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A Review of Specialist Mathematics Schools in England

Harry Richardson, University of Leeds

Abstract

This paper supplements a presentation on Specialist Mathematics Schools in England given at the Research Students' Education Conference (RSEC) conference, was held on 18th July 2024. In 2023, Kings College London Mathematics School (KCLMS) obtained the highest A-Level grades of any school for the third year in a row (Bellos; 2023). Successes such as these have seen the number of mathematics schools grow. With new approaches to pedagogy and curriculum, it is important to understand what they offer to students and how a mathematics school education will impact students currently and beyond. This paper will provide a review of mathematics schools, their place in the English education system as well as the curricular and pedagogical practices they employ to support advanced level mathematics through my ongoing PhD research.

Keywords

Specialist Mathematics Schools
Mathematics Curriculum
University Sponsorship
STEM Education
Higher Education Preparation

Introduction

Mathematics schools originate from a policy in 2011 from the Conservative and Liberal Democrat coalition government. They are designed to take top mathematicians from General Certificate for Secondary Education (GCSE) and develop their academic capabilities, beyond the A-Level curriculum (Department for Education; 2021). Ten years since King's College London Maths School (KCLMS) and Exeter Mathematics School (EMS) opened in 2014, four more schools have opened across England (see table 1 for a list of mathematics schools currently open) with another four set to open by 2028 (Norden, 2024). Yet, despite significant government expenditure and development into this policy, there has been little academic research on these schools. To date, there are only two academic articles featuring maths schools (Golding, 2018; Thompson, 2022) and only one of them has specific focus of a maths school. With seven new mathematics schools currently open since Golding's publication, it serves as a good point to look at the maths schools together, highlighting similarities and differences between them and the evolution of the older schools. This paper will start by situating mathematics schools in the education system. The next section will discuss the conditions schools must abide by to operate. This will be followed by admissions process.

Cambridge Maths School	CMS
Exeter Mathematics School	EMS
Imperial College London Mathematics School	ICLM
Lancaster University School of Mathematics	LUSoM
Leeds Maths School	LMaS
King's College London Mathematics School	KCLMS
Surrey Maths School	SMS
University of Liverpool Maths School	ULMaS

Table 1: Abbreviations Table of Maths Schools

The subsequent sections will discuss my ongoing PhD research, the methodology, the aims of the project and the ongoing results collated to date. The next section discusses different parts of the curriculum including lectures and research projects. This paper will conclude with a section on maths schools' pedagogy with data from my PhD project with a final summary of maths schools.

Maths Schools in the Education System

Specialist mathematics schools are free schools for students aged 16–19, the penultimate and final years of secondary school. Unlike state schools and other free schools, they are exempt from following the national curriculum, they can determine the start and end of the workday and decide how many holidays students and staff have (UK Government, no date). In addition to the funding allocated by the 16–19-year-old free school formula, they also receive an extra £350,000 on top of current Government funding (Department for Education, 2021).

Maths School Requirements

Mathematics schools must be sponsored by a university where entry requirements for a full-time undergraduate mathematics degree average 136 UCAS tariff points, which is broadly equivalent to grades of AAB at A-Level (Department for Education, 2021). They are also required to provide significantly more outreach than a typical sixth form and must attract pupils from disadvantaged and under-represented backgrounds; widening participation and access to an education that students may not otherwise have (Department for Education, 2021). They can also be part of a Multiple Academy Trust (MAT) and they can be affiliated with a local college (Department for Education, 2021), allowing students to study subjects beyond the Science, Technology, Engineering and Mathematics (STEM) field.

Maths School Admission

Mathematics schools admit students based on academic selection and therefore cannot be defined as schools but as 'educational institutions' (UK Government, 2021). This is because state and free schools must follow the Schools Admissions Code and cannot admit pupils based on academic ability (Department for

CORRESPONDING AUTHOR: PYHR@LEEDS.AC.UK

Education, 2023).

Although each school differs slightly, there are three broad stages applicants must complete. For the first stage prospective students submit an application to join the school including GCSE grades and references from teachers (see table 2 for detailed breakdown of minimum entry requirements).

As per table 2, the general minimum requirement for entry is a grade 8 in Maths and Physics (equivalent to previous grades of A-A*) and at least a 5 in English (equivalent to previous grade of C). The second part of the application is to sit an entrance exam. This involves questions from GCSE exam papers. The majority of questions are problem-solving based. The final stage is to have an interview with the headteacher and other members of the staff. Competition for places varies across schools. KCLMS receives with approximately ten applications for one place (KCLMS, 2022) compared to other schools who have not filled all their vacancies (University of Liverpool Maths School, 2023). Year groups typically have a capacity of 70-80 students which varies by school.

The PhD Project

My PhD project is focused on students' progression through their respective Maths School and to their destination after school. The study focuses on maths schools' curricula and pedagogy; how students experience and interpret these elements of their school and if and how their relationship with Maths and Sciences change.

The methodology is three-fold. The first element of the methodology was to send out a questionnaire to all Year 13 Maths School students. This was to gather background information, demographic data and to an extent inform the second stage of the data collection. The second stage of data collection was to take a sample of students from each school (approximately three students per school) and interview them across 2-3 years, depending on the year they were selected. Semi-structured interviews were conducted to capture students' experiences of the curriculum and the pedagogy at specific moments during their time at their school. This process was conducted in the first year and the second year of the project- following students from Year 13 to their future destination(s), tracking in what ways the curriculum and pedagogy has impacted them beyond school.

In addition to interviewing students, several teachers were invited to take part in one-off interviews to discuss their school's curriculum in more detail and the experience they wanted the students to go through. It also allowed a comparison to be made whether students were achieving the outcomes teachers desired. The teachers invited for participation were teachers who were either in senior management or heads of their departments. It may be that one teacher may occupy several roles. All students and staff have been made anonymous and have been given pseudonyms.

This project has received approval from the University of Leeds (MEEC 22-044) in accordance with the respective school regulations. All subsequent quotes from teachers are from interviews conducted in the last two years.

Curriculum

Through my own research with teachers, maths schools' curricula present an innovative approach to maths education using evidence-based research to support their students throughout their time at school.

Teachers consistently identify new ways to improve pedagogy and methods to improve skill development. I've got somebody else who's always reading research papers saying, "What about this? What about this? I've got somebody who is doing some research into problem solving and it's probably one that hasn't got four sort things you can think about, of heuristics, of knowledge, of control (of the whole thing of knowing when to stop when you're doing mathematics). Abigail- Teacher

This is in addition to interacting with experts in academia and in industry to provide real-world experiences and challenges to students (KCLMS, no date; EMS, no date).

Students receive advanced disciplinary knowledge which may transcend different subjects to inform multiple perspectives to create a well-rounded understanding of knowledge, which improves students' ability to use the knowledge in different applications to both familiar and unfamiliar settings.

We go into understanding; we go into proving things. You don't just say Chi-Squared Distribution- look this critical value up and trust it. We look at what the hell Chi-Squared Distribution is. It's way off syllabus- you don't need to know this. Abigail- Teacher

Independent learning is a significant characteristic of the curriculum. Students are encouraged by teachers to find an answer to questions independently of the teacher.

It's getting them to do as much as possible and getting it to be as pupil led as possible, they've got so much to give. When kids asked me how to insert and image into LaTeX I would say, "Take a new tab. Go onto Google and type, 'How to insert and image in LaTeX' and follow the instructions". I'm not the be all and end

Subject	School							
	KCLMS	EMS	ULMaS	ICLMS	CMS	LMaS	LUSoM	SMS
Maths	8	8	8	8	8	7	8	8
Physics	7	7	8	7	8	7	8	7
Combined Science	7	8	8	7	8	7	7/7	7/7
English	5	5	5	5	5	5	5	5
Other Subjects	5	5	5	7/7.5	5	6	5/6	5

TABLE 2: GCSE GRADES FOR ADMISSION INTO RESPECTIVE MATHS SCHOOLS

all." Dave- Teacher

This develops curiosity in students and to begins to prepare students for independent learning at university.

Subjects

All students initially must study Mathematics and Further Mathematics at least to AS-Level, with the expectation they will study them the following year. In addition, students may also take other subjects depending on the school; typically, either: Physics, Computer Science and Chemistry (KCLMS, no date b; EMS, no date c); Leeds Mathematics School, no date) depending on what the school offers. KCLMS only allow their students to study Mathematics, Further Mathematics and Physics (KCLMS, no date b). Other schools have a greater A-Level selection allowing students to study a broader range of STEM subjects and to take more than the standard three A-Levels (Department for Education, 2021). If schools are affiliated with a college, students can select subjects at the college (Imperial College London Mathematics School, no date, Lancaster University School of Mathematics, no date; Exeter Mathematics School no date c) and students, if studying at the college, are not restricted to STEM-based subjects.

Research Projects (Co-Curriculum)

A distinguishing feature of mathematics schools are research projects. Students complete different types of research projects: group, industry and individual, depending on what each school offers. The projects are less structurally and procedurally stringent than an Extended Project Qualification (EPQ) and unlike the EPQs, (worth 28 UCAS points which is equivalent to half an A-Level qualification (AQA, no date), which some maths schools offer) the research projects(s) are not awarded UCAS tariff points (a points system that scores post-16 qualifications and their grade boundaries).

An EPQ is a research project that enables students to develop their skills beyond the A-Level curriculum and is displayed on the students' exam certificates (Gill, 2024). There is some evidence that studying an EPQ reduces the entry requirement into university (Gill, 2024) however, this is not uniform across universities and studying an EPQ has no impact on entry requirements (Thompson, 2018).

For group projects, students are randomly assigned groups based on their ranking of preference of topics which are set by academic staff at the corresponding sponsoring university (U-Maths, no date). It is up to the students to interpret the brief with little assistance from the academic lead. Students are required to present their work in a presentation (KCLMS, no date b; University of Liverpool Mathematics School, no date). Some schools require students to produce a poster, and each school has a presentation day where students present their projects, inviting parents, lecturers, other year cohorts and outreach partners, depending on the school (KCLMS, no date b; EMS, no date c; University of Liverpool Mathematics School, no date).

The industry projects are group projects set by professionals across different STEM fields. The size and types of the companies vary; from international companies such as GCHQ and Dyson to regional businesses (KCLMS, no date b and EMS, no date b). Students are required to present solutions to industry professionals through verbal and written presentations. Unlike the group project where students present their research in layman's terms, students use academic jargon when presenting in the industry group project. Students use the curricular knowledge they learned at A-Level and apply it to real-world problems which they are required to solve. Students may need to learn new knowledge and skills to complete the project (e.g. a piece of software or some programming). See Figure 1 for an example of an academic poster from ICLMS.

For individual projects, students may either create a written presentation which may include using Latex (a software system for typesetting documents) or a poster and deliver a verbal presentation or a combination of these presentation formats to a small group of students and a member of staff. These projects are typically supervised by PhD students at the sponsoring universities where they provide in-depth feedback and support to students throughout their project (University of Liverpool Mathematics School, no date).

Depending on the school, students have varying degrees of autonomy to select their individual projects. Some schools allow students to select their own project topic, however, they must pitch their project to a member of staff to ensure its feasibility.

Lecture Series

Mathematics schools provide students the opportunity to complete modules in STEM topics. Modules are created and presented by teachers in a lecture format- with the aim to prepare students for university style teaching in addition to the module content being near or at undergraduate level (EMS, no date a). In addition to the lectures, there may also be workshops where students' complete problem sheets. The research projects as well as the modules do not count towards the final A-Level grade or UCAS tariff points. Most schools require the modules not to be based on topics covered in the A-Level curriculum.

Advanced Entry Tests

Maths schools are also equipped to prepare students for advanced entry exams into university for example, the Mathematics Admission Test (MAT) and the Sixth Term Examination Papers (STEP) (EMS, no date; KCLMS, no date; University of Liverpool Mathematics School, no date; Leeds Maths School, no date; Imperial College London Mathematics School, no date a).

Pedagogy

Maths schools that have been involved in the PhD project strongly encourage collaboration. Collaborative learning is a pedagogy that involves students working on activities in groups small enough so everyone can participate (Education Endowment Foundation, no date). Evidence shows that collaborative learning has a positive impact on students in STEM subjects compared to literacy (Education Endowment Foundation, no date) and can improve students' attitude towards studying maths and lead to significant improvements in mathematical performances (Abd Algani, 2021). It has been shown to improve deeper learning, problem solving skills and students' ability to socialise with their peers (Shimazoe and Aldrich, 2010).

In Maths Schools, collaborative learning involves students working in groups to solve problems, ensuring all members of the group participate. Maths classes have small whiteboards on walls across the classroom and some schools also have desks that students can write on to encourage collaboration. A common technique used in schools is Think, Pair and Share; a low-risk technique where students think about a problem individually before sharing their ideas with their partner. The pair will then report their ideas back to the class or the larger group (Sapsuha and Bugis, 2013).

Some teachers employ flipped learning in their classrooms. Flipped learning is a pedagogical approach where students learn content outside the classroom using a variety of resources (Educause, 2012). By learning the concepts outside the classroom rather than inside the classroom, students and teachers can tailor their instruction depending on students' needs. They can also focus on delivering more advanced questions as students will have studied the basis of the topics before class time (Harris, Harris et al, 2016). Flipped learning allows students to learn at their own pace and their own style which gives them autonomy over their own learning (Fulton, 2012).

Lectures are used by some schools to deliver A-Level curriculum content to students. Lectures are a controversial pedagogy, especially in higher education with regards to the effectiveness of lectures in improving students' education. This is argued because of its passive characteristics, the length of lectures and

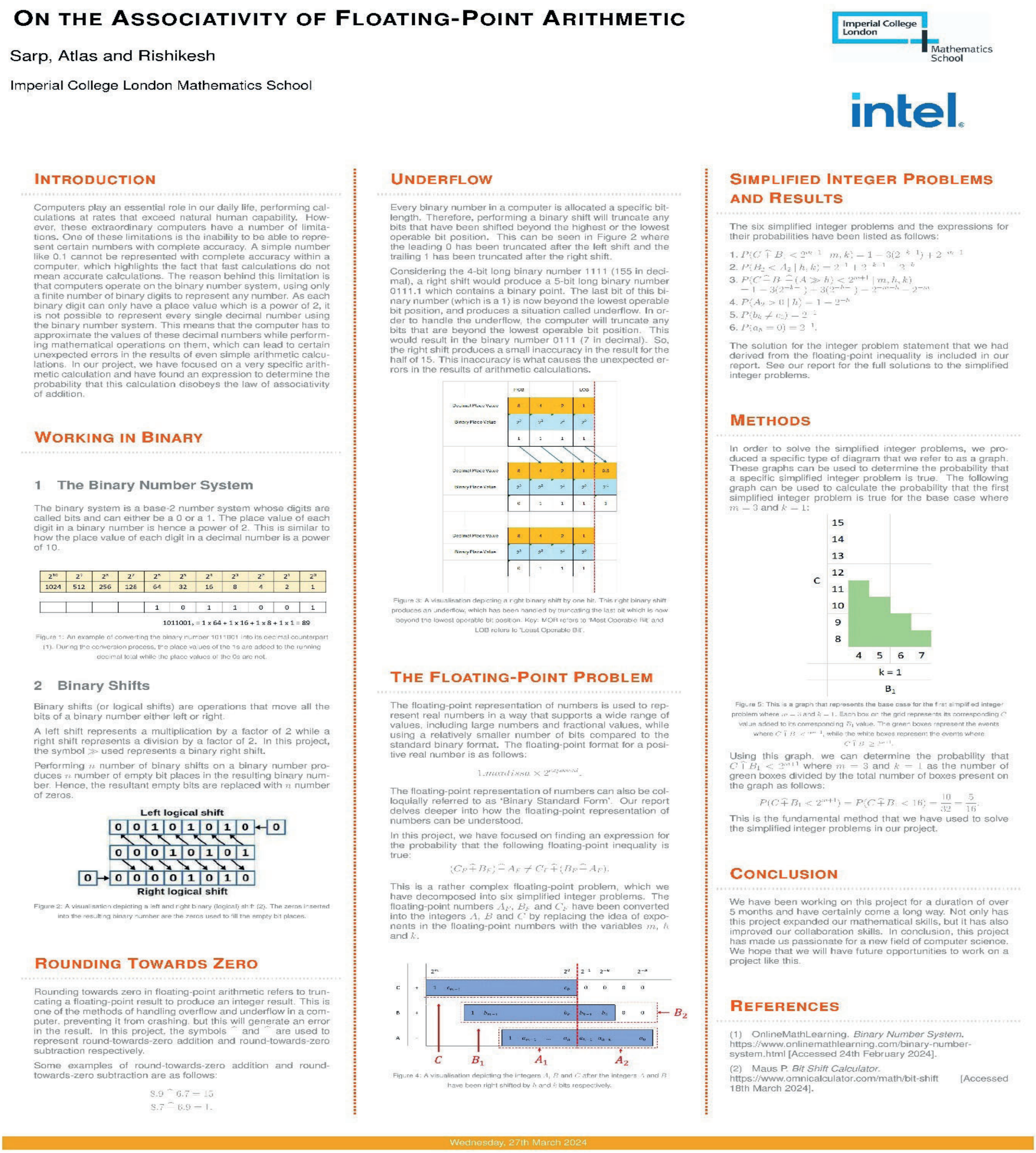

FIGURE 1: EXAMPLE OF AN ACADEMIC POSTER

students' perceived lack of engagement with the material delivered to them (Mosvold, 2021).

Homework is used by schools for several purposes. All schools use homework as revision for previous material and for practising exam style questions. Some schools also use homework to provide material beyond the A-Level curriculum to stretch the highest performing students. These might include Maths Olympiad questions or university admission questions. Some schools also use it as a preface for new material to be covered in the upcoming week. Schools varies between setting time completion approximations for each subject versus the volume of homework to be completed within a particular time. The time taken to complete the homework typically ranges between 2-3 hours for each subject. Homework is either marked by the students with solutions being uploaded at the start of the academic year or at the end of each week after the homework due date or marked by the teacher at the end of the week, depending on the school and on the subject.

Conclusion

The purpose of this paper has been to present a very brief overview of specialist mathematics schools in England: their context within the education system, the curriculum, and their pedagogy.

Despite being relatively new, they attract some of the country's highest academic achieving STEM students, reflected in the high entry requirements.

The curricula are broad, going beyond the typical A-Level curriculum, in breadth and depth; with students approaching problems using collaborative methods with their peers.

A distinguishing feature of Maths schools are their lecture series, delivering content similar to undergraduate level mathematics and in the same format. It is designed to simulate a university environment to prepare students for the transition to higher education.

Students also have the ability to complete research projects in different fields of STEM allowing them to explore topics in detail, either beyond the A-Level curriculum or by studying topics that are included in the A-Level curriculum but studied later in the year, culminating in a student presentation day to a varying audience of experts and lay people.

In future papers, I will present results of students' experiences as they complete their last year of school and as well as interviews from teachers, detailing their expectations of the maths schools, the students and their experiences of teaching at the maths schools.

References

Abd Algani, Y. M. (2021). The effect of the collaborative learning technique on students 'educational

performance in math. Journal for the Mathematics Education and Teaching Practices, Vol 2(2), pp. 81-91.

AQA. [no date]. Introduction. [Online]. [Accessed 24/09/2024]. Available from: https://www.aqa.org.uk/subjects/projects/project-qualifications/EPQ-7993/introduction

Bellos, A. (2023). Can you solve it? The school with the best A-level results in the UK. [Online]. The Guardian. [Accessed 23/07/2024]. Available from: https://www.theguardian.com/science/2023/sep/04/can-you-solve-it-the-school-with-the-best-a-level-results-in-the-uk

Department for Education. (2023). Becoming a 16 to 19 academy: advice for Sixth Form Colleges. [Online]. Department for Education. [Accessed 17/06/2024]. Available from: https://assets.publishing.service.gov.uk/media/63da4d52e90e0773de5961a6/Becoming_a_16_19_academy_advice_for_sixth_form_colleges.pdf

Department for Education. (2021). How to apply to set up a maths school for 16 to 19 year olds. [Online]. Department for Education. [Accessed 01/05/2023]. Available from: https://www.gov.uk/government/publications/how-to-open-a-maths-school/how-to-apply-to-set-up-a-maths-school-for-16-to-19-year-olds#annex-a-criteria-for-maths-schools

Education Endowment Foundation. [no date]. Collaborative learning approaches. [Online]. [Accessed 20/07/2024]. Available from: https://educationendowmentfoundation.org.uk/education-evidence/teaching-learning-toolkit/collaborative-learning-approaches

Educause (2012). Things you should know about flipped classrooms. [Online]. [Accessed 15/06/2024]. Available from: https://library.educause.edu/~/media/files/library/2012/2/eli7081-pdf

Exeter Mathematics School. [no date]a. Curriculum X. [Online]. [Accessed 24/07/2024]. Available from: https://exetermathematicsschool.ac.uk/curriculum-x/

Exeter Mathematics School. [no date]b. Exeter Mathematics Certificate. [Online]. [Accessed 24/07/2024]. Available from: https://exetermathematicsschool.ac.uk/exeter-mathematics-certificate/

Exeter Mathematics School. [no date]c. Our Curriculum. [Online]. [Accessed 24/07/2024]. Available from: https://exetermathematicsschool.ac.uk/our-curriculum/

Fulton, K. P. (2012). 10 Reasons to Flip. New Styles of Instruction, Vol 94(2), 20-24.

Gill, T. (2024) 'The extended project qualification in England: does it provide good preparation for higher education?'. [Online]. Oxford Review of Education, pp. 1–21. Available from: https://doi.org/10.1080/03054985.2024.2325966

Gill, T. (2016). Assessing the equivalencies of the UCAS tariff for different qualifications. Research Matters: Issue 21. PP. 16-23.

Golding, J. (2019). Progression through a mathematics specialist school: a study of trajectories of the first two cohorts through King's College London Mathematics School. UCL Institute of Education: London, UK.

Harris, B., Harris, J., Reed. L., & Zelihic, M. (2016). Flipped classroom: Another tool for your pedagogy tool box.

Developments in Business Simulation and Experiential Learning, Vol 1(43), 325-333.

House of Commons Education Committee. (2024). Ofsted's Work with Schools. [Online]. House of Commons. [Accessed 23/07/2024]. Available from: https://committees.parliament.uk/publications/43079/documents/214440/default/

Imperial College London Mathematics School. [no date]a. Super Curriculum. [Online]. [Accessed 25/07/2024]. Available from: https://www.iclms.ac.uk/super-curriculum

Imperial College London Mathematics School. [no date]b. Taught Curriculum. [Online]. [Accessed 24/07/2024]. Available from: https://www.iclms.ac.uk/taught-curriculum

Kings College London Mathematics School. (2022). Financial Statement 2021-2022. [Online]. [Accessed 23/07/2024]. Available from: https://www.kingsmathsschool.com/assets/pdf/financial-statement-2021-2022.pdf

Kings College London Mathematics School. [no date]a. Extended Curriculum. [Online]. [Accessed 24/07/2024]. Available from: https://www.kingsmathsschool.com/curriculum/extended-curriculum

Kings College London Mathematics School. [no date]b. Our Courses. [Online]. [Accessed 23/07/2024]. Available from: https://www.kingsmathsschool.com/curriculum/our-courses

Lancaster University School of Mathematics. [no date]. Studying at LUSoM, [Online]. [Accessed 24/07/2024]. Available from: https://lusom.ac.uk/study/

Leeds Maths School. [no date]. Curriculum. [Online]. [Accessed 24/07/2024]. Available from https://lmas.ac.uk/courses/

More than a Score. (2020). Too Many Tests for No Good Reason. [Online]. Institute for Education, University College London, [Accessed 23/07/2024]. Available from: https://www.morethanascore.org.uk/wp-content/uploads/2020/01/Parents-research.pdf

Mosvold, R. (2024). Research on Discussion in Mathematics Teaching: A Review of Literature From 2000 to 2020. *In* Wang, J. *Proceedings of the 14th International Congress on Mathematical Education Volume II: Invited Lectures*. *Shanghai, China,* pp.473-488.

Norden, J. (2024). Maths schools miss launch target amid site struggle. [Online]. TES Magazine. [Accessed 23/07/2024]. Available from: https://www.tes.com/magazine/news/secondary/maths-schools-miss-launch-target-amid-site-struggle

Sapsuha, S and Bugis, R. (2013). "Think Pair Share Technique To Improve Students' reading Comprehension," Journal Jupiter, Vol. 13 (2), pp.101–111.

Shimazoe, J., & Aldrich, H. (2010). Group work can be gratifying: Understanding and overcoming resistance to cooperative learning. College Teaching, Vol 58 (2), pp.52-57.

Thompson, E. (2018). Developing your research project: preparing students to succeed at a Russell Group university, [Online]. JCS Conference, [Accessed 23/07/2024]. https://jcsonlineresources.org/wp-content/uploads/2019/03/FINAL-Emma-Thompson-presentation-1.pdf

Thompson, N. (2022). Vygotskian scaffolding techniques as motivational pedagogy for gifted mathematicians in further education: a diary-interview study, Journal of Further and Higher Education. [Online]. 47(1), pp. 1-21 Available from: https://doi.org/10.1080/0309877X.2022.2142103

U-Maths. [no date]. The University Maths School Idea. [Accessed 24/07/2023]. Available from: https://umaths.ac.uk/the-university-maths-school-idea

UK Government. (2021). School Admissions Code. [Online]. Department for Education. [Accessed 24/07/2023]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1001050/School_admissions_code_2021.pdf

UK Government. [no date]. Types of School. [Online]. UK Government. [Accessed 20/07/2023]. Available from: https://www.gov.uk/types-of-school/free-schools

University of Liverpool Maths School. [no date]. Aspiring Mathematicians Programme. [Online]. [Accessed 24/07/2024]. Available from: https://liverpoolmathsschool.org/curriculum/aspiring-mathematicians-programme/

University of Liverpool Maths School. (2023). Annual Report and Financial Statement 2022-23. [Online]. University of Liverpool Maths School. [Accessed 24/07/2024]. Available from: https://liverpoolmathsschool.org/wp-content/uploads/2024/01/11686521-University-of-Liverpool-Maths-School-2223-FinStat.pdf