Teaching Mathematics and its Applications: An International Journal of the IMA (2023) **42**, 249–265
https://doi.org/10.1093/teamat/hrac017 Advance Access publication 5 October 2022

A survey of Mathematics Learning Support in the United States

Ciarán Mac an Bhaird[†,*] and David A. Thomas[‡]

[†]*Department of Mathematics and Statistics, Maynooth University, Maynooth, Co. Kildare, W23 HW31, Ireland*
[‡]*Mathematics Education Associates (math-ed.com), Great Falls, MT 59401, USA*

[*]*Corresponding author: E-mail:* ciaran.macanbhaird@mu.ie

[Received December 2021; accepted September 2022]

Mathematics Learning Support (MLS) has been widely available in Higher Education Institutions in the United States (US) for decades. However, until recently, there has been little research that considered the extent of provision. In this paper, we present the results of a survey of MLS with responses from 268 institutions across the US, which indicate that such support is well established across responding institutions. To place these results in context, we compare them to other recent international surveys of provision. We discuss what these findings mean and the collaborative opportunities that are available for US and international practitioners and researchers in this area.

1. Introduction

Higher Education (HE) in the United States (US) has been struggling for years to meet the expectations of parents, students and political leaders, many of whom believe that essentially all high school graduates should pursue post-secondary education via undergraduate level community colleges and/or universities (Kolluri & Tierney, 2018). Unfortunately, many of those graduates are underprepared when they continue mathematics after high school (Evensky *et al.*, 2006). For example, Hoachlander *et al.* (2003) reported that approximately 54% of entering community college students lacked essential skills associated with success in post-secondary Mathematics and English courses. This observation has been echoed in many subsequent papers, including McCormick & Lucas (2011), Houser & An (2015) and Burrill (2017). The situation in other colleges and universities is similar in type and magnitude. This concern over the mathematical standards of students transitioning from secondary school, often labelled as the 'mathematics problem', is also evident internationally, for example in Ireland (Gill *et al.*, 2010), the UK (Lawson, 2003), Germany (Gueudet, 2008) and Australia (Rylands & Coady, 2009). Mathematics Learning Centers (MLCs) have been established as one response to this issue (Lawson *et al.*, 2020).

Recent reports in the US have also expressed concern about how mathematics is taught in HE, for example the standard of teaching to non-specialist mathematics students (PCAST, 2012) and the connections to other disciplines (NRC, 2013). The 2015 Mathematical Association of America (MAA) report on undergraduate mathematical sciences stated that

> '*The high rate of failure in post-secondary mathematics classes is an embarrassment to our profession. It is a major contributor to increased attrition rates, and it lengthens time to degree at all types of post-secondary institutions. Mathematics courses are the most significant barrier to degree completion in both STEM and non-STEM fields.*' (Saxe & Braddy, 2015, p. 28).

Concurrently in the US, shrinking instructional budgets have led many colleges and universities to reduce support for or selectively eliminate remedial and developmental mathematics courses (Berkopes & Abshire, 2016).

Research suggests that regular engagement with MLCs can impact student retention and progression (Pell & Croft, 2008; Berry *et al.*, 2015). In the US, a growing body of research focused on the retention and success of mathematics and statistics students has emerged and diverged, addressing a wide spectrum of needs, behaviours, strategies and outcomes. For instance, Wurtz (2015, p. 2) reported that, at a Southern California community college, '*students who utilized a learning assistance center were three times as likely to be successful in their course and almost twice as likely to persist to the subsequent term*'. The impact of MLS services on student success and persistence is not limited to transition and/or introductory mathematics courses. According to the MAA National Study of College Calculus (Bressoud *et al.*, 2015), although more than one third of US Calculus I students are assisted by undergraduate mathematics peer tutors, undergraduate mathematics tutoring is under researched (Mills *et al.*, 2017).

The authors met via the sigma (Centre for Excellence in Mathematics and Statistics Support) network in 2016 and began a correspondence focused on MLS practices in Ireland and the UK and the role that surveys of MLS provision can play in instigating practitioner collaboration. The first author had been an editor on the then recently completed survey of MLS provision in Ireland (Cronin *et al.*, 2016). Among many outcomes, this report provided insight into how commonplace MLS was in Irish HE and on the range of MLS available. The corresponding terms 'level' and 'type' of MLS are often used in such studies, and we adopt that terminology in our paper. At that time, to our knowledge, there was no community of practice for MLS in the US and no survey of the extent of MLS provision had been completed. As a result, we decided to carry out such a survey. We had one research question: What is the level and type of MLS provided in US HE?

In this paper, we provide a brief overview of previous surveys of MLS provision. We describe both MLS in the US and the US HE system, and we outline our methodology and results. We then discuss our findings in comparison with the most recent surveys across Ireland, Germany and the UK. We also include a 2017 survey from the US (Mills *et al.*, 2020), which, although not a survey of the extent of MLS provision, does provide relevant context as it focused on MLS and was carried out just prior to our own. We close with observations on the answers we found to our research question and their implications for future MLS research and collaboration in the US and internationally.

2. Background and methodology

2.1 Surveys of the extent of MLS provision

Surveys of MLS provision have become increasingly commonplace and have been used to great success to help facilitate communities of practice across different countries, and indeed, between countries. The surveys are well described elsewhere, for example in Lawson *et al.* (2020) and many of the survey reports or papers spend considerable time describing other surveys and or comparing their findings to previous ones. To avoid repeating such descriptions here, we provide a very brief timeline of the surveys along with comments on the growth of MLS. There are other surveys outside the US, for example

Grove *et al.* (2018), which considered the types of MLS provided in much more detail. However, as they are not surveys of the extent of provision, we do not consider them in this section. Further detail on the three most recent surveys of the extent of provision (Cronin *et al.*, 2016; Grove *et al.*, 2020; Schürmann *et al.*, 2021) is included in Section 4 to facilitate a comparison with our own survey data.

The earliest surveys of the extent of MLS provision were conducted in the UK, starting with Lawson *et al.* (2001) who reported that 46 of 95 institutions answering a questionnaire indicated that they provided some sort of MLS. Forty-one of these then answered questions about the operation of their MLS, which is summarized in the rest of the paper. Systematic and sustained MLS was emerging in the UK at this time, led largely by the work started in the 1990s by Loughborough University and Coventry University (Croft *et al.*, 2015). Together, they established and led UK-wide and international dissemination activities of benefit to those providing MLS at other universities. A 2004 survey (Perkin & Croft, 2004) found that 66 of 101 institutions were providing MLS. In 2005, Loughborough and Coventry universities collaborated in founding the **sigma** Centre for Excellence in Teaching and Learning (CETL) in the provision of mathematics and statistics support. From 2010, CETL helped to establish a network of regional hubs in England and Wales, provided funding and other assistance to establish new MLCs, run workshops and conferences focusing on effective teaching and learning support and created new resources for practitioners and students needing MLS.

The next survey of provision in the UK demonstrates the remarkable growth of MLS (Perkin *et al.*, 2012), with 88 of 103 responding institutions providing MLS. Similar growth was also being documented in other countries. A 2007 survey in Australia found that 32 of 39 universities had some level of MLS (MacGillivray, 2009). MLCs had been in existence in Australia since at least 1984 (Dzator & Dzator, 2018). In the Republic of Ireland, where there were approximately 21 HEIs at this time, a 2008 report found that 13 provided MLS in some capacity (Gill *et al.*, 2008). As a result of the momentum gathered from that report, together with the commencement of annual workshops (Gill *et al.*, 2010), and, inspired by sigma, the Irish Mathematics Learning Support Network (IMLSN) was formed in 2009. Its aim was to provide a forum for practitioners in Ireland to learn about best practice in MLS, both from each other and from colleagues in the UK. MLS had commenced in an informal way in Ireland in the late 1990s with the first MLC opening in 2001 (Cronin *et al.*, 2016).

In 2015, there was an investigation of the state of MLS at 31 institutions in Northern Ireland and the Republic of Ireland (Cronin *et al.*, 2016), including universities and institutes of technology. They found that 25 of 30 responding Higher Education Institutions (HEIs) provided some level of MLS. This report, which we label as Ireland2015, is featured in more detail in Section 4. While funding for the sigma CETL finished in 2016, sigma took steps to ensure that the community of practitioners would continue to meet, collaborate and add to the numerous publications available to support the work of practitioners and researchers within the MLS community (https://www.sigma-network.ac.uk/). The sigma network was established, and an international steering committee was put in place to ensure that the CETL-MSOR (Continuing Excellence in Teaching and Learning in Mathematics, Statistics and Operations Research) annual conference continued. This conference, while not exclusively for MLS, is considered by MLS practitioners, especially in Ireland and the UK, as the annual international MLS conference. The next survey of MLS provision was implemented by members of the Scottish Mathematics Support Network in 2017 (Ahmed *et al.*, 2018), and they found that 13 of 17 HEIs in Scotland provided MLS. In 2018, another survey focused on MLS in England and Wales. Grove *et al.* (2020) reported that a total of 78 of 88 responding HEIs provided MLS. This survey, which also contains some comparisons of findings with the 2017 Scottish (Ahmed *et al.*, 2018) and 2015 Irish (Cronin *et al.*, 2016) surveys, is reported on in further detail in Section 4 where it is labelled EnglandWales2018.

Prior to the distribution of our survey, the authors were aware of the details, in some cases provisional, of the surveys listed previously. During the survey distribution and subsequent initial analysis, three further relevant studies came to our attention. Two from the US are described in the next section, and the third was from Germany. Although MLS has been a feature of German universities for at least two decades (Bausch *et al.*, 2014), few studies have been conducted characterizing MLS at German universities. In 2019, a systematic review of the websites of 190 German universities was conducted and the researchers reported on survey results from 61 MLCs across 51 HEIs (Schürmann *et al.*, 2021). This survey, which we provide more detail on in Section 4 under the heading Germany2019, also contains some comparisons with other surveys of MLS provision already mentioned (Cronin *et al.*, 2016; Ahmed *et al.*, 2018; Grove *et al.*, 2020).

2.2 *US HEIs and MLS in the US*

Higher (i.e. tertiary or post-secondary) education in the US includes the following:

- Non-degree programmes offering certificates and diplomas delivered by community and technical colleges, and
- Degree programmes at the associate (2 year), bachelor (4 year), masters and doctoral levels delivered by a variety of public and private institutions.

Anecdotal evidence suggests that MLS has been established in the US for several decades, but, according to Matthews *et al.* (2013), published research on any such MLS has been sparse. In 2016, *QMaSC: A Handbook for Directors of Quantitative and Mathematics Support Centers* (Coulombe *et al.*, 2016) was published. *QMaSC* appears to be the first systematic, collaborative attempt to describe the roles, responsibilities, challenges and operational features of MLCs in the US. The handbook is described on https://scholarcommons.usf.edu/qmasc_handbook/ as follows:

> '*. . . a resource for people who lead, manage or direct Mathematics and Quantitative Support Centers (QMaSCs). In the chapters below, directors will find information about how to 1) manage a center, 2) interact with other entities on their campus, 3) train and build a staff, 4) assess their center, and 5) start a new center. Each chapter is written by an experienced center director recognizing the diversity of QMaSCs. Additionally, there are ten case studies authored by directors representing a range of centers, from community colleges to liberal arts colleges to large research institutions*'.

While not a survey of the extent of MLS provision, this collaborative publication provides evidence for a community of practice in MLS in the US. Each chapter offers well-founded insights and practical advice, with a small number of references to research-based findings and best practices. Essentially, the handbook was written by and for practitioners charged with delivering meaningful, sustained support to struggling mathematics students, especially those in transition-to-university and core mathematics courses.

Reporting on another survey of MLS that was issued in 2017, and closed in the summer of 2018, Mills *et al.* (2020, p. 1) offer a '*snapshot of the day-to-day operations of mathematics centers in the USA*'. We will report on this research in more detail in Section 4 under the label US2017. While it is not a survey of the extent of provision, they did receive responses from 75 HEIs who provided MLS. The paper gives an overview of different types of MLS in the US and provides additional insights on the state of MLS and related areas in the US prior to their survey. For example, they describe studies that consider the support offered to students taking Calculus I, which is a common requirement for most undergraduates in the US (Johnson & Hanson, 2015). They refer to research on mathematics tutoring, for example,

Tinsley *et al.* (2018), and also to investigations of the synergy between students and MLS tutors. See, for example, James & Burks (2018). Mills *et al.* (2020) also reveal that the National Science Foundation had funded two projects in relation to MLS. One relates to the work of Coulombe *et al.* (2016). The second '*was the Mathematics Learning Resources Leadership Workshop, which brought together directors of mathematics tutoring centres and mathematics education researchers to collaborate on the development of a research agenda relating to mathematics centres*' (Mills *et al.*, 2020, p. 7). This funding seems to have created some impetus, resulting in working group meetings at Research in Undergraduate Mathematics Education (RUME) conferences and the establishment of the Mathematics Learning Center Leaders, which hosts weekly online meetings and has a mailing list with 107 members (Mills *et al.*, 2020, p. 7). While subsequent work appears to not focus exclusively on MLS, it does play a prominent role and this is very encouraging.

2.3 *Methodology*

The authors started to think about this project seriously at the end of 2017 and had two issues to resolve. First, we needed to develop a suitable survey, and secondly, we needed to identify some way to get the survey to the appropriate person(s) within individual institutions. We reviewed the existing surveys of MLS mentioned in Section 2.1 and which were published prior to 2018. We identified 31 questions that we felt would yield useful information and allow us to make informed further steps. We sent the draft survey to two MLS practitioners, one in Ireland and one in the UK, both of whom had significant experience with surveys related to MLS. They were happy with the questions but suggested that there were too many for a first survey of MLS provision. They observed that the most recent surveys in Ireland and the UK had.

> '*built up a reputation and an MLS community, and as such there is a level of trust, willingness and openness, along with a commitment to support the Networks, that encourages people to complete the survey. Here it is a new initiative, and . . . it might be better to think of this in two parts, a shorter survey to capture where provision exists (i.e. An extent of provision) and then a more detailed follow up to those who are offering MLS to capture the details*'.

Furthermore, considering the large potential number of respondents, they suggested that we reduce the number of questions and limit the number of open response options. We reflected on their feedback carefully, identifying questions that would be more suitable for subsequent surveys and adjusted accordingly. The final survey had 13 questions, and examples of the questions that we removed included those related to the administration of the MLC, number of MLC staff, faculty opinion and referral processes. Ethical approval was granted in April 2018.

According to the National Center for Educational Statistics (https://nces.ed.gov/fastfacts/display.asp?id=84), there are 4313 degree granting HEIs in the US. In order to identify potential respondents for our survey, we searched websites on a state-by-state basis, identifying the email addresses of Mathematics Department heads at over 2500 community colleges, colleges and universities. A letter outlining the purpose of the *Survey of Mathematics Learning Support in US Higher Education* (from now on labelled US2018) was e-mailed to each department head in April 2018. Links within the letter provided direct access to the online survey and other information. Recipients were asked to complete the survey themselves or to forward it to the MLC director at their institution. Advertisement of the survey and emailing of institutions continued throughout summer of 2018, and the survey closed in October 2018. In total, 268 responses were received, a response rate of $\sim$10%. Descriptive statistical tables are used to summarize the fixed responses, and the open question responses were analysed using thematic analysis

(Braun & Clarke, 2006). The authors coded these responses separately, identifying and coding any patterns that emerged. They then compared and discussed their findings, and agreed on the main themes in the responses to this question.

3. Results

The survey had four parts, under the following very broad headings: General (Questions 1–2), MLS (Questions 3–8), no MLS (Questions 9–10) and follow-up (Questions 11–13).

3.1 General questions (items 1–2)

In Question 1, respondents were asked to indicate their type of institution. They were given the following options and asked to check (tick) all that applied: Public, Private, Community College, Vocational Technical College, Liberal Art College, Business College, Arts College, University and Other. All 268 answered this question. The Public College category was used to aggregate numerous Liberal Arts Colleges. No 'Other' category was indicated by respondents. The responses are given in Table 1.

In Question 2, respondents were asked if their institution currently provided MLS. All 268 responded, with 254 indicating Yes and 14 No. The responses are broken down by institution type in Table 2.

3.2 Questions for respondents who provide MLS (n = 254)

These respondents were then asked to select the MLS space available, given the options 'Dedicated Math Center', 'General Learning Support' and 'Other' where they could add further answers. The 254 responses are broken down by institution type in Table 3. We have added a column that gives the number of institutions who indicated that they offered support in more than one format.

The most common 'Other' responses were Science or STEM specific supports (7), Peer Tutoring (4), Supplemental Instruction (4) and three each for 1–1 tutoring, Math Lab and Quantitative Reasoning/Learning Support. Supplemental Instruction is a term used to describe targeted support for specific introductory modules or courses that are problematic for students. In US HE, the term 'Math Lab' is commonly used to refer to a remedial or tutorial service. The remaining 20 'Other' answers were unique, covering supports as broad ranging as 'office of diversity and inclusion specific', 'Classroom (in class) support' and 'electronic testing'.

In Question 4, respondents were asked about who had access to their MLS services. They were given the options: Undergraduate Students (UG), Postgraduate Students (PG), High School students (HS), Adult Education students (AE) and Other (O), where they could specify. All 254 responded, with 97.2% indicating undergraduates, 27.2% adult education students, 23.6% postgraduates and 13.4% high school students. The responses are broken down by institution type in Table 4, and the numbers in brackets in the UG column are the number of institutions who indicated that they offered services only to undergraduate students.

As can be seen from the table, almost all respondents reported that their service was available to either only undergraduates or to undergraduates and at least one other cohort. Half the 'Other' comments, all from 'Public Community/Technical College' respondents, referred to being available to the general public or the community. For example, '*Being a community college we are willing to assist anyone in the community. However, current students take priority*'. The remaining 'Other' responses covered

TABLE 1. *Responses by Type of Institution (N = 268)*

Type of Institution	Number
Private college	69
Public community/vocational technical college	64
Public college	58
Public university	43
Private university	34

TABLE 2. *MLS Provision by Type of Institution (N = 268)*

	MLS Provision	
Type of Institution	Yes	No
Public community/vocational technical college	63	1
Private college	61	8
Public college	57	1
Public university	43	0
Private university	30	4

students studying online, '*incoming students*', '*students enrolled with a partner institution*' and '*Faculty and Staff*'.

Question 5 was an open response question, where respondents were asked to briefly describe what services students can avail of in their MLS. Due to the open nature of this question, there was a broad range of responses. Respondents provided different levels of detail, which, when coded, largely fell into three main themes: type of support available, details on topics/courses/subjects covered and description of tutors.

All 254 respondents referred to the 'type of support available', with 'tutoring' or 'access to tutors' being mentioned 192 times. Eighty-two referred to 'drop-in' or 'walk-in' tutoring and there were 24 references to 'appointments' or 'scheduled sessions'. Fifty-two respondents specified '1–1' or 'individual appointments', while 41 cited 'groups', including '*small group tutoring*' and '*assistance setting up study groups*'. Twenty-six respondents referred to the tutoring as 'free' and five mentioned 'private' tuition. Twenty-two responses included 'workshops', 21 'supplemental instruction', 15 'online tutoring' and 12 referred to 'study skills'. Comments that fell under 'type of support available' also included access to computers (29), textbooks (17) and calculators (16), which were available in the MLC to use there, to borrow or rent. The majority of respondents offered more than one option, for example '*Scheduled or walk-in face-to-face tutorials or, increasingly, online tutorials for online students*' and '*We offer drop-in tutoring, appointment based 1-1 tutoring, small group tutoring, and online tutoring*'.

One hundred and eleven respondents provided some details on the 'topics/courses/subjects covered' by their services. Forty-five comments were very general, for example '*Tutoring in all math topics/courses offered by the college*', usually without any further detail. However, the majority of comments (68) either provided a list of specific topics covered '*Walk-in tutor service for Basic Algebra, College Algebra, Trigonometry, or Calculus I*' or indicated that there was a range from pre-calculus or developmental mathematics up to some specific level '*math students have drop-in access to tutors at all levels of*

TABLE 3. *Type of MLS Space by Type of Institution (N = 254)*

Type of Institution	MLS Space			Selected
	Dedicated	General	Other	More than one option
Public community/vocational technical college	46	28	11	19
Public college	42	29	10	19
Private college	31	26	16	10
Public university	26	22	4	8
Private university	17	19	3	8
Total	162	124	44	64

TABLE 4. *Access to MLS Services by Type of Institution (N = 254)*

Type of Institution	Access to MLS Services				
	UG	PG	HS	AE	O
Private college	61 (43)	8	3	12	1
Public community/vocational technical college	60 (25)	10	19	24	4
Public college	57 (28)	22	7	12	2
Public university	43 (21)	14	6	10	0
Private university	30 (16)	8	0	10	1
Total	251 (133)	62	35	68	8

math from developmental math through Calculus, including Statistics'. A further 28 comments indicated the provision of help with mathematics for other subjects, for example '*Guided studying in math and statistics applications in all social science, math, and science disciplines*'. A small number of comments referred to support also being provided for software, time management, test preparation/exam revision, study skills and mentoring.

Seventy-seven comments provided different levels of detail or 'information on tutors'. Peer tutors were most commonly mentioned (35), for example '*Help with homework and explanation of topics covered in class by peers*'. Some of the tutors labelled as 'undergraduate/student tutor' (14) may also have been peer tutors, for example, '*Tutoring, space usage for quiet study, dedicated collaborative study groups with student tutors for leaders*'. However, several of these comments also indicated the undergraduates were final year or 'math majors'. In a similar vein, several other tutor descriptions can be difficult to separate. For example, 24 comments referred to 'tutors' or 'math tutors', nine mentioned 'paid tutors' or 'professional tutors' and six stated '(post)graduate tutors'. In terms of other tutor descriptors, 'teaching assistant' was mentioned once and there were 10 references to 'instructors'. Finally, 12 comments referred to faculty, '*Some faculty have chosen to schedule some of their office hours and be available in the learning center*'.

The number of hours per week that the MLS was available was asked in Question 6, with the options 1–5, 6–10, 11–15, 16–20 and more than 20. Of the 220 respondents who answered this question, none selected the first three options. The breakdown by institution is displayed in Table 5.

In Question 7, respondents answered the Question 'Is your MLS/Math Center open during the summer session?'. While the majority (59%) of respondents indicated that they were open in the summer, there

TABLE 5. *Hours per Week by Type of Institution (N = 220)*

	Hours per Week	
Type of Institution	16–20	>20
Public community/vocational technical college	2	57
Public college	5	47
Public university	0	43
Private college	6	35
Private university	2	23
Total	15	205

TABLE 6. *Summer Session by Type of Institution (N = 254)*

	Summer Session	
Type of Institution	Yes	No
Public community/vocational technical college	61	2
Public college	38	19
Public university	35	8
Private university	9	21
Private college	7	54
Total	150	104

was a clear distinction between the responses from public colleges and other respondents. The breakdown by institution type is contained in Table 6.

Finally, in this section, respondents were asked how long their MLS had been operating. There were seven fixed options given, 'This is our first year', 1–5 years, 6–10, 11–15, 16–20, more than 20 and Unsure. From the 233 respondents who were sure, over 65% indicated that they had been established at least a decade prior to the survey, and over 85% had been established for more than 5 years. The breakdown by institution type is displayed in Table 7.

3.3 Not providing MLS (n = 14)

In Question 9, respondents were asked for their opinion on why their institution did not provide MLS. Twelve responses provided relevant details. The most common reasons given were attributed to lack of resources, either staffing or financial '*Told it has to do with budget restrictions. Believe the administration does not recognize the need*'. Several responses also indicated that small institution or class sizes seemed to negate the need for extra support. One respondent identified the lack of a dedicated space as an issue, and that students '. . . *desire them* [drop-in sessions] *but do not follow through . . . With a committed physical space and elevated marketing for our online and in person tutoring . . . I think there would be a higher level commitment for all parties*'.

In Question 10, respondents were asked to indicate whether or not their institution previously had MLS, two selecting yes and 12 no.

TABLE 7. *Years of Operation by Type of Institution (N = 253)*

	Years of Operation						
Type of Institution	1st	1–5	6–10	11–15	16–20	>20	Unsure
Public community/vocational technical college	0	10	11	7	5	28	2
Public college	0	5	10	4	8	27	3
Private college	2	12	13	9	5	16	3
Public university	0	1	8	7	7	14	6
Private university	0	3	4	3	4	10	6
Total	2	31	46	30	29	95	20

TABLE 8. *Potential Collaboration by Type of Institution (N = 268)*

	Potential Collaboration		
Type of Institution	Yes	No	Other
Public community/vocational technical college	47	16	1
Private college	43	21	5
Public college	40	16	2
Public university	28	12	3
Private university	21	12	1
Total	179	77	12

3.4 Follow-up to the survey

The survey closed with three questions seeking to determine if respondents would allow follow-ups on individual responses if required (Q11), whether or not they were interested in further projects or discussions about potential collaborations in the US in relation to MLS (Q12) and, if they agreed, to provide their email addresses (Q13). The responses to Q12, broken down by institution, are reported in Table 8, with more than 65% of respondents interested in further projects or collaborations. Eleven of the 12 Other responses indicated ‘maybe’, but all provided their email addresses.

4. Discussion

In order to discuss the implications of our survey results, we considered them both in the context of the most recent international MLS surveys of the extent of provision and with respect to US2017. To this end, while noting that all five surveys did not all collect the same information, we make comparisons of responses, where possible, sorted by the following categories:

- Institutional survey responses as a national snapshot of MLS provision in HE
- Description, capacity and history of MLCs
- Students served
- Services offered

4.1 *Institutional survey responses as a national snapshot of MLS provision in HE*

As we did not have a network of MLS practitioners to issue US2018 to, it was distributed to Heads of Schools in HEIs all across the US. We received 268 responses, with 254 of these institutions providing MLS. Despite the large number of responding HEIs, the response rate is low when considered as a proportion of all HEIs in the US. Nevertheless, as far as the authors are aware, this was by far the largest number of respondents that there has been to a survey related to MLS provision. Furthermore, responses came from across all types of colleges and universities in US HE and, as such, it seems to suggest that MLS is commonplace across US HE.

For US2017, similarly without recourse to a nationwide network of MLS practitioners, the researchers used a variety of methods to distribute the survey. For example, university websites were checked to identify the contact details of appropriate people to issue the survey to, and they also used mailing lists generated from various related projects, e.g. RUME. The authors state that '*we have a record of 381 mathematics centres at universities that were contacted via email and we have a total of 75 responses to the survey. Thus, an estimated response rate is 19.7%*' (Mills *et al.*, 2020, p. 8). If measured as a proportion of total number of HEIs in the US, the response rate is much lower. However, their study was not explicitly a survey of the extent of MLS provision, rather '*the focus of this report is on the day-to-day operations of mathematics centres at universities in the USA*' (Mills *et al.*, 2020, p. 9). While the number of questions used in US2017 is not clear, their data represent an interesting insight into US MLS, with the 75 respondents from both public (54) and private (21) universities of different sizes across 34 states.

Surveys of the extent of MLS provision outside the US typically have much higher response rates. For example, Ireland2015 was issued to 31 institutions, including almost all HEIs on the island of Ireland. Thirty of 31 responded, with 25 of the HEIs offering MLS. The survey, which had 58 questions, was issued to all different types of HEIs. IMLSN membership was used to assist with identifying the appropriate individual to contact in each institution. EnglandWales2018 was sent to 111 HEIs identified through the Higher Education Statistics Agency (https://www.hesa.ac.uk/). The survey, which had 13 questions, was distributed initially via the sigma mailing list. There were responses from 88 HEIs across all different university types, with 78 providing MLS. In Germany, a country without a network of MLS practitioners, the data for Germany2019 were initially collated through website analysis. The survey team identified 190 suitable universities '*... that were public or under public law and were either full universities, universities of education, universities of applied sciences or technical universities of applied sciences*' (Schürmann *et al.*, 2021, p. 102). Across 51 of these HEIs, they found 61 MLCs.

4.2 *Description, capacity, and history of MLCs*

It appears that MLS is relatively well established in the US and has been available in many institutions since at least the 1990s. In US2018, over 40% of respondents indicated that their MLS had been in place for more than 20 years with just 14% selecting 5 years or less. This is reinforced by data from US2017 '*The average number of years that these centres have operated is 17.46, with a standard deviation of 13.15 (n=62 answered this question). Twenty five percent of* [sic] *have operated for more than 30 years*' (Mills *et al.*, 2020, p. 8). While this information was not collated in the Germany2019 survey, the data reported in Ireland2015 and EnglandWales2018 show similar longevity for MLS. Grove *et al.* (2020) report that MLS had been offered for more than 5 years in 70% of institutions, and for more than 10 years in 53% of institutions.

US2018 found that most institutions indicated opening during summer months, with this more likely among public rather than private institutions. This was not considered in the other surveys. We also found

that all respondents with MLS were open more than 16 hours each week, with the majority open more than 20. While a direct comparison with US2017 is not possible, as they reported on the number of tutor hours available rather than opening hours, we can consider the other three surveys. EnglandWales2020 provides opening hour details based on the provision type. For example,

> '. . . *among those institutions offering one-to-one bookable appointments and providing details 42% (21 out of 50) offer their provision for between 5 and 15 h per week, and 30% (15 out of 50) for more than 15 h per week during term time. Similar trends are seen for the drop-in provision where 32% (19 out of 60) of institutions offering this form of mathematics support and again providing details, make the provision available to learners for between 5 and 15 h per week; a further 33% (20 out of 60) make drop-in support available for more than 15 h per week.*' (Grove *et al.*, 2020, p. 92).

Germany2019 also found that '*On average, centres were open 23.4 h per week and support was offered during 17.4 h per week. The range is very high with 1.5 to 91 opening hours and 1.5 to 45 support hours (in mean)*' (Schürmann *et al.*, 2021, p. 105) and Ireland2015 '*In 24% of institutions, five hours per week at most of (face-to-face) MLS was available while another 24% of institutions offered more than 30 hours per week.*' (Cronin *et al.*, 2016, p. 9). Similar to US2018, both Germany and Ireland found some differences in opening hours depending on the type of institution.

When we consider the type of space used to provide MLS, the most common response in US2018, from almost 64% of respondents, indicated that they had a dedicated center for MLS, and over 48% were part of a general support centre. Just over 25% of responses indicated that they offered MLS through more than one avenue. Only Ireland2015 considered a similar question. They found that '*A dedicated space for MLS existed in 80% of institutions; the nature of the space was very diverse. In 63% of cases (n=22), this space was shared, primarily with other academic supports*' (Cronin *et al.*, 2016, p. vi).

Finally, in this section, we consider details on the tutors who are providing MLS. While this question was not explicitly asked in our survey, it is interesting to look at the 77 responses to Question 5 that provided some details. The terms most commonly used included peer tutors, math tutors or undergraduate or student tutors. A small number also mentioned instructors or faculty. In US2017, they reported that '*96% of the mathematics centres offered tutoring by undergraduates and 65% have tutoring by graduate students and faculty*' (Mills *et al.*, 2020, p. 9). In Ireland2015, 48% of institutions used postgraduates, 36% used undergraduate tutors and 72% had at least one full-time staff member tutoring. Universities were more likely to use a range of different tutors, whereas other institutions were more reliant on full-time staff. In EnglandWales2020, they found, among several different types of tutors, that 26% of respondents used undergraduates, 42% used postgraduates and 63% had full-time or part-time MLS specific staff. They also identified some variety in the type of staffing used among different university types. Germany2019 also looked at the breakdown of MLS staff but using terms that are not easily amenable here for a useful comparison. Nevertheless, they did also report that the type of staffing used often varied depending on the university type.

4.3 Students served

Almost all institutions (253 of 254) who provided MLS in US2018 made this available to undergraduates, with over half of these providing support for undergraduates only. This figure for undergraduates compares with 80% of institutions in EnglandWales2018 and 54.2% in Germany2019. Such figures were not available from the Ireland2015 or US2017 data. We also found that 24% made support available to postgraduates. This is slightly higher than Ireland2015, which reported 17%, and much lower than EnglandWales2018 with 75%. While we also found that 27% of responding HEIs offered supports to

adult education students and almost 14% to high school students, there were no comparable figures in the other surveys, and indeed, only Ireland2015 mentioned supports for school students.

Information on the topics, subjects or courses supported by MLS also provides some further insight on the students served, though these data were not collected in surveys outside the US. Again, while this question was not specifically asked in US2018, 111 respondents provided some details in their open responses to Question 5. Based on the answers given, support seemed to be most commonly provided for courses from Algebra, through Calculus 1 or 2, but primarily for courses that precede Calculus. This seems largely consistent with US2018, where they found that '. . . *80–99% of the mathematics centres offer tutoring for Pre-Calculus and Calculus 1–3. The next most common courses are College Algebra and Trigonometry*.' (Mills *et al.*, 2020, p. 14).

4.4 Services offered

In terms of the services offered, from US2018 it is clear from the coding of open responses, that there was a broad range of tutoring available with drop-in or appointments being mentioned most often, and these could include 1–1, small groups or study groups. The majority of respondents offered more than one option. In US2017, the findings appear similar with drop-in being selected by almost all respondents, and 1–1 and small group tutoring, both appointment based, being the next most commonly selected. The larger the institution, the less often these two options were selected. In Germany2019, drop-in was also available in all institutions, but this was one of the criteria of the initial web analysis that led to institutions being selected in the first place. Ireland2015 reports '*drop-in service was available in 88% of institutions, workshops were offered at 64% of institutions and 44% offered an appointment-based service*' (Cronin *et al.*, 2016, p. vii), and for EnglandWales2018 '. . . *it is overwhelmingly the case (75 out of 78 (96%)) that the vast majority of institutions with mathematics support offer provision that includes either, or both of, one-to-one bookable appointments and drop-in . . . Typically, support is provided by more than one means*' (Grove *et al.*, 2020, p. 91–2).

5. Conclusion and next stage

There are a number of limitations to this study. For example, the survey was issued to Mathematics Department heads to complete themselves or forward to staff more directly associated with MLS. However, not all MLCs are in academic departments and, as a result, some may not have received the survey in the HEIs that we contacted. Furthermore, variations in perspective among respondents related to their various roles within the HEI are unaccounted for in the study. A second limitation arises from the preliminary nature of the study and its sampling procedure. We do not claim that the sample is representative of the population of US HEIs, but this study is not about drawing inferences about that population. It is about the level and type of MLS in the institutions who responded to our survey and about hearing the perspective of people who might be interested in further dialogue and collaboration. In Bayesian thinking, the results of this survey may be regarded as informing our 'prior' knowledge of MLS in subsequent research activities. As such, we believe that this paper provides an interesting first look at the extent of MLS provision in US HE.

This survey received more responses from distinct institutions than any previous survey of MLS provision carried out worldwide, and initial comparisons with other studies suggest that MLS is well established in the US and that MLS services in England and Wales, Ireland, Germany and the US share many common features. At many institutions, MLS services focus on helping first- and second-year

students struggling to adapt to mathematics in HE. The retention and timely graduation of these students now serve as important metrics in the evaluation and funding of HE.

There have been several developments in MLS in the US since this survey was completed. In addition to the MLS related working group at the RUME conferences, the Joint Meetings of the MAA and American Mathematical Society, in January 2020, had its first ever panel discussion on MLS. The Joint Meetings are the world's largest mathematics gathering and the session, co-organized by the first author, had panellists from both the US and the UK. It was clear from panel and participant contributions that MLCs are now viewed on many campuses in the US as a nexus of change in the support of struggling mathematics and statistics students.

In terms of next steps, it would be interesting to consider some of the challenges facing MLS everywhere. These include the evaluation and documentation of its impacts, the identification of productive strategies, methods and materials, the development of national and international MLS professional networks and the need for research and development funding focused on both the theoretical and practical aspects of MLS development and delivery. The fact that the majority of respondents to our survey indicated that they would be interested in further projects or collaborations bodes well for the future of MLS development in the US. Some investigations may directly relate to our study. For example, why are private HEIs less likely than public HEIs to offer MLS during the summer? There is also considerable scope for further surveys on the extent of provision, perhaps focusing on specific types of institution and using the growing connections being established by MLS practitioners and researchers in the US to achieve higher response rates.

Finally, the Covid-19 pandemic has forced many scholars and educational institutions to reconsider the integration and delivery of face-to-face, remote and blended approaches to mathematics teaching, learning and assessment in higher education. A recent Google Scholar search using the keywords pandemic education impact university mathematics since 2020, yielded over 17,000 articles. In the search for new, empowering, adaptable and sustainable models of university mathematics education, the authors believe that a renewed interest in and support of MLS in US HE would be productive and welcome on many campuses.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

Ahmed, S., Davidson, P., Durkacz, K., Macdonald, C. & Richard, M. (2018) The provision of mathematics and statistics support in Scottish higher education institutions (2017)—a comparative study of the Scottish mathematics support network. *MSOR Connect.*, 16, 5–19. https://doi.org/10.21100/msor.v16i3.

Bausch, I., Biehler, R., Bruder, R., Fischer, P. R., Hochmuth, R., Koepf, W., Schreiber, S. & Wassong, T. (eds.) (2014) *Mathematische Vor- und Brückenkurse*. Wiesbaden: Springer Fachmedien Wiesbaden.

Berkopes, K. & Abshire, S. (2016) Quantitative measures for assessing learning centers: an agenda and exploration. *Learn. Assist. Rev.*, 21, 109–126. Available at https://files.eric.ed.gov/fulltext/EJ1114492.pdf accessed 21 December 2021.

Berry, E., Mac an Bhaird, C. & O'Shea, A. (2015) Investigating relationships between the usage of mathematics learning support and performance of at-risk students. *Teach. Math. Appl.*, 34, 194–204. https://doi.org/10.1093/teamat/hrv005.

Braun, V. & Clarke, V. (2006) Using thematic analysis in psychology. *Qual. Res. Psychol.*, 3, 77–101.

Bressoud, D., Mesa, V. & Rasmussen, C. (eds.) (2015) *Insights and Recommendations From the MAA National*

Study of College Calculus, vol. 109. MAA Press, Available at https://www.maa.org/programs/faculty-and-departments/curriculum-development-resources/national-studies-college-calculus (accessed 21 December 2021).

Burrill, G. (2017) Challenges in the transition from high school to post secondary mathematics. *The Role of Calculus in the Transition from High School to College Mathematics* (D. Bressoud ed). MAA & National Council of Teachers of Mathematics, pp. 67–74. Available at https://www.maa.org/sites/default/files/RoleOfCalc_rev.pdf accessed 21 December 2021.

Coulombe, G., O'Neill, M. & Schuckers, M. (eds.) (2016) *QMaSC: A Handbook for Directors of Quantitative and Mathematics Support Centers*. Tampa FL: USF Libraries—Tampa Library. Available at http://scholarcommons.usf.edu/qmasc_handbook/ accessed 21 December 2021.

Croft, A. C., Lawson, D. A., Hawkes, T. O., Grove, M. J., Bowers, D. & Petrie, M. (2015) **sigma**—a network working! *Math. Today*, 50, 36–40.

Cronin, A., Cole, J., Clancy, M., Breen, C. & Ó Sé, D. (2016) An audit of mathematics learning support provision on the Island of Ireland in 2015. *An Irish Mathematics Learning Support Network Report* (J. Cole, A. Cronin, C. O'Sullivan & C. Mac an Bhaird eds) Available at http://www.sigma-network.ac.uk/wp-content/uploads/2019/02/Audit-of-MLS-provision-Ireland.pdf accessed 21 December 2021.

Dzator, M. & Dzator, J. (2018) The impact of mathematics and statistics support at the academic learning centre, Central Queensland University. *Teach. Math. Appl.*, 39, 13–28. https://doi.org/10.1093/teamat/hry016.

Evensky, J., Kao, D., Yang, Q., Fadele, R. & Fenner, R. (1997) Addressing prerequisite mathematics needs—a case study in introductory economics. *Int. J. Math. Educ. Sci. Technol.*, 28, 629–639. https://doi.org/10.1080/0020739970280501.

Gill, O., O'Donoghue, J. & Johnson, P. (2008) An audit of mathematics support provision in Irish third level institutions. *Regional Centre for Excellence in Mathematics, Teaching and Learning*. Republic of Ireland: University of Limerick.

Gill, O., O'Donoghue, J., Faulkner, F. & Hannigan, A. (2010) Trends in performance of science and technology students (1997–2008) in Ireland. *Int. J. Math. Educ. Sci. Technol.*, 41, 323–339. https://doi.org/10.1080/00207390903477426.

Grove, M. J., Croft, T., Lawson, D. & Petrie, M. (2018) Community perspectives of mathematics and statistics support in higher education: the role of the staff member. *Teach. Math. Appl.*, 38, 43–59. https://doi.org/10.1093/teamat/hrx017.

Grove, M. J., Croft, T. & Lawson, D. (2020) The extent and uptake of mathematics support in higher education: results from the 2018 survey. *Teach. Math. Appl.*, 39, 86–104. https://doi.org/10.1093/teamat/hrz009.

Gueudet, G. (2008) Investigating the secondary–tertiary transition. *Educ. Stud. Math.*, 67, 237–254. https://doi.org/10.1007/s10649-007-9100-6.

Hoachlander, G., Sikora, A. C., Horn, L. & Carroll, C. D. (2003) Community college students. *Educ. Stat. Q.*, 5, 121–128.

Houser, L. C. S. & An, S. (2015) Factors affecting minority students' college readiness in mathematics. *Urban Educ.*, 50, 938–960. https://doi.org/10.1177/0042085914536998.

James, C. & Burks, L. (2018) The distribution of mathematical work during one-on-one tutor problem solving. *Proceedings of the 21st Annual Conference on Research in Undergraduate Mathematics Education* (A. Weinberg, C. Rasmussen, J. Rabin, M. Wawro & S. Brown eds). San Diego, CA, pp. 1603–1604 Available at https://par.nsf.gov/servlets/purl/10108499 (accessed 21 December 2021).

Johnson, E. & Hanson, K. (2015) Academic and social supports. *Insights and Recommendations From the MAA National Study of College Calculus* (D. Bressoud, V. Mesa & C. Rasmussen eds). MAA Press, pp. 69–82 Available at https://www.maa.org‌/programs/faculty-and-departments/curriculum-development-resources/national-studies-college-calculus (accessed 21 December 2021).

Kolluri, S. & Tierney, W. (2018) College for all in capitalist America: the post-secondary emphasis in the neoliberal age. *Tertiary Educ. Manag.*, 24, 1–12. https://doi.org/10.1080/13583883.2018.1440417.

Lawson, D. (2003) Changes in student entry competencies 1991–2001. *Teach. Math. Appl.*, 22, 171–175.

Lawson, D. A., Halpin, M. & Croft, A. C. (2001) After the diagnostic test—what next? Evaluating and enhancing the effectiveness of mathematics support centres. *MSOR Connect.*, 1, 19–23.

Lawson, D., Grove, M. J. & Croft, T. (2020) The evolution of mathematics support: a literature review. *Int. J. Math. Educ. Sci. Technol.*, 51, 1224–1254. https://doi.org/10.1080/0020739X.2019.1662120.

MacGillivray, H. (2009) Learning support in mathematics and statistics in Australian universities—a guide for the university sector. *Australian Learning and Teaching Council*. Available at http://www.mathcentre.ac.uk/resources/uploaded/guide--altc-learning-support-in-maths-and-stats.pdf (accessed 21 December 2021).

Matthews, J., Croft, T., Lawson, D. & Waller, D. (2013) Evaluation of mathematics support centres: a literature review. *Teach. Math. Appl.*, 32, 173–190. https://doi.org/10.1093/teamat/hrt013.

McCormick, N. J. & Lucas, M. S. (2011) Exploring mathematics college readiness in the United States. *Curr. Issues Educ.*, 14, 1–27. Available at http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.456.6079&rep=rep1&type=pdf accessed 21 December 2021.

Mills, M., Tallman, M. & Rickard, B. (2017) Research opportunities for RUME researchers in the context of mathematics resource centers. *Presentation at the Annual Meeting of the Special Interest Group of the Mathematical Association of America on Research in Undergraduate Mathematics Education*.

Mills, M., Rickard, B. & Guest, B. (2020) Survey of mathematics tutoring centres in the USA. *Int. J. Math. Educ. Sci. Technol.*, 53, 948–968. https://doi.org/10.1080/0020739X.2020.1798525.

Pell, G. & Croft, T. (2008) Mathematics support—support for all? *Teach. Math. Appl.*, 27, 167–173.

Perkin, G. & Croft, A. C. (2004) Mathematics support centres—the extent of current provision. *MSOR Connect.*, 4, 14–18.

Perkin, G., Lawson, D. A. & Croft, A. C. (2012) *Mathematics Learning Support in Higher Education: the Extent of Current Provision in 2012*. Loughborough, UK: sigma. Available at https://www.mathcentre.ac.uk/resources/uploaded/52789-mls-in-uk.pdf (accessed 21 December 2021).

President's Council of Advisors on Science and Technology's (PCAST) (2012) *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*. Washington, DC. Available at https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf: White House Office of Science and Technology Policy accessed 15 December 2021.

Rylands, L. J. & Coady, C. (2009) Performance of students with weak mathematics in first-year mathematics and science. *Int. J. Math. Educ. Sci. Technol.*, 40, 741–753.

Saxe, K. & Braddy, L. (2015) *A Common Vision for Undergraduate Mathematical Sciences Programs in 2025*. Washington, DC: The Mathematical Association of America Available at https://www.maa.org/sites/default/files/pdf/CommonVisionFinal.pdf (accessed 15 December 2021).

Schürmann, M., Gildehaus, L., Liebendöffer, M., Schaper, N., Biehler, R., Hochmuth, R., Kuklinski, C. & Lankeit, E. (2021) Mathematics learning support centres in Germany—an overview. *Teach. Math. Appl.*, 40, 99–113. https://doi.org/10.1093/teamat/hraa007.

The National Research Council (NRC) (2013) *The Mathematical Sciences in 2025*. Washington, DC: The National Academies Press Available at https://www.eu-maths-in.eu/wp-content/uploads/2016/02/2013-USA_report_mathematics_2025.pdf (accessed 15 December 2021).

Tinsley, C., Rawlins, B., Moore-Russo, D. & Savic, M. (2018) Math help centers: factors that impact student perceptions and attendance. *Proceedings of the 21st Annual Conference on Research in Undergraduate Mathematics Education* (A. Weinberg, C. Rasmussen, J. Rabin, M. Wawro & S. Brown eds). San Diego, CA, pp. 301–310 Available at https://par.nsf.gov/servlets/purl/10108499 (accessed 21 December 2021).

Wurtz, K. A. (2015) Impact of learning assistance center utilization on success. *J. Dev. Educ.*, 38, 2–10.

Ciarán Mac an Bhaird is an Associate Professor and Director of the Mathematics Support Centre at Maynooth University. He was appointed to his roles in the Department of Mathematics and Statistics in 2007. He has received multiple awards in recognition of his teaching and support of students. He was a founding committee member of

the Irish Mathematics Learning Support Network and conducts research in algebraic number theory, mathematics education and the history of mathematics. https://orcid.org/0000-0001-5971-7709.

David Thomas received his EdD in Curriculum & Instruction (Mathematics) from Montana State University in 1983 and has served as a Professor of Mathematics Education at several US research universities, as a Fulbright Scholar in South Africa and a Fulbright Specialist in Botswana and Nepal, and as an investigator/director on approximately $8 M in grant-funded R&D projects.