Mathematics resilience: What is known in the pre-tertiary mathematics education research and what we have found researching non-mathematics-specialists

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This paper describes a two-phase pilot study that explored mathematical resilience amongst non-mathematics-specialist students in a tertiary institution in the UK. Two cohorts of first-year undergraduate students completed a modified version of an existing mathematical resilience instrument. This instrument measures the extent to which respondents are mathematically resilient. The association between respondents' level of mathematical resilience scores and the type of pre-tertiary mathematics qualification they had achieved was explored. Also, the association between respondents' level of mathematical resilience scores and their programme of study was explored. Semi-structured interviews were conducted with a small number of first-year and second-year students to explore their experiences of learning mathematics and the strategies they use to persist with mathematics. Some preliminary findings of this pilot study and their implications for mathematics learning support practice and further research are reported.

Keywords: mathematical resilience; tertiary mathematics; non-specialists; economics

Introduction

Tertiary institutions in the UK and elsewhere have made great strides in addressing the challenges that students face when they transition from school to tertiary Mathematics. This has been achieved, in part, through the provision of mathematics learning support centres, and increasingly, peer assisted learning support programmes. For some students, the challenges persist despite the support available. Tertiary mathematics pedagogy, which traditionally is transmissionist, could be the source of the continuing challenges that some students face (Williams, 2015). However, I will argue that the transition from school to tertiary Mathematics is a complex phenomenon and cannot be explained in terms of university mathematics pedagogy alone. As mathematics learning support practitioners, we may not have the opportunity to directly influence change in the enduring tertiary mathematics pedagogy at the institutions in which we practise. However, we can develop mathematics study strategies and skills programmes to support students to persist with their study of mathematics in the disciplines outside the mathematical sciences. An understanding of the construct of mathematics resilience, how it can be measured and developed in students would inform mathematics learning support practice in the higher education (HE) sector.

Mathematics resilience is not only a buzzword in mathematics education research but also a topic of which there exists an increasing number of projects and

research studies that aim to understand and develop mathematics resilience amongst learners of mathematics. Johnston-Wilder and Lee (2010) define mathematical resilience as "a positive approach to mathematics that allows people to overcome any affective barriers presented when learning mathematics" (p.1). This definition suggests that when faced with challenges in their learning of mathematics, some students may independently or otherwise develop skills and strategies that enable them to adapt positively to overcome these challenges. Mathematical resilience then describes the "quality by which some learners approach mathematics with confidence, persistence and a willingness to discuss, reflect and research" mathematics problems (Johnston-Wilder and Lee, 2010, p.1). Recent work on mathematics resilience has focused on either school mathematics or workplace numeracy. The research has found that students with high levels of mathematical resilience are more likely to persevere and succeed in mathematics than those with low levels of mathematics resilience. Also, the research suggests that when coached, students can develop mathematically resilient strategies upon which they can draw to persist with their learning of mathematics (Johnston-Wilder and Lee, 2010).

If a mathematical resilience coaching programme were to be developed for students in the HE sector, it would be informative to measure and explore the extent of mathematical resilience amongst HE learners and to design programmes tailored to their needs. It is plausible to suppose that the findings of research on school or workplace mathematical resilience may be applicable to students in the HE sector. However, questions that remain to be answered are: 1) how can mathematics resilience amongst HE students be measured and how can data collected through such measurement be analysed? To the best of my knowledge there is limited availability of instruments for measuring mathematics resilience of students in the HE education sector. Ricketts, Engelhard and Chang (2017) developed and validated, for high school students, a short instrument they called *Academic Resilience in Mathematics*. More recently, Kooken, Welsh, McCoach, Johnston-Wilder and Lee (2016) have also developed a 25-item scale for measuring mathematics resilience amongst pupils. I opted to adapt Ricketts et al.'s (2017) scale due to its brevity, bearing in mind the limitations of the questions (e.g. there were no negatively worded items, see Appendix A). The overall goal of the current study was not to critique Ricketts et al.'s instrument but to inform my thinking about future design of similar instruments for students in the HE sector and how the data collected via such an instrument might be analysed. This study, I hope, will provide insights that will inform a research proposal that might involve multiple institutions and the mathematics learning support practitioners' community. Two research questions which were addressed in this pilot study were: 1) to what extent are first-year students of Economics and related studies mathematically resilient? 2) what could a mathematics resilience coaching programme for tertiary non-mathematics-specialist students look like?

Methodology

Participants, methods and procedure

A report commissioned by the Higher Education Academy (HEA) found that students of Economics and related studies reported that "there was much more Mathematics involved than they expected in Economics degree programmes" (Dawson, 2014, p.18). The report also notes that some students who enrol in UK universities to study for a degree in Economics and related studies do not always have "like for like"

equivalent of A-level Mathematics qualification. Some may have GCSE or its equivalent national and international qualifications. Thus, there is a diversity of mathematical experiences of students of Economics and related studies. Therefore, I included this group of students in this study so that I can gain insights into the mathematics education of students of Economics and related studies and contribute further to the knowledge base of tertiary mathematics education research. Environmental Science students at the research site study Mathematics and Economics modules as part of their degree programmes. So I also included this group of students in order to compare their level of mathematics resilience scores with those of students studying Economics and related studies. Two hundred and three students of Economics and related studies and Environmental Science participated in this study.

A mixed methods approach was employed in the study. This involved a short survey of first-year students using an adapted version of a previously validated Likert scale type questionnaire (see Appendix A). Responses were collected from students at the start of their lecture in February 2017. Participants' responses to the completed paper questionnaire were entered into an online version designed with Qualtrics. Qualtrics facilitates the data coding and offers an SPSS file format of the data to download. The analysis was conducted using SPSS version 24. The questionnaire was supplemented by semi-structured interviews with two first-year and seven second-year students. Appendix B is a sample of interview questions that explored students' learning experiences and strategies they use to persist with mathematics. Ethical approval was sought through the ethics committee of the Department of Education at the University of York. Participants were assured of anonymity of their identity and confidentiality in respect of their responses to the questionnaire items and the interview questions.

Data Analysis

How Likert scale type data may be analysed has been debated over 50 years and the lack of consensus often gives way to "great confusion of students, practitioners, allied health researchers and educators" (Carifio & Perla, 2008, p.1150). Researchers in different disciplines (e.g. English as Second Language and Education) take up sides of the debate through the procedures they employ in their analyses of Likert scale type data. Some quantitative researchers argue against the use of *mean* as a measure of central tendency and *standard deviation* as a measure of variability of Likert scale type data. They suggest the median and/or the mode as the appropriate measure of central tendency for the Likert scale type data. This view is justified because Likert scale type data for individual items of the scale tend to be skewed, with respondents choosing extreme scale values. So, when the analysis of Likert scale type data focuses on individual items, relationships and/or associations between variables are best explored using non-parametric statistical test.

However, others (e.g. Jamieson, 2004) have argued that where a Likert scale is unidimensional and measures a theoretically developed construct, a composite score of the Likert scale items can be computed as a measure of the construct (e.g. resilience and/or anxiety). The level of measurement of such composite scores may be assumed to be an interval scale. This view point is also justified because such composite scores may have a distribution suitable for parametric statistical analyses. Because the instrument shown in Appendix A measures mathematical resilience, the total score of the nine items in the instrument for each respondent was computed. The

possible minimum and maximum scores of the instrument are 9 and 54 respectively. The mathematical resilience of respondents were classified as low (< 36 scores) and high (≥36 scores). In this paper, I focus on part of the analyses of the data which used chi-square test to explore the association between the level of mathematical resilience scores and: 1) the type of pre-tertiary mathematics qualification achieved; 2) the type of degree programme.

The recorded interviews were transcribed. Preliminary coding of the transcripts was carried out in NVivo 11 to identify potential themes for further analysis. The goal was to identify strategies used by interviewees to persist in their learning of mathematics. In the next section, I present the results on the association between the level of mathematics resilience scores and the background characteristics of participants. I also briefly summarise three salient themes from the interview transcripts that may inform the development of mathematics resilience coaching programmes for students studying mathematics in other disciplines.

Findings and Discussions.

Differences in mathematics resilience between different student groups

The reliability of the mathematical resilience instrument used in this study was assessed and the Cronbach alpha for the 9-item scale was 0.75. This was comparable to that reported in Ricketts et al.'s (2017) study from which the current instrument was adapted. Table 1 shows a crosstabulation of *level of mathematics resilience scores* and *pre-tertiary mathematics qualification.* A chi-square test of independence was performed to examine the association between the level of mathematics resilience scores and the type of pre-tertiary mathematics qualification presented by the participants for admission. The association between these variables was statistically significant, χ^2 (2, n = 203) = 21.88, p<.001. I had expected students with A-level Mathematics qualification to have high level of mathematics resilience scores and this was supported by the crossbulation in Table 1 and the chi–square analysis.

Level of Resilience Scores	Pre-tertiary Mathematics Qualification		
	A-level Maths (n=115)	GCSE and AS level Maths (n=58)	International Maths Qualification (n=30)
High Resilience Scores	86%	53%	73%
Low Resilience Scores	14%	47%	27%
Total	100%	100%	100%

Table 1 Crosstabulation of degree programmes and level of mathematics resilience scores

The majority of the participants studying Environmental Science have only GCSE or its equivalent. The majority of participants studying single honours Economics also have A-level Mathematics qualification. Similarly, the majority of joint honours Economics students also have A-level Mathematics qualification. Table 2 also shows a crosstabulation of *level of mathematics resilience scores* and the *type of degree programmes of study* followed by participants. A chi-square test of independence was performed to examine the association between the level of mathematics resilience scores and the type of degree programme of study. The

association between these variables was statistically significant, χ^2 (2, n = 203) = 13.4, p<.01. I had expected no differences between groups in which the vast majority of members have A-level Mathematics qualifications. However, what was surprising is that there was statistically significant differences in the proportions of students with high levels of mathematics resilience scores with respect to single honours and joint honours Economics students.

Level of Resilience Scores	Type of Degree Programme of Study		
	Single Honours Economics (n=73)	Joint Honours Economics (n=70)	Environmental Science (n=60)
High Resilience Scores	88%	74%	60%
Low Resilience Scores	12%	26%	40%
Total	100%	100%	100%

Table 2 Crosstabulation of degree programmes and level of mathematics resilience scores

Planning for coaching mathematics resilience

A preliminary review and coding of the seven interview transcripts revealed emerging themes which include: help seeking behaviour; awareness of maths learning support; internet as a mathematics learning environment; peer support and collaborative learning; and pre-enrollment revision through self-study. Within these themes there are specific strategies (for example, example generation, weekly practice and problem solving, etc.) that participants use to cope and be successful in their learning of tertiary Mathematics. A mathematics resilience coaching programme may aim to develop in students some of these strategies to help them to persist with their learning of tertiary Mathematics.

Conclusions and implications for further research

The results of this pilot study indicate that the proportion of students with low mathematics resilience scores was significantly higher for joint honours than single honours Economics students. Similarly, the proportion of students with low mathematics resilience scores was significantly higher for Environmental Science students than single and joint honours Economics students. Indeed, a one-way ANOVA also confirmed differences in the means of the raw mathematics resilience scores of the three group of students who participated in this pilot study.

The results, then, show that there is an opportunity for mathematics learning support practitioners to develop mathematics resilience coaching programmes for some cohorts of students of Economics and related studies.

In a future research, I would look at developing a mathematical resilience instrument specifically for the HE sector. I will consider Rasch modelling as a statistical approach to the development and validation of such an instrument.

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Appendix A – An adapted Mathematical Resilience Instrument (Ricketts et al. 2017)

How well do the following statements describe you?
1=Strongly Disagree, 2=Disagree, 3=Disagree Somewhat,
4=Agree Somewhat, 5=Agree, 6=Strongly Agree

Item	1	2	3	4	5	6
I am good at dealing with setbacks (e.g., bad coursework mark, negative feedback) in mathematics.	☐	☐	☐	☐	☐	☐
I do not let study stress get to me in mathematics	☐	☐	☐	☐	☐	☐
I think I am good at dealing with pressures in mathematics.	☐	☐	☐	☐	☐	☐
I do not let a bad maths grade affect my confidence.	☐	☐	☐	☐	☐	☐
I have someone to help me with maths.	☐	☐	☐	☐	☐	☐
I believe that maths will be useful to me in the future.	☐	☐	☐	☐	☐	☐
I believe that if I work hard at maths, I can do well at it.	☐	☐	☐	☐	☐	☐
I know where to get help if I am having trouble with maths	☐	☐	☐	☐	☐	☐
I plan to graduate from university.	☐	☐	☐	☐	☐	☐

Appendix B – Sample Interview Questions

Q10. How do you deal with pressures of meeting the deadlines for your maths assignments?

Q13 What are your views on the statement: “Some people are good at maths and some just aren’t”?

Q15. What are your views about learning mathematics through discovery, experimentation and memorisations?