Measuring the 'effectiveness' of Programme and pedagogy on maths disposition and self efficacy measures

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Abstract

The aim of this paper is to report our work in progress on the measurement methodology and some preliminary results of our analysis on an incomplete data set. We report on the analysis of the effect of some specific 'process variables' (pedagogy and Programme in AS level mathematics) on value added to some 'learning outcomes' (measures of disposition), and how background variables such as gender, proxies of class, etc. influence these. The data set comprises of disposition measures at two data points early and late in the AS year, and does not yet include measures of grades or UCAS decisions that will follow later in the project. We focus on students disposition to 'further study mathematically-demanding subjects' and their 'mathematics self-efficacy' in this paper, and find some statistically significant but uninterpretable process effects related to Programme, pedagogy and EMA grant support.

1. Introduction

This paper presents some preliminary results from the first phase of the quantitative analysis of the survey data gained from the ESRC TLRP research project on widening participation in HE, '*Keeping open the door to mathematically-demanding F&HE programmes'*. In this paper we address the first research question of the project which focuses on measuring the effectiveness of distinctive maths courses. We particularly ask "How effective is "Use of Mathematics" (UoM) in comparison to matched traditional "Mathematics" AS (ASTrad) programmes in promoting learning outcomes (LO) for 16-19 students?"

We partly drew on social science literature on widening participation that suggests a positive disposition towards a subject, especially their self-efficacy in relation to the subject studied (Bandura and Locke, 2003) and personal commitment to success is often decisive in persistence with study. In particular we ask (i) How does 'effectiveness' vary with measures of affective and cognitive LO? And (ii) How does 'effectiveness' vary for different groups of students (e.g. classified by gender, SES, family education, postcode, college-type).

Here we present the results of a quantitative analysis of the value added to the 'soft' learning outcomes established through the project (at this point we have to disregard the 'hard learning outcome of mathematics attainment scores", since these are not available up to date). Hence, we focus on 'mathematics self-efficacy' scores, from a new instrument already validated (see

Wake & Pampaka, 2007, Pampaka et al, 2007), as well as the intention to participate further in HE and study mathematically demanding subjects.

We show how these 'soft LO' measures differentiate by students' AS programme (UoM versus ASTrad), prior GCSE grade and other background variables (mentioned above) by employing Generalised Linear Models (Hutcheson & Sofroniou, 1999). The soft measures will be treated as response variables, whilst explanatory variables will consist of the programme and the other background variables. These models will allow the effect that each explanatory variable has on the response variable to be determined, each time.

The main contribution of this paper regards measurements of the effectiveness of two distinctive programmes of mathematics (UoM and ASTrad) on learning using 'disposition' measures, for different groups of students. Implications for policy and practice will be discussed.

2. Caveats

The data set used here comprises two 'main study' data collection points, and we do not yet even have the AS grades/ results in the data set. In addition, we have not yet processed the data on 'drop outs', who we are energetically seeking, and their missing data has an impact on the substantive results here and their interpretation.

The current set of data will be complemented by a further data collection point in autumn 2007, when final grades UCAS decisions and 'drop out' data will be finalised. We are therefore reporting here only some tentative results, which will be supplemented in a paper in late 2007. Furthermore these results focus exclusively on the measures of maths-disposition and self-efficacy. Nevertheless we believe the results and methodology will be of interest.

3. Methods

The survey data analysis uses Generalised linear modelling (GLM) of learning outcome (LO) variables over time intervals extending eventually through three data points between September 2006 to November 07 (we are reporting the two data points from 09.06 and 05.07)

The LOs include measures of disposition or commitment to study 'in HE', and 'mathematically-demanding courses in future', and 'self-efficacy in the use of mathematics'. Eventually, the analyses used here will be applied to value added to measures of attainment (from GCSE to AS, and if the project is extended to A2 and university first year) and to UCAS decision-making (which will extend to university choices if the project is extended).

The result will be models of the effects on LOs at the end of each time interval of background variables (e.g. GCSE grades, gender, proxies of class such as EMA grants, postcode and parental education) and earlier 'input' measures (including LOs from previous time intervals) and 'process' conditions (eg AS Use vs Traditional Programmes, pedagogy, and – if the project is extended - university transitional conditions).

Process variables at AS mathematics: 'Programme' and 'pedagogical style'

The key variable we study is the Programme being studied, either a tradition AS Mathematics, or the new AS "Use of Mathematics". We are aware of the problems of separating out the 'process' from the 'background' effect here: for many reasons the 'Uses of mathematics' attracts different students, and maybe even teachers from the traditional AS mathematics course. It is a common policy for instance in many Colleges to direct weaker students to the AS Use of Mathematics, and students who are committed to developing an HE direction in STEM for instance are highly likely to opt for Traditional AS Mathematics even if they have weak grades. There may well be other effects unknown to us, though our project is expending considerable effort in case studies to make sure we do understand the processes involved.

Nevertheless, it is our view that there are significant implications for students learning the different programmes: the Uses of Mathematics course includes Coursework, a focus on applications and 'use' in the texts, and access to technology in the examinations (as well as being encouraged in the teaching of the course). Our case study work does provide support for the notion that these can make a difference for learners (see Davis et al., this seminar).

In addition, we have developed and are employing a teacher scale for 'self-reported teacher and subject-centred pedagogy' in 6fFE. This instrument has been developed in response to our recognition that the predominant style of 'teacher- and subject- centred' teaching style in AS level teaching may be significant (see Wake et al., this symposium). The development of this scale is to be reported elsewhere, but essentially consists of items modified slightly from those used by Swan (2007) to diagnose "transmissionist", "discovery" and "connectionist" pedagogy among 6th form and Further education College teachers of GCSE Mathematics. Our Rasch/IRT analysis of these items (with Swan's data and our own) produced a clear one dimensional scale, with 'transmissionism' opposed by all the discovery and connectionist responses. For measurement purposes then, we havea single dimension in our measurement instrument, which we call a measure of the degree of ‘teacher and subject-centred’ pedagogy. (See Pampaka et al., under review for AERA).

This then enables us to analyse the interaction of Programme and ‘pedagogical style’, and how the resulting ‘process’ influences student outcomes.

The background variables in use are in some cases clear and relatively unproblematic (gender, GCSE grade, language, HE-family history) and in other cases may be problematic as it is not clear how to interpret ‘process’ as separate from ‘background’. Consider the EMA grant, which may be used as an indicator of background (though can be criticised of course). It is also a process factor, in the sense that it may be a requirement of an EMA student that they attend classes (or even extra classes as we found in one College).

Of course, these are problems of interpretation rather than technique: the GLM model does not recognise differences between process, background, and indeed input. However, we pay due regard to the interpretational demands of the data in the ’ordering’ of the model building. Therefore we build models over one interval between data points for each outcome variable, modelling value added by starting with the relevant outcome variable as an input measure, and adding processes before background variables. Step 1: what is the ‘value added’ Step 2: how is this a function of processes; step 3, how is this function modulated by background variables.

The extension of this modelling over more data points is designed to reveal the truly significant intervals/moments during students progression into HE: their UCAS decisions, clearing/entry to university and so on. Our results will also serve to situate the interview and case study insights within a broader context and identify outlier students and institutions of interest to further study later in the final stage.

The measures and other variables

The variables in our design for an extended 3 year study are illustrated in Table 1 showing when the data will be used to model input/output variables: background variables were mostly collected at data point 1 (DP1) but will enter the models before inputs; Learning outcomes including ‘soft’ measures of disposition (to study in HE: HEDis; to study maths, MathDis; and mathematics self-efficacy: MSE) and ‘hard’ measures (grades, etc) and STEM intentions-or-choices are collected at almost every data point and used as both inputs and outputs in models.

The ‘conditions’ will be course studied in 6fFE and HE, and type of maths pedagogy in 6fFE and Transition-type in HE. More details for the measure of Mathematical self efficacy and other variables can be found in appendix 1, whereas the development of the other two disposition measures is detailed in Williams et al. (this symposium).

The analysis reported in this paper however arises from DP1 and DP2 only (Table 2), and draws only on ‘dispositions’ (actual data used in these analyses is emboldened in Table 1).

Table 1: Design of data collection

Background Variables		**Year 1 (9.06-6.07)**		Year 2		Year 3	
		DP 1 **Start of AS**	**DP2** **End of AS**	DP3 Start of A2	DP4 End of 6fFE	DP5 Start of HE year 1	DP 6 End of HE year 1
Family-in-HE LPN by postcode, EMA, Gender Language (Eng/non-Eng/bi), Ethnicity, College	Grades	GCSE grades	AS grades		A2 grades		Hey1 outcome
	Dispositions	**HEDis-1** **MathDis-1** **MSE-1**	**HEDis -2** **MathDis-2** **MSE-2**	HEDis -3 MathsDis-3 MSE-3	HEDis -4 MathDis-4 MSE-4	MathDis-5 MSE-5	MathDis-6 MSE-6
	Intentions/ Choices/ Decisions	Uni-int 1 STEMint1	Uni-int 2 STEMint2	Uni-int 3 STEMint3	UCAS choice	UNI-course choice	UNI-course choice
Conditions / processes		**Maths-Pedagogy** **AS maths Programme**	Maths-Pedagogy A2/BTEC/courses	Maths-Pedagogy A2/BTEc/n courses	Transition-Type UNI-course	Transition-Type UNI-course	

Table 2: Distribution (frequencies) of students according to gender and course

ender	**Maths Course**		Total
	AS Trad	**AS UoM**	
DP1			
Male	769	341	1110
Female	511	153	664
Total DP1	**1280**	**494**	**1774**
DP2			
Male	413	235	648
Female	288	108	396
Total DP2	**701**	**343**	**1044**

Results

We report the models built in the following order: first the GLMs of outcome measure at DP2 (data point 2) regressed on the same measure for DP1 (data point 1) with intervening process variables, namely Programme (Use of maths versus Traditional) then pedagogy (as score on a 'teacher- and subject- centred' transmissionist scale) then EMA grant, then GCSE grade, then background variables. This allows us to interpret the influence of each in a systematic fashion.

Before we examine the regression models we note that the process variables 'pedagogy' and 'Use of maths' are correlated, with a significant t-value, and mean pedagogy scores for the two groups of teachers differing by 0.13 logits (a modest difference in the scale, which spreads the teachers between -2 and +2 logits approx.)

HE maths-disposition

First then, the models for value added to maths-disposition. Table 3 shows statistically significant negative effects for pedagogy (Table 3.a: slope -0.2) and Use of Maths course (Table 3.b: slope -0.34) separately and slopes -0.17 and -0.29 in the joint model (Table 3.c). The addition of EMA (Model in Table 3.d) as a further process variable (notwithstanding all the caveats about this above) is not statistically significant and has a negligible effect on the other slopes.

Table 3: Models for HE maths-disposition

Table 3.a	Coefficient B	s.e.	t	p
(Constant)	-0.22277	0.04965	-4.487	<0.001
MdispDP1	0.67276	0.03585	18.769	<0.001
pedagogy	-0.19697	0.06443	-3.057	<0.01

F (2, 680) =182.1, $p<0.001$, R^2=0.3487(Adjusted R^2=0.3468)

Table 3.b	Coefficient B	s.e.	t	p
(Constant)	-0.07209	0.04739	-1.521	0.129
MdispDP1	0.62525	0.03164	19.763	<0.001
pedagogy	-0.33963	0.08175	-4.155	<0.001

F (2, 951) =250.3, $p<0.001$, R^2=0.3449 (Adjusted R^2=0.3435)

Table 3.c	Coefficient B	s.e.	t	p
(Constant)	-0.12029	0.06001	-2.004	<0.05
MdispDP1	0.63191	0.03807	16.598	< 0.001
course	-0.28911	0.09515	-3.039	<0.01
pedagogy	-0.16564	0.06563	-2.524	<0.05

F (3,674) =123.8, $p<0.001$, R^2=0.3553(Adjusted R^2=0.3524)

Table 3.d	Coefficient B	s.e.	t	p
(Constant)	-0.07641	0.07329	-1.043	0.297
MdispDP1	0.63327	0.03892	16.272	< 0.001
course	-0.30343	0.09658	-3.142	<0.01
Pedagogy	-0.17046	0.06719	-2.537	<0.05
EMA (yes)	-0.07895	0.08703	-0.907	0.364

F (4, 657) =89.7, p<0.001, R^2=0.3532(Adjusted R^2=0.3493)

The next models introducing GCSE grade and other background variables are shown in Table 4. Although the effects of grade are not statistically significant, they amend the model slopes in the expected direction (the higher grades have higher effect) and in this model the slope for 'Use of maths' is reduced.

Table 4: Model for HE maths-disposition with background variables

	Coefficient B	s.e.	t	p
(Constant)	-0.02138	0.11613	-0.184	0.854
MdispDP1	0.62367	0.04027	15.487	<0.001
Course	-0.24576	0.10756	-2.285	<0.05
Pedagogy	-0.17429	0.07024	-2.481	<0.05
EMA [yes]	-0.08261	0.09002	-0.918	0.3591
TierGrade[T.A*]	0.23279	0.21596	1.078	0.2815
TierGrade[T.HigherB]	-0.21246	0.13891	-1.529	0.1267
TierGrade[T.HigherC]	-0.29462	0.21457	-1.373	0.1702
TierGrade[T.IntermB]	0.01041	0.13944	0.075	0.9405
TierGrade[T.IntermC]	-0.18646	0.15952	-1.169	0.2429

F (9, 622) =37.43, p<0.001, R^2=0.3513(Adjusted R^2=0.342)

Additionally, the modelling of background variables gender (slope 0.12) and whether they are about to become 'first generation into HE' (slope 0.02) are not significant, as shown in Table 5 below.

Table 5: Model for HE maths-disposition with more background variables

	Coefficient B	s.e.	t	p
(Constant)	-0.18340	0.12083	-1.518	0.129
MdispDP1	0.62865	0.03955	15.895	< 0.001
Course	-0.31333	0.09830	-3.187	<0.01
Pedagogy	-0.16905	0.06766	-2.499	0.012
EMA[T.yes]	-0.03930	0.09003	-0.436	0.662
Gender[T.male]	0.12664	0.09216	1.374	0.169
firstgenerationHE[T.yes]	0.02358	0.10276	0.229	0.818

F (6, 638) =58.42, p<0.001, R^2=0.3547(Adjusted R^2=0.3487)

In conclusion, we find that the most significant determinant of students Maths disposition at data point 2 is their disposition at data point 1. However, in so far as shift occur during the year, we find that following the Use of maths programme is the next most important factor, and has the effect of reducing the students maths-disposition. Additionally, the pedagogy has a further negative effect, that is, transmissionist or 'teacher- and subject-centred teaching' is likely to further depress the students maths-disposition.

Mathematics Self-efficacy

Following the same routine procedure for the learning outcome 'self-efficacy' we see in table 6 that there is no statistically significant results for pedagogy and Programme (Table 6.a), but now a surprise, EMA (Table 6.b) is a significant negative slope (-0.20). What can this mean? Recalling that EMA may be a signifier of background, i.e. a proxy for class, as well as a possible process variable, we introduce background variables into the model and see that (i) GCSE grades, and (ii) gender are significant, and introducing both have the effect of reducing the slope of EMA. Nevertheless the end result is that the effect of EMA has been robust, and negative on mathematics self-efficacy at data point 2.

Table 6: Models for Mathematics Self-Efficacy with process and background variables

Table 6.a	Coefficient B	s.e.	t	p
(Constant)	0.77126	0.06009	12.835	<0.001
MSE-DP1	0.44205	0.03575	12.366	<0.001
pedagogy	0.02026	0.05924	-0.342	0.732
Course [UoM]	0.03299	0.08030	0.411	0.681

F (2,712) =51.8, $p<0.001$, $R^2=0.1792$(Adjusted $R^2=0.1757$)

Table 6.b	Coefficient B	s.e.	t	p
(Constant)	0.85356	0.07238	11.793	<0.001
MSE-DP1	0.44376	0.03676	12.072	<0.001
pedagogy	-0.01439	0.06082	-0.237	0.813
Course [UoM]	0.03874	0.08211	0.472	0.637
EMA [Yes]	-0.20468	0.07787	-2.629	<0.01

F (4, 681) =39.68, $p<0.001$, $R^2=0.189$(Adjusted $R^2=0.1842$)

Table 6.c	Coefficient B	s.e.	t	p
(Constant)	0.77326	0.10620	7.281	<0.001
MSE-DP1	0.41885	0.03767	11.118	<0.001
EMA[T.yes]	-0.17050	0.07774	-2.193	0.0287
Pedagogy	0.01060	0.06139	0.173	0.8630
Course[T.UoM]	0.11045	0.08884	1.243	0.2142
TierGrade[T.A*]	0.32295	0.18870	1.711	0.0875
TierGrade[T.HigherB]	0.07876	0.12012	0.656	0.5123
TierGrade[T.HigherC]	0.18922	0.18967	0.998	0.3188
TierGrade[T.IntermB]	-0.02993	0.12089	-0.248	0.8045
TierGrade[T.IntermC]	-0.03107	0.13932	-0.223	0.8236

F (9, 644) =16.87, $p<0.001$, $R^2=0.1908$(Adjusted $R^2=0.1795$)

Table 6.d	Coefficient B	s.e.	t	p
(Constant)	0.64902	0.13948	4.653	<0.001
MSE-DP1	0.44622	0.18865	11.297	<0.001
EMA[T.yes]	-0.17333	0.08428	-2.057	<0.005
Course[T.UoM]	0.12477	0.09523	1.310	0.1907
Gender[T.male]	0.14498	0.08637	1.679	0.0938
Pedagogy	0.02926	0.06374	0.459	0.6463
TierGrade[T.A*]	0.31404	0.03950	1.665	0.0965
TierGrade[T.HigherB]	0.05931	0.12567	0.472	0.6371
TierGrade[T.HigherC]	0.20770	0.19317	1.075	0.2827
TierGrade[T.IntermB]	-0.00267	0.12666	-0.021	0.9832
TierGrade[T.IntermC]	-0.08329	0.14869	-0.560	0.5756
firstgeneratinHE[T.yes]	0.05269	0.09739	0.541	0.5887
LPNo[T.Yes]	-0.08557	0.09664	-0.885	0.3763

F (12, 548) =14.51, p<0.001, R^2*=0.2412(Adjusted* R^2*=0.2)*

Work is currently also under way to model the HE-disposition scale following a similar methodology. Future work will also deal and report on any interactions that are significant as these can also be incorporated into such models.

Conclusions

We have demonstrated our methodology for evaluating the effectiveness processes of Programme and pedagogy (and EMA) on two of our measures of learning outcomes for students, taking account of some of the salient background variables. Our preliminary results suggest that all three processes can be statistically significant, especially the Programme. However, we have to recognise that this data set is incomplete as yet and we have not yet incorporated missing data and ‘drop out’ into the analysis: this is quite likely to change the substance of our results.

The interpretation of these tentative findings substantively is proving problematic. It is easy to speculate: for instance we think it is likely that students following a Use of Maths programme become increasingly confirmed in their decision not to follow a maths course in HE as they progress with their studies. It is certainly not hard to make up a story to account for the negative impact of transmission teaching on maths-disposition. But then why is there not a similar effect on self-efficacy: the slopes of the Programme and pedagogy variables being positive in that case (though not statistically significant). At this pointing time we have not yet done enough analysis to draw substantive conclusions, but offer these findings as hypotheses, to provoke questions for further exploration when we have a more complete data set.

References (not completed):

Bandura, A. and Locke, E.A. (2003). Negative Self-Efficacy and Goal Effects Revisited. *Journal of Applied Psychology*, 88(1): 87-99.

Hutcheson, G.D. and Sofroniou, N. (1999). *The Multivariate Social Scientist: Introductory statistics using generalized linear models*. Sage Publications.

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Appendix 1

BACKGROUND VARIABLES

Gender = (M,F), ethnicity= many (see survey instrument: http://130.88.43.249/tlrpq/) and language of first choice= (English, other, bilingual) and College=name.

Family-in-HE= 0 (first in their family to go to HE) 1 (siblings have gone to HE); 2 (one or more parents have gone to HE)

EMA (Educational Maintenance allowance)= (yes,no); LPN (low-participation-neighbourhood based on the post code of the students home address) = (0,1)

Mathematics self-efficacy (MSE)

Taking an individual's self efficacy to be their belief in their capability to successfully complete an identified range of actions in a given field, we devised an instrument that has been validated and used so far to measure students' self efficacy in their use of mathematics during the first year in 6fFE for student studying AS levels. In order to define the construct we utilised the concept of general mathematical competences which had proved useful at this level of the curriculum (as developed and used by Williams, Wake, & Jervis, 1999). In addition, we included in this instrument six purely symbolic mathematical items (e.g. solving an equation in x). The (30 item) item-bank spans: Level 1 (immediately post-compulsory study, GCSE); Level 2 (towards/at the end of the first year of pre-university optional mathematics study, 'AS') and Level 3: (post 'AS' study). The items (with some extras) were validated initially and calibrated with a pilot sample and subsequently confirmed with the full survey sample using Rasch rating scale (including checks for Differential Item Functioning - DIF) multidimensional logistic modelling (Bond and Fox, 2001; Linacre, 2003; Briggs and Wilson, 2003). Although there are some signs of two-dimensionality ('uses' and 'pure' MSE items) the single scale was deemed fit for purpose (see Pampaka, 2006; Wake & Pampaka, 2007 CERME).