Qualitative data collected on mathematical difficulties experienced by students in a mathematical support centre produce a surprising result?

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Abstract

In September 2013 we embarked on a project to develop a process of recording accurate qualitative data on each student visit to the Mathematics Support centre in UCD. We wished to determine the topic for which each student sought support and to identify any basic mathematical difficulties they were experiencing. In the first semester 2014-2015 we undertook an extensive eight-week qualitative data collection. This data collection period resulted in entries recorded and coded on over 2,000 student visits. In this paper we will describe when we first realised that our method of coding the data was not the best means of answering our research aim and we will discuss our new approach to flagging the data. Finally we will show how our analysis of the data has led to a novel approach to developing effective supports for our students.

Keywords: mathematics support centres; basic mathematical problem areas; data collection; evidence based approach; support module and time specific; lecturer evaluation.

Background

The increasing importance of quantitative skills across multiple programmes at third level has been identified by many authors among them Steen who states "in today's world, the majority of students who enrol in post-secondary education study some type of mathematics. Tomorrow, virtually all will." The Mathematics Support Centre (MSC) in University College Dublin (UCD) is embedded as a university-wide resource. Visitors to the MSC may be students studying a mathematics degree programme, or may be taking mathematics modules as part of another programme of study for example, Agriculture, Business, Engineering or Science. In addition students, such as those undertaking degree programmes in Geography, Psychology, Medicine or Social Science who are not studying any mathematics module but need some knowledge of mathematics for their programme, also attend the Centre.

Since September 2008, the MSC in UCD has maintained an electronic record of each student visit to the centre. This data has included the student's previous mathematical education, their student number, the programme they were taking, and the module for which they were seeking support. At the completion of their session with each student the tutor added to the database, details of the topic they had covered with the student. This included the codes representing the mathematical problem areas experienced by the student. We refer to these tutor comments as *topic entries.* These anonymous *topic entries* were available to the module lecturer in real-time.

Diagnostic testing, as carried out in many third-level institutions, is believed to have been effective in identifying and highlighting widespread areas of mathematical weakness. It is normally limited to first year classes with a large mathematical content. "Measuring the mathematics problem" (Hawkes & Savage, 1999) recommended that students who are embarking on mathematics-based degree courses should have a diagnostic test on entry and they emphasized the importance of follow-up support.

Aims

We had always believed that mathematical difficulties experienced by students were common across many third level programmes. Our research project planned to identify the mathematical topics and concepts that cause persistent difficulties for students in order to better target the provision of effective supports.

Method

However, we found the nature of the *topic entries* prior to 2014 lacked the specific detail to enable the proposed analysis to take place. We realised that to identify the mathematical topics with which students experience difficulty we needed to identify the nature of the data we required and then work with the tutors to find ways that this could be done efficiently.

In September 2014, we commenced our data collection. This involved eight weeks of intensive collaborative work with the tutors to ensure the quality and authenticity of the data collected. Each entry was coded by the tutors under twenty-eight separate codes. Curley and Meehan (2015) describes our efforts and those of the tutors over the last 18 months to collect this data as efficiently as possible.

Preliminary analysis

In January 2015 we began an analysis of our data. There were 2,012 entries to our database over the eight weeks. Many of these *topic entries* were coded under more than one problem area. A *topic entry* recorded information on the issues for which the student sought support and were entered and coded by the tutor after each student visit. Here is one example of a *topic entry* including the specific codes.

> Working on complex numbers. had not seen them before university. How to solve equations with complex roots. eg. z^2 +3 = 0; Z^3 +8=0 Found root = -2 but then did not know how to find the other roots. Did not know that imag roots occur in twos and had forgotten long division and to use the -b formula to find the other roots. In another cubic equation did not remember remainder theorem but once they got one solution they could finish the question. Difficulty with de Moivre and equating coefficients to find equalities for cos2A and Cos3A {fact},{comnum}, {trig}, {quadeq}, {app},{r}, {alg1} {concepts}, {alg1}

Our first task in the analysis of our data was to collect the *topic entries* assigned by the tutors under each specific code. When tutors believed that a student was seeking help for a more advanced topic they coded these entries as {adv}. After examining each coded entry to verify that they were coded correctly I either re-coded or removed codes on any entry if in my opinion it did not represent a basic problem area or the information was insufficient to explain the coding. So for example I re-coded as advanced {adv} or removed the respective code in approximately 15% of items coded as {vec}, 11% of those coded as {stat} but over 28% of those coded as differentiation {diff}. The latter removals were mainly as a result of entries under multivariable calculus and applications all of which I re-coded as advanced. A small number of students attended the MSC to study but did not seek help. These visits were also removed leaving a total of approximately 1,500 entries. All remaining *topic entries* were then listed under the different codes. The chart shown in Curley and Meehan (2015, p.6) represents the numbers of the major codes at the completion of the above process.

Here are some more examples of our *topic entries.*

1. Plotting functions. Student was not aware of method: Finding roots and critical points. Plot sin function between amplitudes. Solve ode using integrating factor method. Needed complete explanation {diff} {int} {g} {fun} {diffeq}.

2. Student had a question regarding moment of inertia, real issue was in conversion from cartesian to circular coordinates. Did a simple example to explain .[NC: Tutor drew rt angled triangle with sides x,y,r and showed sin(theta) = x/r implies x = r sin(theta) and showed this on a circle.NC] {trig}

3. Student came in with a problem with indices. The student was confused between 2^{1/3} and 2^{-3}. The student thought that 2^{1/3}=1/(2^3) but was fine once it was explained. {ind}[NC: tutor wrote cube root(2) = 2^(1/3); 2^(-3) = 1/2^3 NC]

The coding in the first entry refers to problems with differentiation, integration, graphing, functions and differential equations. So this entry would have been listed five times, once under each code. The second example is simply a question on trigonometry and the third a problem with indices. Note that as ease of entry for the tutors the mathematical content, when it was felt it was advantageous to include it, was entered in LaTeX form.

For the next step in the analysis of our data Dr Maria Meehan and Dr Anthony Cronin, manager of the MSC had agreed to check the coding for authenticity. As only parts of each entry were representative of the student's trouble-spot, I again looked at each entry and highlighted the entry where it referred to the specific code. Here are some of these entries coded under {mat} for matrices, the significant area is shown in italics.

1. *Wanted to know what transpose of a Matrix was. [NC:tutor gave general example. NC] Wanted to know proof by induction.* [*NC: show \array (1 1\\ 01\\)^n = \array (1 n\\ 0 1\\) NC]*. Prove identity for finding argument of complex number holds. Didnt know how to find argument of complex number in quadrant other than first. {mat},{trig},{comnum}

2. Student had forgotten how find eigenvectors having found eigenvalues. Helped him find one eigenvector. *Had slight difficulty row reducing. Also some problems with notation but ran off to a class [NC: (A-lamdaI) = \array 1 -2 2\\ 0 0 1\\ -4 8 2\\ = \array 0\\ 0\\ 0\\. so X_1 = -t, X_2 = t and X_3 =0, What was worrying the student was the 0 0 0 row until tutor explained.NC]* {mat},{eigen}

Entries under ten of the major codes were emailed to the Maria and Anthony in March 2015.

After much thought and discussion we eventually realised this method of coding was not giving us the information we were looking for. The problem areas under each code were very diverse and it was difficult to extract useful information from the data. I decided it might still give us some useful information in the area of algebra by breaking it down under different problem areas but this also turned out to be fruitless. So where would we go from here?

A change in direction

In conjunction with the topic coding we had also recorded two other significant elements that we thought might provide a better method of analysing the data. The first of these was the module descriptor for each *topic entry* and the second was the time and date the student entered.

We decided to look at the *topic entries* for thirteen large first year modules and three second year modules. We organised these under specific module headings and flagged the first year modules as M1 to M13 and the second year modules as M21 to M23. Now the entries seemed to make sense. We began to see clearly that there were major *trouble-spots* once the *topic entries* were shown as module specific. Let us now look at some examples from module M2.

> M2: Student had difficulty in solving equations involving trigonometry, fractions and basic algebra{trig} [NC: Tutor said main problem resolving vectors. NC] {vec}.
>
> M2: Force diagram. Use cos and sin to break forces to component parallel and perp to plane. Also listing perpendicular and parallel force when calculating force balance {vec},{trig}
>
> M2: Working on … problem involving splitting vectors into components parallel and perpendicular to a slope. Just having difficulty visualizing the problem, was not having any issues with the maths itself {vec},{mod}

It is clear from the above examples that some students in this module were having difficulty resolving vectors.

The next question we looked at was whether similar mathematical modules, for example modules in calculus, had similar problems. So we looked at *topic entries* for some of these modules but we also included the dates of these entries. We found the problem areas which were similar in content occurred at different times in the semester and in some cases that different modules presented with different levels of the same problem area. In the following examples we look at a first year module M13 and a second year module M21. Students in both cases have met modules in Statistics for the first time at university level.

> M13: 2014-11-03; (Tutor) went through normal distribution and finding zscore/probabilities from the tables. Also went through where to use the sample mean formula vs sample proportion formula for calculating z {stat} [NC: Tutor did question where mean = 62106 and st dev'n = 25000 and number in sample = 225 find prob of <= 55,000. tutor showed z= -4.26 and Prob(z<= - 4.26) = Prob (1 - Z >=4.26) Tutor mainly working off student's notes. NC] {stat}
>
> M13: 2014-11-05; [NC: Student knew nothing about normal distribution.NC] (Tutor) explained how the z score is calculated in the normal distribution. Also did an example calculating areas. [NC:Mean =8, st devn = 5, find prob of x >= 8.6 ; Z = 0.12; P(Z> 0.12) = 1 - P(Z< 0.12) =0.4522 so 45.22% NC] {stat}
>
> M13: 2014-11-10 14:30:01; Looking up the tables when calculating probabilities for the normal distribution. [NC: x ~ N(57.1, 9.7^2) find P(x < 40) NC] … (Tutor) also explained why for continuous distributions the probability of the random variable being strictly equal to any value is 0. {stat}
>
> M21: 2014-10-06 Student came in with normal distribution problems. I think the main problem was that the student has looked up online several different types of tables and didn't know which one to use. We looked at the tables where the area is the area from the

mean upwards. We also looked at how to use these tables to find percentage points and how to use the percentage point tables. {stat}

M21: 2014-10-09 ; Explained to student how to read the normal distrib'n tables. Told student it was a symmetrical curve. Covered a number of examples starting with filling in the z score and reading various values from the tables to find probabilities. {stat}

M21: 2014-10-16 ; Student had difficulty in understanding normalising a variable from x to z z=(x-xbar)/sigma [Nc: tutor took example of mean = 17 and st dev'n = 2 find prob of value less than 21 and another example of mean = 4.5 . st dev'n = 0.5 and find prob of value less than 5 so needed to find P(z<1).NC] {stat}

We can see here that students in M21 needed support in this area approximately one month before those in M13. The nature of mathematics as progressive learning would in our opinion point to the importance of delivering support as soon as it is needed and thus prevent students falling back further. From our data we perceive that the students studying module M21 would benefit from support a month before those in M13.

Provision of effective Supports

With an emphasis on module specific and timely support we introduce a novel method of student support which we call *Hot Topics.* Bearing in mind that *topic entries* are available to the module lecturer in real-time the MSC, in discussion with the lecturer, plans to run a tutorial called a *Hot Topic.* The essence of this tutorial is it is organised by the MSC, with reference to the lecturer's notes, at the precise time it is needed, it has a very small number of students, and it covers a very precise area at a very basic level. This is insured by the lecturer announcing the *Hot Topic* at lectures, emphasizing that only those who have difficulty in this area should attend. Students are required to sign up if they wish to come and numbers are limited. A video of the *Hot Topic* is made available subsequently on line for those students who require it.

Conclusion

In summary when we consider a large university where mathematics support is required for many different programmes we believe our findings have added an important addition to work done in this field and reveal that student mathematical *trouble-spots* are module and time specific and we suggest further research in this area would be beneficial.

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