources. Almost all of the students who responded to this question identified Videos and/or Websites (Fig. 4) which is consistent with similar studies of students in Australia (Dalby *et al.*, 2013). Students valued video tutorials because they could work at their own pace and pause and rewind. These reasons are often quoted by students as an advantage of such resources (Loch *et al.*, 2012; Henderson *et al.*, 2015) though Trenholm *et al.* (2015) and Henderson *et al.* (2015) warn that such a facility may promote strategic learning.

On the other hand, lecturers sought technology-enhanced resources that were interactive or could provide students with a conceptual explanation first, followed by examples (Table 3). Additionally, they sought online quizzes that could help develop students' proficiency in some basic mathematical skills.

Finally, students and lecturers both mentioned the MLSCs as being very helpful. The themes that emerged from the coding of this data were in line with those found in the 2014 report on student evaluation of MLSC (O'Sullivan *et al.*, 2014).

### *5.2 Nature of the resources*

235 (or over 51%) of the students who responded to the questionnaire ($n = 460$) mentioned either solutions, examples, sample answers or step-by-step procedures in response to at least one of the open-response questions (Table 4).

Students recommended examples for a variety of reasons such as enabling practise or in preparation for examinations; S378 required more 'Practice sheets for topics and exams to get used to the type of questions', and S1 found the lecture notes helpful because they '. . . consisted of examples & exam type questions, therefore good prep for exams.' Many students referred to the value of worked examples and solutions in both Khan Academy and Wolfram Alpha as S95's response illustrated 'Wolfram alpha completed the question for me and showed me how to get there'. Students also found that there is a need to scaffold the difficulty of the examples, with S290 finding YouTube videos helpful because they contained '. . . multiple examples that get progressively more difficult . . . '. Lecturers recognized the need for examples and referred to the examples they gave in the handouts or those available in books. L19 said that the textbook was recommended because of '. . . the extensive use of examples'. Weinberg *et al.* (2012) found that students mostly valued textbooks because they contained examples.

Students also wanted solutions or worked-out answers to questions and examples. Some students required the solutions to check their answers; others wanted full detailed answers that showed how to solve the problem. For example, S307 found tutorial handouts useful because they contained 'Exam questions with solutions because I could practice and then check answers'. Weinberg *et al.* (2012) found that over 30% of students valued solutions to check answers. Students in this survey also

considered that they learned from solutions, though it is clear that the learning involved was procedural rather than conceptual: 'You could see how a problem was figured out so you could mimic it for other questions' (S34). This is in line with what Muir (2014) found with the use of Khan Academy; students consider that gaining procedural knowledge gives them deeper understanding. On the other hand, the lecturers generally did not suggest they should provide solutions, in fact L21 wanted: 'Textbooks for which complete solutions don't exist on the web.' Abramovich (2014) outlined how lecturers can develop mathematical problems that enable students take advantage of forums such as Wolfram Alpha to develop solutions rather than simply to seek them.

Both lecturers and students mentioned the use of resources in the development of understanding in mathematics. There were 81 students who mentioned understanding in response to the resources questions (Table 4). Further analysis of these responses revealed that 22 students specifically referred to resources which helped them understand a particular topic whereas 48 considered that examples or solutions can help them develop understanding. The remaining students referred to resources such as lecture notes or videos as having helped develop understanding. For example, S431 said 'using examples makes the topics and their ideas easier to follow and understand what to do and what is being asked'. Using worked examples to improve understanding is consistent with research by Atkinson *et al.* (2000) and Rach and Heinze (2011), as long as the correct learning strategies are employed. Seven of the lecturers mentioned the need for resources that would develop students' mathematical understanding. Lecturers saw the need to tie in practise and understanding. The response from L24 was typical of what is required. 'The most useful resources to my mind are those that actually force students to think about the concepts in a unit as well as to get some practise. Thus the resources should be highly interactive'.

## 6. Conclusion

In this paper, we sought to answer four research questions. In answer to the first question on the types of resources students used and lecturers recommended, we found that students relied mostly on lecture notes, tutorial notes and books. However, over half of the students accessed online resources such as Khan Academy, YouTube videos and Wolfram alpha. Similarly lecturers recommended handouts and books but they preferred online resources that they had developed themselves rather than the freely available ones. In response to the second research question which examined institutional difference in resource types, there is evidence that the distribution of responses was not independent of the HEI, university students often used books while IoT students relied more on lecture notes.

The third research question investigated the type and nature of the resource material used and recommended by the students and lectures. We found that while students currently use paper-based resources, all of the students who responded to the relevant question recommended resources be made available online as videos or on websites. More students indicated that they would like online resources ($n = 230$) than those who reported having used any previously ($n = 130$). This leads us to question why such students did not use existing online resources and under what circumstances would they be inclined to use them? One possibility is suggested by S97, who stated that 'If there were tailored video tutorials with the exact topics being done in the courses that would be good'. Most of the lecturer suggestions are based on technology-enhanced resources; the lectures were made aware of the project objective when responding to the questionnaire. Students wanted examples, solutions and step-by-step procedures to be made available with few students referencing the development of deep understanding. On the other hand, lecturers were more concerned with the development of interactive resources to promote conceptual understanding such as screencasts and online quizzes, though they recognized the need for examples in the development of procedural ability. Both students and lecturers recognized the need to apply the mathematics in students' own disciplines or in the 'real

world'. These differences may be as a result of the phrasing in the questionnaires, lecturers were specifically asked to link the resources to the difficulties they had outlined in response to the first part of the questionnaire, whereas students were asked to list resources that they found helpful.

The final research question asked whether there was a difference in the students and lecturer responses. Lecturers were more interested in recommending quality resources that would help develop student understanding rather than 'off the shelf' solutions and students generally wanted more examples and solutions, which they considered would help with understanding. There appears to be a difference between what students and lecturers mean by mathematical understanding though more research is required to further investigate this. There were also similarities between student and lecturer responses, for example currently students use and lecturers recommend paper-based resources and both lecturers and students want tailored online resources to be developed.

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## Appendix A. Open response questions on resources from student survey

1. Please list any resources that you have found helpful for dealing with first year mathematics topics. [*Please give as much detail* (*e.g. web address*) *as possible*.]
   Books:_____
   Handouts: _____
   Videos: _____
   Websites: _____
   Other (please specify): _____
   2. If possible, please indicate why the resources listed above were useful.
   _____
   3. Are there any gaps in the resources available? Please explain.
   _____
   4. Have you any advice on the resources you would like us to develop?
   _____
   5. How should these resources be made available?
   Print-based: _____
   Videos: _____
   Websites: _____
   Other (please specify): _____
   6. Any other comments
   _____

## Appendix B. Open response questions on resources from lecturer survey

1. Please list any resources that you have found helpful to aid students with the difficulties outlined above.
2. If possible, please indicate why the resources listed above were useful.
3. Are there any gaps in the resources available? Please explain.
4. Have you any advice on the resources you would like us to develop?
5. How should these resources be made available?

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