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Mathematics Learning Support in Higher Education

Mathematics learning support (MLS) is free support offered to students who are studying any form of mathematics in a Higher Education Institution (HEI); support which is available in addition to their standard lectures and tutorials. The need for such support was identified over time in a number of publications, particularly from the UK, Ireland and Australia (e.g. Gill, 2006; Rylands & Coady, 2009; Sutherland & Dewhurst, 1999), due to the significant numbers of first-year students entering HEIs who exhibited weak mathematical backgrounds but still needed to undertake one (or several) mathematics modules (Organisation for Economic Co-operation and Development, 1999; Savage, Kitchen, Sutherland, & Porkess, 2000; Sutherland & Pozzi, 1995). This issue has been labelled the "Mathematics Problem", and a detailed review can be found in Lawson, Croft, & Waller (2012).

MLS strives to provide a solution to the "Mathematics Problem" by supporting students in overcoming any difficulties they might have with mathematics in a relaxed, informal atmosphere (Lawson, Halpin, & Croft, 2001). The most common form of MLS is in-person support, offered on a one-to-one or small group basis (Cronin, Cole, Clancy, Breen, & Ó Sé, 2016; MacGillivray, 2009;

Perkin, Lawson, & Croft, 2012). This usually takes the format of drop-in sessions, whereby students attend whenever they like for as long or short a time as suits them; but some MLS is offered on an appointment basis instead (Barton & Bowers, 2015; Grove, Croft, Lawson, & Petrie, 2018a). The advantage of a drop-in approach is that students can be helped in rotation, with a tutor setting small goals for each student, while they help another student, before returning to assess how the first student is progressing. The difficulty is in timetabling the correct number of tutors for the optimal hours in terms of maximising the support provided, but the best solution for this will often depend on the particularities of the institution involved. However, it seems that of late, in the UK at least, there has been a move towards providing both drop-in and appointment options, possibly for more advanced topics or to allow students a guarantee of assistance (Grove et al., 2018a).

Other forms of MLS offered include workshops on problematic topics; support tutorials, in which the material from regular tutorials is covered at a slower pace; and online supports. The latter is far less widely available than in-person supports, with a recent Irish audit listing online support provision in 48% of institutions who offer MLS (Cronin et al., 2016) and a similar Scottish one reporting figures of 61% (Ahmed et al., 2018). This online support usually consists of websites, an institutional Virtual Learning Environment (VLE) site, links to videos or resources, or formative assessment programmes. Recently, some HEIs have experimented with the provision of one-to-one MLS on an online basis (Breen, O'Sullivan, & Cox, 2016; Grove et al., 2018a; Hawkes & Hodds, 2016), but this approach is largely still in its early stages. Social media is also of late being used by MLS (Voake-Jones, 2016), but primarily for publicity purposes, with MLS services setting up accounts on Facebook, Twitter or Instagram to allow students to check timetables and locations of services.

Growth of mathematics support

In the UK, Ireland, and Australia, there has been particularly widespread growth in the area of MLS over the past twenty years.

This can be tracked through a series of surveys, audits and studies undertaken in each place; although the methodologies and sampling approaches differed considerably, it is clear there is an upward trend throughout in the provision of MLS.

As early as 1994, a survey was sent to 800 Further Education Institutions (FEIs) and HEIs in the UK, of whom 142 (17.75%) responded, all of whom offered some form of MLS at that time (Beveridge & Bhanot, 1994). A similar survey three years later found that drop-in MLS workshops were offered by 56% of the 200 FEI/HEI respondents (Beveridge, 1997). In 2001, 48% of the HEI respondents had MLS (n=95) (Lawson et al., 2001); by 2004, this had risen to 62.3% (where n=106) (Perkin & Croft, 2004); with a further rise to 85% of the 119 HEIs surveyed 8 years later (Perkin et al., 2012). A more detailed review of these developments is available in Lawson, Croft, & Waller (2012).

As far afield as Australia, a similar pattern emerged, with the first MLS-type role identified as early as 1973, and the first two MLS centres established in 1984 (MacGillivray, 2009). By 1999, 46% of Australian HEIs offered MLS drop-in services (12 out of 26) (Taylor, 1999) whereas by 2007, 85% (33 out of 39) of Australian HEIs had some form of MLS (MacGillivray, 2008).

The formal provision of MLS in Ireland started somewhat later, with the first MLS centre opening in the University of Limerick in 2001 (Gill, Mac an Bhaird, & Ní Fhloinn, 2010); however, growth in MLS provision has been rapid and widespread . A detailed account of these early years can be found in Gill, Mac an Bhaird & Ní Fhloinn (2010). However, within seven years, an audit of MLS reported on MLS provision in 13 HEIs in the Republic of Ireland (Gill, O'Donoghue, & Johnson, 2008). Seven years later again, another Irish audit showed MLS provision in 83% (25 of 30 respondents) of HEIs on the island of Ireland, 20 of which were based in the Republic (Cronin et al., 2016).

Several helpful guides to setting up and operating MLS centres have been produced to assist those interested in doing so, based on best practice in the area (Croft, 2000; Croft, Harrison, & Robinson, 2009; Mac an Bhaird & Lawson, 2012). Across Europe, MLS

services have also been established in countries such as Portugal (de Almeida & Gomes, 2015), Norway (http://www.matric.no/dropin), Switzerland (http://www.mathematikzentrum.ch/home-en/) and the Czech Republic (http://msc.utb.cz/, http://msc.vsb.cz/, https://mathstat.econ.muni.cz/), although the majority of these are still in their early years of operation, while in New Zealand, a number of HEIs now offer MLS services (e.g. http://mathsfirst.massey.ac.nz/, https://www.math.auckland.ac.nz/en/for/current-students/maths-help.html, https://www.victoria.ac.nz/student-learning/studyhub/maths-and-stats).

National networks and conferences

In parallel with this growth in mathematics support has been the formation and expansion of formal MLS national networks, which promote MLS and run seminars, workshops and conferences encouraging research and best practice in MLS. In 2005, the sigma Centre for Excellence in University-wide Mathematics and Statistics Support was launched as a HEFCE-funded (Higher Education Funding Council for England) Centre for Excellence in Teaching and Learning (CETL), consisting of a combination of the Loughborough and Coventry MLS support services. Together with the MSOR Subject Centre of the Higher Education Academy, they established the CETL-MSOR annual conference series, with the first of these conferences taking place in 2006 (Fletcher, 2013). Subsequently, in 2010, the sigma network was formed, with particular remit for MLS in England and Wales (Croft et al., 2014). The Scottish Mathematics Support Network (SMSN) was set up in 2008 (Ahmed & Durkacz, 2012), at a meeting funded by sigma, and has since gone on to hold annual meetings. The Irish Mathematics Learning Support Network (IMLSN) was formally established in 2009, although the Irish Workshop on Mathematics Learning and Support Centres had been running since 2006 on an annual basis (Mac an Bhaird, Gill, Jennings, Ní Fhloinn, & O'Sullivan, 2011). In recent years, the sigma, SMSN and IMLSN networks have come together to jointly run the CETL-MSOR conference, with it being hosted by a different network each year. In 2018, it ran for the first

time outside of England or Wales, when it was held in Glasgow, Scotland (http://www.sigma-network.ac.uk/cetl-msor/cetl-msor-conference-2018/), and in 2019, it will be held in Dublin, Ireland. This co-operation between networks has been a feature of the MLS networks since their inception, and greatly contributes to the sharing of ideas and resources throughout the community. Again, this experience is mirrored in Australia, where the biennial Delta conference (the Southern Hemisphere Symposium on Teaching Undergraduate Mathematics and Statistics) provides a dissemination outlet for those working in MLS provision in the area (MacGillivray & Croft, 2011).

Notable research in mathematics support

The establishment of national MLS networks alongside regular MLS conferences has contributed greatly to the level of research that has been conducted to date in MLS, with evidence of scholarly practice across MLS (Samuels & Patel, 2010). This research has focused on areas such as student usage/non-usage of MLS; student retention/performance; impact of MLS; training of MLS staff; and non-traditional entrants to HEIs. An in-depth discussion of MLS research to-date is beyond the scope of this chapter, so instead we provide a brief overview of the main themes explored, highlighting some of the most influential papers. For a more detailed review, particularly in relation to the evaluation of MLS services, Matthews, Croft, Lawson, & Waller (2013) should be consulted.

Usage of mathematics support

Some of the earliest research in the area of MLS centred around usage of the services, in particular attendance at drop-in services. Many early studies reported the number of unique visits, students, spread of disciplines covered and pattern of visits to show engagement with the service (e.g. Croft, 2000; Ní Fhloinn, 2010; Woodhouse, 2004). Analysis of these patterns of engagement can assist with planning around such issues as the optimal opening hours for the service; the number of tutors needed at various times; and whether additional

space is required to facilitate MLS users during busier periods (MacGillivray & Croft, 2011), as well as justifying the existence of MLS by showing student engagement. These studies progressed on to considering which students were using MLS, and found that in many cases, it was not only those at risk of failing who engaged with MLS, but also those who wanted to improve a top grade (Croft & Grove, 2006; MacGillivray, 2009; Patel & Little, 2006; Pell & Croft, 2008). Analysis of an Irish multi-institutional survey showed that female students were almost two and a half times more likely to engage with MLS than male students, while controlling for prior mathematical achievement, degree programme, and HEI attended (Ní Fhloinn, Fitzmaurice, Mac an Bhaird, & O'Sullivan, 2016). Students' reasons for using MLS have also been investigated, with students mentioning upcoming exams/assignments, a need for extra help, a desire to improve their understanding, and the fact that they find mathematics difficult as some of their motivations for attendance (O'Sullivan, Mac an Bhaird, Fitzmaurice, & Ní Fhloinn, 2014).

As well as investigating the usage of MLS, another important focus is on the non-users of MLS services. Ideally, the only non-users of MLS would be those students who do not need to avail of the services. However, it has long been observed that this is not the case (Mac an Bhaird, Fitzmaurice, Ní Fhloinn, & O'Sullivan, 2013) and there remains a cohort of students who do not engage with MLS in any way and subsequently fail their mathematics module. A national survey undertaken in Ireland by the IMLSN found that roughly one-third of the 1,633 respondents had engaged with MLS, another third had not as they felt they did not need to, and a final third had not but may have needed to (O'Sullivan et al., 2014). Symonds (2009) conducted interviews and focus groups with both users and non-users of MLS in an attempt to determine the barriers to MLS usage. She found that those who engage with MLS are generally "well-motivated and cognitively engaged" while non-users who could have benefitted from MLS lacked the motivation to engage. Other barriers to engagement that have been reported include fear (Grehan, Mac an Bhaird, & O'Shea, 2011); unawareness or unwillingness to admit that they have a problem (Grehan, Mac an Bhaird, & O'Shea, 2016); and general problems

with MLS structures such as unsuitability of MLS times or locations (Mac an Bhaird et al., 2013).

Student retention and performance

While MLS services aim to provide a partial solution to the "Mathematics Problem", they do of course incur a financial cost to each HEI, primarily in terms of staff costs, but also in terms of space and resources. However, these costs pale in comparison with the loss of revenue incurred by HEIs by students dropping out in the first year of their undergraduate programme (Faulkner, Hannigan, & Fitzmaurice, 2014). The justification for MLS is both moral and financial: if students are accepted into a HEI, there should be a reasonable expectation that they will be able to be successful in their studies, should they use the supports available to them; and students who drop out or fail to progress in their studies represent a loss of revenue to any HEI. Research into the effectiveness of MLS has been ongoing by MLS practitioners, but often with a focus (either direct or indirect) upon retention. It can be very difficult to determine whether MLS was the key reason behind the retention of any given student (Ní Fhloinn, 2010). However, the national survey undertaken by the IMLSN (which asked students directly about retention) found that 22% of respondents who had availed of MLS had considered dropping out of their degree programme due to difficulties with mathematics, and almost two thirds of these cited MLS as having had a positive impact upon their retention (O'Sullivan et al., 2014). In addition, sigma have produced a guide specifically aimed at Pro-Vice-Chancellors in the UK, outlining the benefits of MLS and highlighting the related research in this area (Croft, Grove, & Lawson, 2016), as the financing of MLS services is an ongoing challenge for many practitioners.

Another approach to improve student retention through MLS involves diagnostic testing, with supports put in place for those students deemed to be "at-risk" as a result (LTSN MathsTEAM Project, 2003). Such diagnostic testing is not always undertaken by MLS services, but commonly they are linked, with students recommended to engage with MLS at an early stage if they score low

on the test (Carr, Murphy, Bowe, & Ní Fhloinn, 2013; Robinson & Croft, 2003). While such diagnostic testing has also provided practitioners with a benchmark of mathematical proficiency over time (Faulkner, Hannigan, & Gill, 2010; Gill, O'Donoghue, Faulkner, & Hannigan, 2010; Lawson, 2003; Treacy & Faulkner, 2015), there has been evidence to suggest that students also find the process useful (Ní Fhloinn, Mac an Bhaird, & Nolan, 2014).

In addition to improving student retention, studies have also been undertaken in relation to the impact of MLS upon student examination performance (Hillock, Jennings, Roberts, & Scharaschkin, 2013; Lee, Harrison, Pell, & Robinson, 2008; Rylands & Shearman, 2018), showing overall improved performance among those who engaged with MLS. The IMLSN study mentioned above reported 56% of respondents who had used MLS thought it had some or a large impact upon their subsequent examination performance (Ní Fhloinn et al., 2014), with students mentioning improved grades and better understanding. In the case of students considered to be "at-risk" of failing their mathematics module, those who engaged with MLS did better on average than those who did not (Berry, Mac An Bhaird, & O'Shea, 2015; Gallimore & Stewart, 2014). More recently, Jacob and Ní Fhloinn (2018) studied MLS data in an Irish HEI over the past 12 years and used binary logistic regression to show that, when prior mathematical achievement and module studied were kept constant, the odds of a student who engaged with MLS once passing their module were 1.63 times higher than for one who had never engaged; and for those who attended 15 or more times, the odds were almost 14 times higher.

Impact of mathematics support

In addition to performance and retention, the impact of MLS upon the students who engage with the services is another large area of research. When researching impact in relation to MLS, "there is a danger of confusing impact with student satisfaction" (Green, 2012, p.3), although student satisfaction with the service is also a key issue, as this will impinge upon usage. As a result, although many MLS services issue regular student surveys to gauge student

satisfaction, many researchers have gone further than this in the study of impact. A number of recent studies, for example, have investigated mathematical confidence for users of MLS (Dzator & Dzator, 2018; Gillard, Robathan, & Wilson, 2012; Ní Fhloinn, Fitzmaurice, et al., 2014; Wilkins, 2015), all finding self-reported improved confidence levels for students after engaging with MLS. Another study showed that 65% of respondents felt MLS helped them to cope better with the mathematical demands of their overall course (Ní Fhloinn, Fitzmaurice, et al., 2014). MLS has also been shown to help students to overcome previous negative experiences and perceptions of mathematics (Nzekwe-Excel, 2010), and to help them with their approach to study (Carroll & Gill, 2012). An innovative, qualitative study conducted with 2nd and 3rd year mathematics students engaged with MLS considered the manner in which MLS developed a "social learning space" for these students, rich with peer support (Solomon, Croft, & Lawson, 2010).

MLS staff and training challenges

Recruiting and training MLS tutors is an outstanding challenging for those involved in MLS. Those who tutor in MLS come from a variety of backgrounds: in Ireland, 48% of MLS services use postgraduate students as tutors; 36% use undergraduates; and 72% had at least one full-time academic staff member working as a tutor (Cronin et al., 2016); in Scotland, the corresponding figures are 61% using postgraduates, 8% undergraduates and 69% using full-time academic staff (Ahmed et al., 2018); while in England/Wales, the most recent figures suggest 49% using postgraduate tutors, 12% using undergraduates, and almost 90% using full-time academic staff (Grove et al., 2018b). Attempts have been made to standardise the training process for MLS tutors in recent years, particularly through the sigma, SMSN and IMLSN networks (e.g. Croft et al., 2013; Fitzmaurice, Cronin, Ní Fhloinn, O'Sullivan, & Walsh, 2016; Pfeiffer, Cronin, & Mac an Bhaird, 2016). These initiatives have generally consisted of standardised tutor training workshops being offered in different locations, open to any MLS tutors from any institution. These can be of particular benefit to those in

smaller institutions, where training opportunities may otherwise be limited. Sigma have also produced a detailed guide on tutor training, highlighting best practice in this area (Croft et al., 2011). Recent research has shown the importance of such training, by highlighting the issues that can arise when MLS tutors do not have a background in education (Walsh, 2017).

Non-traditional students and MLS

Research in the area of MLS has also focused on those non-traditional entrants to HEIs who may need particular support, such as mature students or students with accessibility issues. The definition of "mature student" can differ slightly between countries (e.g. over 21 in the UK; over 23 in Ireland), but in general, this term refers to students who enter HEIs at an older age than is traditional, and not directly from school. An Irish study found that a statistically significant higher proportion of mature students engaged with MLS when compared with traditional students (62% vs 32%) (Fitzmaurice, Mac an Bhaird, Ní Fhloinn, & O'Sullivan, 2016). Mature students stressed their desire to understand the material (Breen, Prendergast, & Carr, 2015; Ní Fhloinn, 2008) and how the one-to-one nature of MLS assisted greatly with this (Breen, Prendergast, & Carr, 2015), and that they changed their study habits as a result of MLS, approaching study with the right attitude (Dzator & Dzator, 2018).

Another group of non-traditional entrants that frequent MLS services are students with accessibility issues, for example dyslexia, dyscalculia, autistic spectrum disorder or AD(H)D, among others. From 2003, the Dyslexia and Dyscalculia Interest Group (DDIG) (http://www.lboro.ac.uk/departments/mec/activities/maths-statistics-support/thedyscalculiaanddyslexiainterestgroup) based within the Mathematics Education Centre in Loughborough University brought MLS practitioners with an interest in special learning difficulties together with disability support staff with an interest in mathematics. A number of articles appeared in MSOR Connections in particular, to disseminate research in this area among practitioners, addressing areas such as creating accessible

web forms, mathematical equations in Braille, and providing MLS for dyslexic students (e.g. Beacham & Trott, 2005; Ford, 2002; Maddox, 2007; Rowlett & Wright, 2005; Trott, 2003). In 2012, a good practice guide for accessibility issues in mathematical sciences was produced (Cliffe & Rowlett, 2012), although the focus was not specifically on MLS. In 2016, sigma established a Special Interest Group (SIG) on accessibility, who undertook a survey of current awareness of accessibility issues within MLS (Cliffe, Mac an Bhaird, Ní Fhloinn, & Trott, 2019) and are creating a suite of resources for MLS practitioners,to assist them with students presenting with the most common accessibility issues (Cliffe, Mac an Bhaird, Ní Fhloinn, & Trott, 2018)."

Possible future directions for mathematics support

The mathematics support community is continuing to adapt and improve their services with the aim of providing the optimum support to as many students as possible. As a result, there are a number of research movements within the community that may influence future trends in the area. One area which appears likely to come to the fore is that of providing online mathematics support in as effective a means as possible. This area is under-researched as of yet, with the majority of MLS services not also providing an online one-to-one support element, but there is a growing interest in the field (Cronin & Breen, 2015). Online support is not without its challenges, as outlined by the experience in Coventry University (Hawkes & Hodds, 2016; Hodds & Xu, 2018), where take-up of their pilot "around-the-clock" online MLS support was disappointingly low. However, when striving to engage those students who need MLS but do not currently attend, movements towards online provision may attract some of these students into MLS, as well as providing practical solutions for multi-campus HEIs.

In addition, the establishment of Statistics Advisory Services (SAS) have become more widespread in recent years (Patel, De Jager, & Zou, 2010). Some of the demands of statistics support differ from those of MLS: for example, in the University of Sheffield, they found that most requests for statistics support related to carrying out an analysis

for a project, rather than on specific skills as might be requested in MLS (Patel et al., 2010), and as such, SAS is usually provided on an appointment basis in addition to standard MLS services (Owen, Samuels, Wrightham, Leckenby, & Gilchrist, 2011; Samuels & Gibson, 2013). Sigma has recently established a SIG for statistics support, bringing together researchers and practitioners in the field to ensure wider dissemination of their expertise. In addition, this SIG will maintain and develop statstutor (www.statstutor.ac.uk), a free online resource including videos and paper-based resources for statistics support (Owen, Green, Petrie, Davis, & Marriott, 2010). Bringing together both the online element and SAS, Owen et al reported on an initiative where a number of HEIs came together to provide an online SAS across the HEIs, as a means of providing SAS without incurring the full costs of a service for an individual HEI (Owen et al., 2011). It is likely that SAS will continue to expand in the coming years, as demand for their services continues to grow.

A sigma-commissioned report on senior management perspectives on MLS highlighted the benefits of national and international collaboration and networking in relation to the provision of effective supports (Tolley & Mackenzie, 2015). This has always been a feature of MLS provision to date, and it is hoped it will continue thus in the coming years, in order to go on promoting mathematical literacy among undergraduate students; assisting them to achieve their potential mathematically; and improving attitudes towards and experiences of mathematics.

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