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'They [the lecturers] have to get through a certain amount in an hour': first year students' problems with service mathematics lectures

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Drawing on large-scale survey data and interviews with students during their first year at university, and case studies in their institutions, we explore the problems faced by students taking mathematically demanding courses, e.g. physics and engineering. These students are often taught mathematics as a service subject by lecturers of mathematics. Analysis of students' perceptions of transition suggests that 'the lecture' in Higher Education continues to pose problems. Thematic analysis of interview data shows that these problems relate to the way lectures involve 'time pressure' and 'lack of dialogue/interaction' which are practices that we associate with transmissionist pedagogy generally and can also create negative dispositions. A case study of one mathematics course for engineering that we argue made a difference is presented, and conclusions drawn for developing practice which are especially pertinent with the introduction of the Teaching Excellence Framework to monitor and assess teaching in universities.

1. Setting the scene

This article reflects on the approach many Higher Education (HE) establishments have towards teaching mathematics to their undergraduates who are studying mathematically demanding subjects, especially during the transition from school sixth form, Sixth Form College or Further Education (collectively 6fC/FE). For many STEM (science, technology, engineering and mathematics) subjects, mathematics will play a significant role in the students' overall success or failure on these degree programmes but, with many STEM subjects (e.g. physics, engineering, etc.), the necessary mathematics is often taught as a service subject by lecturers of mathematics, rather than of the subject concerned. In addition, to economize on the use of resources, a service mathematics course may cater for more than one subject discipline or indeed more than one 'audience', e.g. overseas students with good mathematical abilities/skills but poor English may be grouped with native English speakers with poor mathematical skills.

The aim of the TransMaths Project[1] was to follow such students' experiences of and engagement with mathematics and investigate how these shape their developing dispositions towards mathematics during their transition to and whilst at university. This article explores the problems that disrupt this process, as the first year students and their lecturers explained more comprehensively in their interviews. Pedagogical practices are also measured through the students' responses to questions about their prior and present mathematics teaching/learning experiences (Pampaka *et al.*, forthcoming and Pampaka & Williams, forthcoming) and these are discussed in the article in relation to relevant literature where there is evidence to suggest that transmissionist teaching in HE is a problem.

2. Literature review

For many students, the transition from 6fC/FE to university can be one of the most substantial of their lives and Clark & Lovric (2008, p. 25) go so far as to describe it as 'a modern-day rite of passage'. They may also be living away from their friends and family for the first time and having to develop their independent living skills very rapidly in order to adapt to university life (Richardson *et al.*, 2012). An additional problem is that they may find themselves being exposed to unfamiliar pedagogic practices, such as extended and uninterrupted lecturers' monologues, meaning that they also have to learn new academic skills in order to meet the demands of their degree programmes.

The lecture style of teaching remains very much the preferred way of educating (or should one say 'delivering to') students in HE. A major issue for the students is that lectures move forward at too brisk a pace, as referenced in this article's title. This problem was explored in a study by Macmanaway (1970) which revealed that 20–30 min is the maximum time that the vast majority (84%) of his students could spend actually attending to what was said in a lecture; a finding that was later corroborated by Gibbs *et al.* (1987). According to educational theorists, traditional lectures can also encourage a shallow approach to learning (Ramsden, 1992; Marton *et al.*, 1997; Waldrop, 2015). This can be compared with rote learning in that the students passively receive information without making connections between the new knowledge and real life and consequently rely on memorizing key facts for examinations (Marton & Säljö, 1976). As the term suggests, deep learning is more profound and involves students reflecting on their learning; however, they may not have time for this process when simultaneously pressured to familiarize themselves with an excessive amount of material (ibid, 1976).

In the 1980s, rather than looking to the work of cognitive psychologists for the best approach to learning, Biggs (1987) looked to the students themselves and arrived at a more sophisticated conception of Marton & Säljö's (1976) 'deep' and 'surface' approaches to learning. Biggs (1996) believed that an individual with a surface approach to learning could be helped to modify his or her behaviour by changing the teaching and learning context via 'constructive alignment'. The starting point of this process is to decide the learning outcomes and then to align the teaching and assessment to those outcomes (Biggs, 1996, 2005). However, a further consideration is that first year students' experiences of learning do not generally seem to align with those commensurate for their field of study (Nulty & Barrett, 1996). This suggests that students' needs may have to be accommodated by tutors and lecturers initially, but with the gradual introduction of more discipline-appropriate ways of learning (ibid, 1996). In addition, Anthony (2000, p. 10) found that a lecturer's attitude to and enthusiasm for mathematics has an important role to play in stimulating learning during the first year in HE, but she suspects that lecturers may see their role as providing information rather than providing opportunities for their students to become actively engaged in the analysis and processing of facts.

1 *Economic and Social Research Council-funded project: 'Mathematics learning, identity and educational practice: the transition into Higher Education'.*

More recently, in order to accomplish a 'smoother' transition into HE, Clark & Lovric (2009) suggest that the first-year programme should be changed to accommodate students' diversity of pre-existing knowledge, thus enabling them to build on these foundations. Moreover, Torenbeek *et al.* (2010) claim that the dissimilarity between the student's secondary and tertiary learning environments and the resulting amount of adjustment needed during the transition into HE impact directly on students' academic achievement. Goetz *et al.* (2013) also found that the subject has a bearing on students' learning, with mathematics and physics proving to be less understandable than languages, for example, and so they suggest that a more detailed introduction should be given to new subject-specific vocabulary and that complex ideas should be accompanied by examples and illustrations. However, due to mathematics often being taught as a service subject on STEM programmes, the mathematics lecturers may have difficulty in providing contextually relevant examples to help the students (Harris *et al.*, 2015). There are also concerns about the high cognitive demands of some programmes and the effect these have on the students studying them; in particular, the general sense of being overworked can have a damaging effect on students' emotions and their motivation (Hugener *et al.*, 2009). However, other researchers do not agree with these findings and suggest instead that, with good management and sufficient teaching support, there should be no negative effect on students' emotional of motivational outcomes (den Brok *et al.*, 2004; Kunter & Baumert, 2006).

Finally, one of the major considerations is the presentation of the course materials within the context of a lecture where transmissionist pedagogies are generally prevalent. Zepke *et al.* (2014) maintain that in the light of increasing fees and students' associated high expectations of their lectures and lecturers, it is not sufficient for students to have to be engaged with their learning; more has to be done by the lecturers to engage them. Consequently, perhaps more careful thought needs to be put into the pedagogies used in HE. The rationale for this article is therefore to explore and reflect on the pedagogic practices adopted by mathematics tutors and lecturers during the students' transition into university by addressing the following research questions:

What problems do the students perceive they experience with lectures (and lecturers) during their transition into university?

How are the students' experiences of mathematics before and during the transition similar, different or correlated?

What are the implications for helping transitioning students?

3. Methodology

The data for this analysis were gathered as part of the TransMaths Project which focused on transitional practices between 6fC/FE and HE. In the survey, students who were for the most part studying mathematically demanding programmes were tracked longitudinally until the end of their first year at university. The case studies investigated educational (transition) practices based on observation, documentary analysis and interviews. The project involved the examination of 13 degree programmes across 5 English universities.

Data for our investigation were gathered via a longitudinal survey of students with a maximum of three data points (DP hereafter): DP1 took place either just before or just after they started HE ($N = 1604$); DP2 shortly after the Christmas break ($N = 875$, with 701 common to the first data point); and DP3 at the beginning of their second year ($N = 901$). As can be seen above, student attrition was endemic in this work (i.e. with students leaving the universities or changing their programmes), so to avoid further complications from these missing data (Pampaka *et al.*, 2014a), our sample is restricted to the case studies and we focus here on the responses to particular (relevant) questions. Therefore our sample consists of 598 students who experienced some mathematics in their courses

(Mathematics = 328, Engineering = 98, Physics = 68, Medicine = 73, and Chemistry = 31), of which we focus and look closely at those in STEM (science, technology, engineering and mathematics) courses. We also interviewed 110 students about their experiences of university mathematics, 50 of which at the same time intervals, i.e. 3 times during 12 months and also discussed some emergent issues (e.g. 6fC/FE teachers teaching in university) in small focus groups. The researchers tried to ensure that the same topics were covered in the interviews by following an open-ended semi-structured schedule throughout. Also, in the following discussion, the students' names have been changed to protect their identities, but the pseudonyms do indicate gender and ethnicity. The universities have also been given pseudonyms: the three traditional universities[2] are 'Northern', 'City' and 'Riverside', the two post-92 universities[3] are 'Modern' and 'Hillside'.

For the purposes of this article, we will concern ourselves with the interview data provided by the engineering students from the project because mathematics plays a more significant role in the outcome of their degrees compared with other cases we investigated such as chemistry and medicine, and, in particular, we examine the case study of one service mathematics course for engineering that we argue made a difference.

4. Findings

The survey responses and the interviews suggest that the students recognize that their learning is supported by their mathematics lectures. However, they report inherent problems with lectures for which they were unprepared. Therefore, we consider it useful to explore this contradiction more thoroughly. The findings presented in the following sub-sections reflect the issues with lectures which emerged from the student interviews and surveys and also interviews with lecturers.

4.1 The interview data

The interview data revealed how mathematics at university is different (i.e. coverage of the curriculum, learning, etc.), but as lectures are the predominant context for teaching, this was a theme which was implicated in many of the comments made by students about their experience at university.

4.1.1 Lack of time in lectures. It seems that students' experience at 6fC/FE does not prepare them for the fast pace of lectures and this appeared to cause problems for many students since the lecture 'conversation' often becomes reduced to a monologue. Ellie explained that it was difficult to concentrate in lectures because of people coming in late or talking close to her so that she missed some of what the lecturer was saying, but she was uncertain about asking the lecturer to repeat what she had missed:

> If you don't get something, like I know people do ask questions in lectures but I don't think you really should. I mean they have to get through a certain amount in an hour and so it's not, it's just not as easy to ask. [*Ellie, Engineering, Riverside*]

This student talk, however, may not have been merely social chatter. Our first-hand experience of these lectures (through observations) reveals that many students were 'on task' and 'thrashing out' the mathematics through interacting in lectures in much the same way as they would have done during

2 *Traditional universities are the British universities founded in the late 19th and early 20th centuries in major cities and also the universities established or expanded during the mid-twentieth century.*

3 *Post-92 universities were created by the reclassification of polytechnics in 1992.*

their A-levels.[4] Ellie spoke about the lack of time during lectures to move 'off piste' from the lecture notes and Stuart explained that it was also difficult, if not impossible, to speak to his mathematics lecturer at the end of the lecture:

> Generally the [mathematics] lecturers are quite hard to get hold of sometimes as well, to be honest. They've got very full timetables. In particular my maths lecturer because, like I said, he's always legging it off to his next lecture and the like so he doesn't get time to stop and chat. [*Stuart, Engineering, Modern*]

These interviews suggest that the curriculum is comparatively crowded with insufficient time for anything other than the planned lecture, and the students sense this urgency. The lecturers also discussed the time pressure they were under in lecturing content due to the constraints of the syllabus:

> I kind of know what I've got to get through, and I wish it was more relaxed but then it's almost sort of like a National Curriculum, I have to tick the boxes and say, yes I have to do extreme values, I have to do tangent planes, and then I have to finish with Lagrange multipliers because I've just set an exercise that is due next Friday that is going to involve that at the end of it, and it has to be done. [*Mathematics Lecturer, City*]

Students and lecturers therefore acknowledge that time is very limited for delivering the mathematics curriculum. Yet why does the need to cover every topic in class persist in HE mathematics? In other subjects, it is quite usual to expect students to engage in reading so that they cover more content 'in their own time' as independent study and the more difficult concepts can then be explained during the lectures.

4.1.2 Lack of interaction in lectures. Economies of scale meant that there were large numbers of students in lectures which, in turn, led to a lack of interaction between the students and lecturers, on an individual basis. The overall effect of this was that the lecturers assumed that the students knew (or perhaps were fluent in) the mathematics that they had previously studied and this consequently meant the lecturers had higher expectations than the students considered reasonable:

> It's like when you're tiny you're taught how to add then, if you were doing accounts or something, you'd just take it for granted that you can add. You know, and honestly it feels like integration say for example, is treated like this in engineering. It's just taken for granted that you know it. But it's like as though it's really easy you know, but it's not necessarily. [*Ellie, Engineering, Riverside*]

Possibly as a result of these high expectations, the students believed that the lecturers made the subject matter unnecessarily complicated and the situation could be improved as explained by Halim:

> First of all, I wouldn't explain things in such a complicated manner, it doesn't need to be explained in such a complicated way; you know, break it down, make it a bit easier. Yeah ok, they're clever people but the way I see it, the easier you make it the better it'll be. [*Halim, Engineering, Modern*]

There was a general reticence amongst the students to ask questions in lectures for fear of appearing stupid. Yet this lack of interaction with their lecturers meant that students were forced to adopt a surface learning approach (Marton & Säljö, 1976) to their studies where they passively took in information during the lecture and then regurgitated it for examinations, rather than seeking an answer so that they could make connections with their previous learning (deep learning).

4 *In the UK (except Scotland), an A-level is an academic qualification in a specific subject, typically taken by school students aged 16–18 years.*

Opportunities to ask questions and to engage with the material were available in tutorials and, although Olufemi did not ask questions during lectures, he endeavoured to ask them afterwards and he was particularly positive about the benefits of tutorials:

> Tutorial teaching is, I think it's alright. The person is actually right in front of you, you know, because for lectures you don't go to the teacher until after the class if you want to ask questions because you don't understand. But at the same time, you know, people are having difficulty getting things in class, but they can't be bothered to ask. [*Olufemi, Engineering, Riverside*]

4.1.3 Lack of experience of university mathematics. This issue is two-fold: not only is the mathematics *teaching* not the same, but also mathematics as a *subject* is not the same because the emphasis on proof and rigour is new to the vast majority of students (Seldon & Seldon, 2003; Pfeiffer, 2010; Jooganah, forthcoming). When asked whether students usually take to the idea of proofs or whether they struggle, one lecturer responded:

> It's a new thing for many of them. They've been taught very much in a methods type capacity up until that point and the idea of a fully watertight proof, the fact that the mathematical proof probably means something different from when the word 'proof' is normally used. You know it would mean something like beyond reasonable doubt, but 'no' that's not good enough for us. Some of them are not really taking to that. I suppose one that comes to mind is the legal situation. They would want to, there are certain people who would want to prove a defence of guilty and, you know, things like 'beyond reasonable doubt' come into this but for a mathematician 'no' that's not good enough, beyond the slightest shadow of any doubt. [*Mathematics Lecturer, Riverside*]

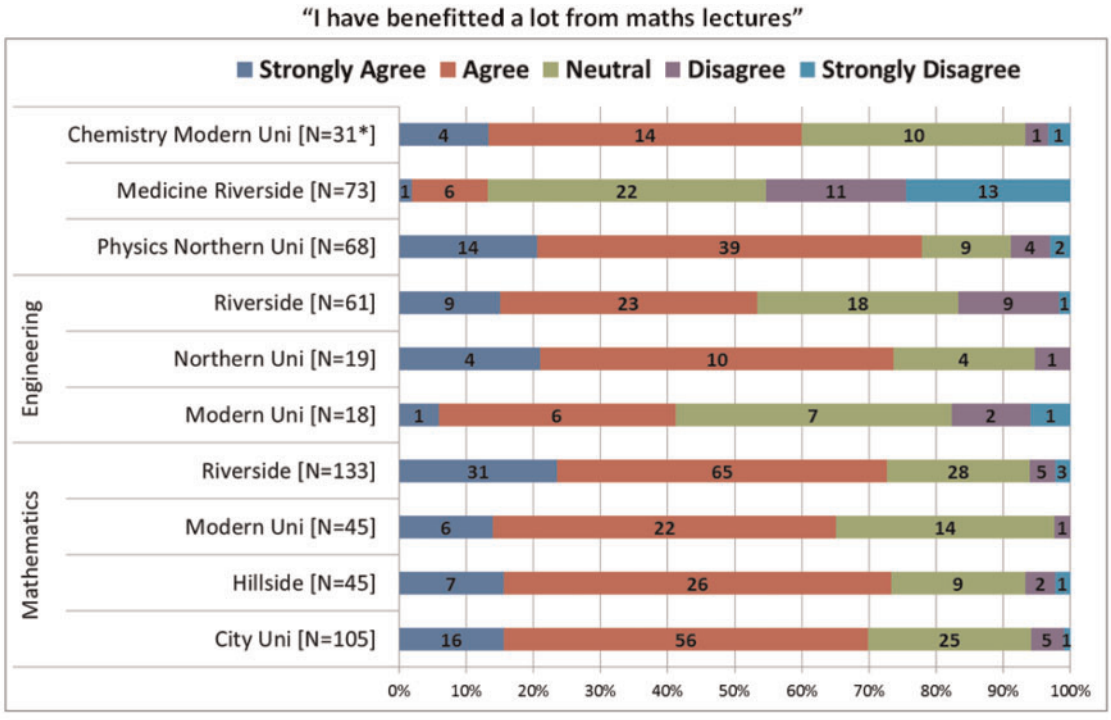
At Northern, the engineering students were taught mathematics in two groups. The majority of the students were taught via lectures (explained in detail in Section 4.3) and one of the students from this larger group explained how he spent days deriving a 'proof' rather than asking for help from his professor because he knew that he had to work it through for himself in order to understand it properly. The example was within the context of Fourier Transforms:

> Well, the professor could say something like, 'Give me a proof' but if you couldn't see it then he'd explain like, 'You do this, this, this and this' and you go, 'Oh, that makes sense', but I don't actually fully understand it. So you go over it again. It's like you don't know it first time. You'll know how to do, like, a high jump first time, and you just keep doing it again and fine tuning it and realize, 'Oh, this is what this is happening here, this is what's happening there exactly'. [*Liam, Engineering, Northern*]

For the majority of the students, the need for conceptual understanding rather than simple procedural fluency is new and unfamiliar. As such, it forms a fundamental transitional issue that shapes students' relationship with lectures during their first year at university. Unlike Liam, many students are not prepared to devote the time to developing this understanding.

4.2 The survey data

4.2.1 Students' perceptions of the benefit obtained from mathematics lectures. In order to address the practices in place to support students in their mathematically demanding courses, we designed an instrument which measured at DP2 what we called 'students' perceptions of the quality and effectiveness of the learning support (for mathematics) during their transition to university' (Pampaka *et al.*, 2014b). One of the items in this measure related to lectures, i.e. 'I have benefitted a lot from maths lectures' and the distribution of the students' responses to the item is shown in Fig. 1.



* Note that the bar charts for each group were derived based on students' valid responses to this question. Missing data resulted from students who considered this question not to be applicable to them (in particular medicine with twenty missing responses).

FIG. 1. Student responses to the statement 'I have benefitted a lot from maths lectures', by subject and university.

As can be seen in Fig. 1, there are differences in students' perceptions about whether they have benefitted from their mathematics lectures. As might be expected, the mathematics students in all cases were positive (around 70%) about their mathematics lectures, whereas only 13% of the medical students (non-mathematically demanding) perceived their statistics lectures (delivered via the university's virtual learning environment) to be beneficial. This may be because the students perceived the subject to be less important for their degree or because of the method of delivery (most students find a big difference between 'live' lectures and recorded lectures) or it may have been a combination of the two factors. Medicine had the largest number of non-responses to this question. Also, the Physics students at Northern University appeared to appreciate their mathematics lectures the most as they reported the highest percentage (almost 80%) of agreement with this statement.

Although mathematics lectures were problematic for some students on most of the programmes involved in the project, what is probably of more interest is the difference between the institutions for the same subject. In particular, the data for engineering in Fig. 1 show a significant difference in the percentage of students that report they benefit from their mathematics lectures, and we examine the reasons why only 42% of the engineering students at Modern and 53% of the engineering students at Riverside considered that they benefitted from their mathematics lectures, compared with 74% of students at Northern University.

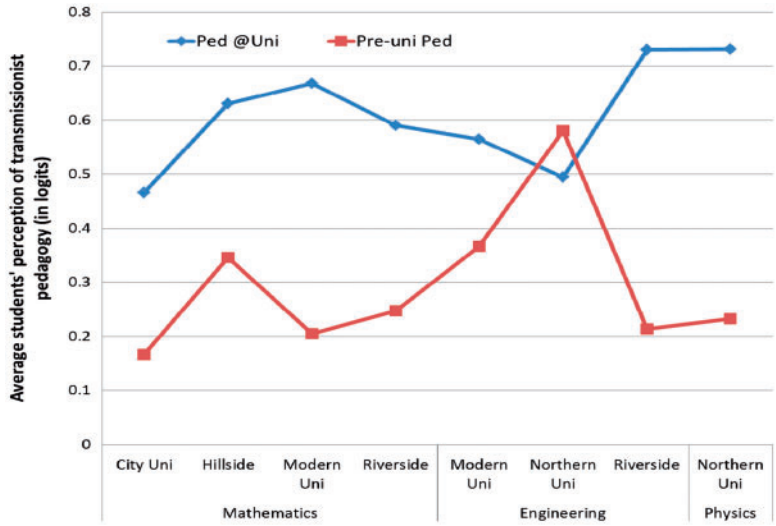


FIG. 2. Average pedagogical practice before and during first year HE.

4.2.2 Students' perception of transmissionist pedagogy during their first year at university. Northern Engineering was also an anomaly in the measurement of transmissionist pedagogy that we developed on the TransMaths project (Pampaka, *et al.*, 2012, Pampaka *et al.*, forthcoming). As shown in Fig. 2, the only exception to the pattern of students believing that teaching at university was overall more transmissionist (compared with pre-university) is the case of Northern Engineering. This case had 30 students who were identified as liable to struggle with service mathematics lectures because of their mathematical ability on entering university (determined by a diagnostic test). The figure also shows that this group had the most transmissionist teaching prior to university which could possibly be the reason why they struggled with the questions in the diagnostic test and were therefore assigned to this smaller group. However, although the survey data provide some overall and aggregated indicators (as per Fig. 2) of students' perceptions of their mathematics lectures and the kinds of transmissionist pedagogy it promotes, the students' interviews explained these patterns further. They revealed some of the contributing factors which exacerbated students' problems with service mathematics, and they also provided detail on the 'different', perhaps more successful approach to teaching mathematics for engineering that was in place at Northern (as hinted at in the survey data in Fig. 2).

In the next section, we examine the case study of service mathematics for engineering students at Northern University.

4.3 The case study of service mathematics at Northern University

Several of the case study universities had 'maths support centres' where students could go, either voluntarily or following direction from their lecturers, to gain help with their mathematics. At Northern this centre was organized by Margaret, a very experienced sixth form mathematics teacher, who appreciated the problems that some of the students experienced:

> You're asking, sometimes, quite young students who've just come to University, to admit to someone that's very senior that they don't understand, and it could be a reflection on the student and seen

> as a bad thing, and maybe a bad mark against them. So that is very hard for them to do that, and then, even if they do that, the lecturer doesn't quite understand and can't get down to their level, and would only explain it again in the way that they've done it in the lecture, and maybe not come to the crux of the problem, you know? But, I think we do need more of a dialogue between students and lecturers, and maybe there has to be someone in-between that can facilitate that, that does have the power to be able to do that. [*Margaret, Maths Support Centre, Northern*]

This is how she saw her role but in order to gain this type of support, the students needed to make the decision that 'yes' they needed help and then make the effort to find out when the support centre was open, and attend. The 'maths support centre' model is used widely within UK universities but the way in which Northern stood out from the rest was that it supported around 30 first-year engineering students by teaching them mathematics together in a small group, rather than with the rest of their year group in a traditional lecture. The numbers in this smaller group were quite fluid and varied from 16–30 students during the lifetime of our research (20 completed the survey), depending on the needs of the students judged on the basis of prior qualifications, the initial diagnostic test and subsequent weekly tests. This course was run by Joanne, a part-time mathematics teacher in 6fC/FE who had been 'bought in' to teach the less able group and she explained the thinking behind her teaching:

> I treat the engineering students much more like college students than I think maybe other lecturers do, because I see them as being very similar to the Year 13's[5] that I have [at 6fC/FE], you know, they're a little bit more mature, but sometimes they just need that spoon-feeding. They need the teaching at step-by-step-by-step and trying not to assume they know anything, so taking them back and, and dividing it down into the smallest parts sometimes is what you have to remember to do. [*Joanne, Mathematics Teacher on the Engineering Programme, Northern*]

Joanne's approach was successful. Her 'lessons' replaced the mathematics lectures for these students; taking exactly the same amount of time and covering similar content. Moreover, with the smaller numbers, students felt more comfortable about asking for clarification which meant that Joanne was able to address the problems as they occurred. Her efforts were appreciated by her students and Joanne explained that some were reluctant to leave:

> We looked at the results last week and six of mine have moved up which hopefully will help the ones that are left in my group although I have to say the six who I told were moving up, they were very reluctant. They said, 'But we're getting sixty-odd per cent, we need your help' and I had to say, 'Other people need my help more'. [*Joanne, Mathematics Teacher on the Engineering Programme, Northern*]

Joanne's 'teacherly' approach and experience was appreciated by her students as explained by her students Martha, Alastair and Jack, in a focus group discussion. Alastair explained the differences between Joanne's classes and the other lecturer's lectures:

> There was no more timetabled time, but she spent more time interacting with us, whereas [the other lecturer] would just stand at the front. It's just, you could ask him a question if you wanted to, but the answers weren't to the same depth. You didn't get the same one-to-one time. [*Alastair, Engineering, Northern*]

Like Alastair, Jack also appreciated the interaction in Joanne's classes:

5 17- to 18-year-olds in secondary education.

> Joanne's is more like a class, like at school was a class. So that's the difference, because lecturers tend to, like, talk to people and just preach the stuff and her class is more interactive. [*Jack, Engineering, Northern*]

It was also apparent to Jack that Joanne had some form of teacher training:

> I thought it was obvious that Joanne, she seemed to have a PGCE or something, like, she was experienced at teaching younger people, and that really came through. She explained things a lot simpler level, and gave step-by-step instructions, whereas with [another lecturer] you sort of had to infer the steps based on people's prior knowledge, because most of them had A-level, if not further A-level maths. [*Jack, Engineering, Northern*]

Moreover, by the beginning of her second year at university, Martha was aware that her mathematics had improved:

> The maths was really, it was okay with Joanne because Joanne really helped us a lot in her class... and now my maths is really better than what it was in the first year, and better than it was before I got into uni anyway. *[Martha, Engineering, Northern]*

So, from what the students told us, Joanne ticked all the boxes in her approach to teaching mathematics to the engineering students which is, no doubt, why they responded so positively to the question about whether they benefited from their mathematics lectures (refer also to Fig. 1). Joanne broke down the content into manageable chunks, gave the students time to ask questions and space to try examples; in fact, she gave them everything that the students from the other universities felt was missing.

It might be argued that this approach is not appropriate for HE, but everyone does not develop into an independent learner at the same rate. By allowing transitioning students who are struggling with mathematics to be supported for a few more months, the potential for them to 'drop-out' because of their mathematics (which is crucial to their engineering studies) is reduced for those who engage. Alastair explains:

> No, I don't think it doesn't mean you're not independent. But I just think it means you have to go find the answer, you're going to find the answer, but you would need to like be shown step-by -step. You just need a push in the right direction. Then you'll just be able to say, 'Yep, that's right, yeah' and then you'll be able to go do it. [*Alastair, Engineering, Northern*]

The argument may be that the students recognized the efforts to create continuity between 6fC/FE and university via Joanne's approach, which is corroborated by Jack's comment about Joanne's teaching being like a class in school and her interviews revealed that she had considered the intended learning outcomes and how best to align her teaching and assessment to those outcomes with these particular students, i.e. she adopted constructive alignment principles (Biggs, 1996). The familiarity of Joanne's teaching may also be positively perceived by the students and thus leave them more disposed to study mathematics, although it cannot be assumed that Joanne was solely responsible for the significantly larger percentage of students stating that they felt they benefitted from their mathematics lectures at Northern. The decision was made to employ Joanne in order to reduce attrition rates at the end of the first year due to engineering students failing the mathematics course; a costly and demoralizing affair for everyone concerned and Margaret wonders why more universities are not concerned:

> But I think, it's really coming to its head now, in universities here, in England, because of the students having to pay for their fees, and if the fees go up more, it's not only the students that'll be

> complaining, it'll be parents and, in particular, in foundation[6] and first year. But I can't see why the universities and departments don't have a real attitude that we have to do better in the foundation and first year, because it's in their own best interests because then, if those students have a good experience, they'll be more inclined to stay on. [*Margaret, Maths Support Centre, Northern*]

However, there were financial implications associated with Northern University's decision to bring in a 6fC/FE teacher to teach a group of 30 engineering students rather than adopt the more usual approach of one service mathematics lecturer teaching the full cohort (approximately 80–100 students). The head of one of the engineering disciplines explained the thinking behind employing Joanne:

> We've done it because we want to give all the students who arrive here the best opportunity to get through the first year. So you know, it's costing us money. Of course we're paying Joanne's wages which is an additional salary that we weren't paying previously, so it's always been done with the best intentions for the students. [*Head of X Engineering Discipline, Northern*]

So Northern considered it worth paying for a part-time 6fC/FE mathematics teacher in order to help their first-year engineering students during their transition into university. Joanne's approach was perceived as ensuring a good understanding of the mathematical content of the engineering course and so was regarded more positively by both her students and those in charge.

5. Discussion

The delivery of the course content in university, i.e. the lecture style of teaching remains privileged but, in reality, neither the A-level nor the Business and Technology Education Council (BTEC)[7] qualifications with their different pedagogic approaches to teaching/learning appear to prepare some students for this change. The qualifications merely signal academic achievement, i.e. they demonstrate exchange value; they do not necessarily suggest that the holder has the ability to adapt this learning into an expedient tool, i.e. that their mathematical knowledge has use-value (see Harris *et al.*, 2015 for further information). Consequently, perhaps more could be done to support students not only in optimizing the time they spend in lectures but also in developing understanding by engaging with the materials, either by completing exercises outside the lecture theatre and by additional reading. For example, perhaps the lecturer from City in particular (and other mathematics lecturers more generally) should have more confidence in their students and recommend a good text book so that they can read up about Lagrange multipliers for themselves. A further issue is the lack of communication between lecturer and students (including asking/answering questions) which meant that their learning experiences were very different to those in 6fC/FE. Macmanaway (1970) and later Gibbs *et al.* (1988) found that most people can concentrate on what is being *said* for only 20–30 min. Therefore, to avoid half of a 1-h lecture being more or less a waste of time for the majority of the students, other teaching approaches should be adopted (ibid). For example, breaking the lecture class into smaller discussion groups of two to four students can be arranged very simply without the need to move places. These groups may discuss a limited topic for a few minutes or a more substantial subject for somewhat longer, with the opportunity for neighbouring groups to be brought together subsequently to discuss

6 A foundation year is an extra year of study at the start of a university course which enables students who do not meet the entry requirements to complete further studies.

7 *In the UK (except Scotland), BTEC is a vocational qualification in an area of work or study, typically taken by school students aged 16–18 years.*

their findings (Gibbs *et al.*, 1988). This change would facilitate a move away from the lecture style of teaching with its transmissionist pedagogies.

In order to help their new students with their study of mathematics, the case study universities had adopted a variety of transitional practices including mathematics/learning support centres, mathematics drop-in centres, online mathematics materials and peer-assisted student support. However, despite these interventions being in place in universities across the UK, Gallimore & Stewart (2014) report that problems persist. It follows, therefore, that universities recognize that the teaching and learning of service mathematics is a problem since so much money, time and effort is expended in an attempt to improve the transitional experiences for their new students. Consequently, at Northern, although Joanne's approach was not necessarily the way that mathematics was usually taught in HE, it was akin to the way the students were familiar with from 6fC/FE, and therefore, this adaptation might be understood by Nulty & Barrett (1996, p. 338) as their 'gradual induction into the culture of their chosen discipline'.

Despite evidence that maths support centres have a positive effect on performance, Mac *et al.* (2009, p. 121) found that the majority of at-risk students (based on diagnostic test results and prior results), did not attend the centres and they therefore concluded that targeting these students was a priority. Northern had achieved this, and this was because a 6fC/FE teacher *replaced* the lecturer for a small group of less mathematically competent students. This meant that students did not have to actively seek help from mathematics support staff, and therefore, the students were more likely to attend and consequently benefit from this support.

Regarding the additional costs of employing Joanne, the head of engineering at Northern considered it worthwhile because she only represented the lost fees of two or three students if they left the programme during or at the end of the first year when they failed their examinations. The student fees at the time of this research in 2008/2009 were £3K per annum with a 'top-up' from the HE Funding Council for England (HEFCE) for UK students and so, if a student left, those fees would be lost to the university. Consequently Joanne's salary would easily be afforded if only two or three most at-risk students did not 'drop-out' and continued with their studies for a further two years. Now, of course, fees are substantially larger thus making employing someone like Joanne even more cost-effective.

6. Conclusion

It seems that the development of pedagogy in HE would benefit from those responsible for mathematically demanding programmes being more critical of lecture-style teaching as being the only way to deliver the curriculum. Moreover, this reluctance to abandon lectures as the main teaching approach, may in fact be contributing to the continuing problems with service mathematics for engineering. This article has discussed interviews with engineering students and staff from three of our case study universities and also supporting survey data from across the project. The over-riding issue reported was that 'mathematics is not the same as it was at school' which could be sub-divided into three key areas namely: lack of time in lectures, lack of interaction in lectures and the lack of experience of the approach to mathematics in university. One innovative solution which proved successful was found at Northern where a teacher's 'lesson' replaced the traditional lecture for as long as was necessary for the students to find their feet as demonstrated by success in the weekly tests. Consequently, the students had everything they felt they needed including the opportunity to learn at a sensible pace, to try examples under supervision, to talk to the teacher and to ask questions.

There are those who will say that they know this already, so why therefore does this contradiction in HE still persist? Economies of scale probably play their part here; it is far less expensive for one person

to lecture to a hundred students than three people to teach groups of 30. However, the introduction of the new HEFCE initiative, the Teaching Excellence Framework, to monitor and assess teaching in universities may encourage those responsible in HE for the delivery of the curriculum to rethink the way content is presented. Also, ignoring the problem in future may not be a sound financial option.

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